

Article

Concomitant Impediments to the Social Acceptance of Sandbag Technology for Sustainable and Affordable Housing Delivery: The Case of South Africa

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Abstract: There is a high level of homelessness in South Africa. Sandbag building technologies (SBTs) have been offered as economical and sustainable alternative building materials capable of speeding housing provision in South Africa. However, their degree of adoption in South Africa remains relatively low. Furthermore, limited research has examined the low adoption and social acceptance of SBTs, requiring thorough research. Therefore, this research investigates the key social barriers to accepting SBTs in housing provision. The study adopted a mixed method research approach that employs a comprehensive literature review in identifying 18 social barriers to using SBTs and a questionnaire survey of 228 building experts based in South Africa to obtain empirical data. The study findings indicated that the significant impediments were related to the lack of understanding of the benefits of sandbags, a lack of sandbag courses and training, and a lack of professional knowledge and skills, among others. A comparative analysis of the perceptions of the diverse categories of survey participants was conducted and discussed. This study's evaluation of significant barriers offers government agencies and construction partners a framework to make realistic and well-informed decisions toward more sustainable and affordable housing delivery.

Keywords: alternative; acceptance; housing; sandbag; technology



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1. Background to the Study

Humans have an innate desire for shelter because it meets their basic security, protection, and shelter requirements. However, over 1.6 billion people—more than 20% of the world's population—lack adequate housing, with an estimated 100 million homeless [1]. Existing studies [1,2] discovered that a lack of adequate and affordable housing concerns many individuals, resulting in homelessness and slum expansion over time. As a result, Africa has the highest number of slum dwellers, with more than 199.5 million people living in slums in Sub-Saharan Africa alone [3,4].

Furthermore, 12.5 million South African households are projected to live in slums without suitable housing [5]. As a result, it is anticipated that South Africa's housing backlog presently stands at around 2.2 million units [6,7]. This implies that conventional construction methods and materials cannot address the issues of insufficient housing and the need for alternative building materials. For example, in the City of Cape Town, the Cape Metropolitan MSDF of 2018 forecasted a housing need of 500,000 units over the next 20 years (2012–2032) [8]. Based on existing resources, eradicating Cape Town's current housing backlog is anticipated to take more than 70 years [8].

Alternative building technologies (ABTs), also known as innovative building technologies (IBTs) or alternative construction methods (ACMs), are seen as a viable option by the South African government and academics for constructing higher-quality low-income housing faster, more sustainably, and at a lower cost [6–9]. Sandbag technology (SBT) is one of the alternative building methodologies employed in South Africa. This study will

be using ABTs and SBTs interchangeably. Existing studies [10,11] noted that ABTs were implemented as a kind of intervention in the housing crisis that had enveloped the country after it became clear that the government lacked the resources to address the massive housing backlog. Ref. [12] noted that ABTs are non-conventional building technologies with features that differ from standard brick and mortar. Their adoption is thought to improve the construction process significantly. For instance, according to [13], a 43 square meter house may be erected in four to seven days using alternative methods, compared to the thirty days it takes to create a comparable unit using traditional brick-and-mortar construction. ABTs have developed throughout time in South Africa. They have been utilised in various construction projects, including houses, schools, health facilities, student housing, public or institutional structures, and highways [6,14]. Most ABTs use locally accessible building materials, while others rely entirely on imported components [12].

According to previous studies [15,16], the sandbag is the most widely available undiscovered alternative building technology in South Africa. Sandbag technology has been presented as a low-cost, sustainable, recyclable, and alternative building material capable of providing housing access [17]. Sandbags are polypropylene bags or polymer materials packed with granular ingredients. They are sometimes known as earthbags or soil bags.

Sandbag technologies evolved from the older 17th-century concept of employing sand-filled bags for military defence and flood control [17]. Sandbags are employed in soil retaining walls and barriers to strengthen the foundation's carrying capacity. In 1990, Architect Nadar Khalili pioneered sandbag building technology (SBT), an innovation for building residences and permanent buildings [18]. In the early 1990s, a need to provide inexpensive homes for millions of refugees and victims of conflicts and calamities inspired the concept of SBTs [19]. Khalili SBTs as a viable solution for building dwellings for the poor and on the moon [20,21]. Sandbag building technologies come in various forms, including curves, linear, and dome walls, with variations in wall colours, lengths, and textures.

SBT is gradually getting widespread recognition as the best answer to the global epidemic of housing shortages [22]. It has been seen as a viable alternative to conventional building methods, providing economic and environmental benefits in delivering affordable housing in many industrialised and developing nations [17]. Existing research has demonstrated that sandbag houses utilise less energy during construction and operation than standard building technologies [17,23]. In their research, researchers [24–26] showed that sandbag houses control the inside temperature of the building by collecting excess heat during the day and releasing it at night, resulting in a relaxed indoor environment in hot and warm weather and is less expensive than traditional methods. Meanwhile, sandbag technology's sustainability and cost benefits have been embraced in developed and developing nations; for example, researchers [17] reported 15,000 sandbag houses globally in 2016. SBTs have been used in countries like the United States, Australia, Brazil, India, Iran, Haiti, and Chile to provide sustainable, inexpensive, low-income, and contemporary housing [24]. Sandbag technologies are widely established in the US building code [27].

Much criticism has been raised on the issue of social acceptance of alternative building technologies by South African housing participants (actors) due to their effect on the housing market in South Africa. Even before any objective judgment is performed, most South Africans consider any alternative to traditional brick-and-mortar technology inferior [28]. Existing literature [24,29] identifies a lack of social acceptability of sandbag technology as a fundamental impediment to the greater worldwide use of sandbag technology. In their studies, researchers [30,31] established that low-income households living in traditional sandbag houses see sandbags as a non-durable and unpleasant material and aspire to a brick or concrete house.

Previous research identified various factors related to the lack of social acceptance of several alternative technologies, including sandbag technology. For instance, Olojede et al. emphasised that alternative technologies have lacked promotion and financial backing from South African financial institutions [28]. One example is the inability of the shipping

container alternative technology to get support from Nedbank and FNB, two of South Africa's four leading banks [12].

Despite the advantages and benefits of sandbag technology in providing inexpensive and sustainable homes, the social acceptance and uptake of the technology in South Africa remain relatively low. Meanwhile, a study of the existing literature [2,32,33] discovered a variety of forces impeding social acceptance and uptake of alternative technologies, such as sandbag technologies, resulting from diverse individuals, stakeholders, and decision-makers involved in the housing market. Therefore, this study investigates the barriers to the uptake of SBTs in housing provision.

Theoretical Background, Knowledge Gaps, Research Objectives, and Value

The concept of acceptance or rejection of new technology, according to Roger, has several stages [34]. It starts with the knowledge stage, in which individuals, stakeholders, and decision-makers are exposed to the technology. It continues with a confirmation period (real-world use of the technology), implementation stages, and adoption. Upham et al. accentuated that a particular group must first accept technology before the group can adopt it; that is, the group members gave it a good rating [35]. As a result, a study into the social acceptance of sandbag building technology is critical for assuring its widespread implementation and adoption for sustainable and affordable housing delivery.

Also, previous studies [35,36] illustrated three stages of social acceptance of new technology: socio-political approval, community acceptance, and market acceptance. Socio-political acceptance entails societal acceptability; here, the government contributes to technology's broad acceptance through laws. Studies by Wustenhagen et al. emphasised that the end-users and citizens must embrace and accept the technology to be accepted by the community [36]. According to Upham et al., market/stakeholder acceptability is the acceptance of experts, investors, and other stakeholders [35]. Therefore, sandbag technology must first be acknowledged and accepted by the South African housing market participants, including end-users, professionals, government housing authorities (National Home Builders Registration Council), housing investors, and financial institutions, before it can be fully adopted.

Grady et al. posited that most professionals did not understand how to use these technologies [2]. Meanwhile, most financial institutions have professionals in the construction industry who advise the institution on the plan to invest in any ABT; as a result, the opinion of professionals on ABT is essential to its acceptance [12]. More so, studies such as those conducted by Rincon et al. and Ben-Alon et al. pointed out that sandbag technology has no standard guidelines or building codes to facilitate its acceptance and adoption [24,37].

For the effective and efficient promotion of new technology adoption, the barriers to adoption must be first recognised and addressed [38]. Meanwhile, many existing studies have pointed out that social acceptance is a major barrier to adopting alternative building technologies, including sandbags [2,17,24,39]. However, none of these previous studies have attempted to analyse the barriers to social acceptance of ABTs (including SBTs) in South Africa. There is a gap in knowledge regarding social acceptance barriers to studies on sandbag technologies. Therefore, this paper examines the critical barriers or impediments to the social acceptance of sandbag building technology in housing provision and whether there are differences in the respondents' perspectives based on their organisational affiliation.

Furthermore, the findings of this study contribute to filling a knowledge gap regarding social acceptance barriers in South Africa and serve as a valuable reference for policymakers and practitioners in taking appropriate measures to mitigate the barriers to the social acceptance of SBTs.

The following is the format of the paper: Section 1 offers context for the research on the barriers to the social acceptance of sandbag technologies in South Africa and the study objectives. Section 2 reviews the key challenges and barriers to the social acceptance of sandbags in housing construction. Section 3 describes the research approach and analytical techniques used in data analysis. Section 4 presents the results of the data analysis, and

Section 5 discusses the study's findings and implications. Section 6 summarises the report and outlines the conclusions and recommendations for improving the social acceptance of sandbags in housing delivery.

2. Literature Review

2.1. Sandbag Technologies in South Africa

In South Africa, conventional materials dominate the housing market. Seventy-eight per cent of government-built dwellings were composed of bricks, while approximately 20 per cent were made of concrete blocks [40]. According to Bosman et al., alternative building materials such as sandbags accounted for a combined utilisation rate of slightly more than 2% [30]. Meanwhile, sandbag building technologies have been used to construct various houses in South Africa, including low-income residential houses, a school, and a pavilion [2,26], as shown in Figure 1.



Figure 1. (a) SBT house under construction; (b) SBT house post-construction.

2.2. The Barrier to the Social Acceptance of Sandbag Building Technologies in Housing Construction

Table 1 highlights the barriers to the social acceptance of SBTs in housing construction. According to previous studies [26,37], developing-country leaders oppose earthen materials like sandbag technology because they are hesitant to build dwellings with ordinary soil. This is also reflected in the lack of government legislation to encourage alternative construction materials such as sandbags [41,42]. According to Zami and Lee, foreign organisations promote sandbag technology since developing country governments are uninterested in ABTs [43]. In addition, researchers [17,20] posited that, unlike conventional technologies, there are no standard construction codes and regulations or guidelines for alternative building technologies, particularly the usage of sandbags, as pointed out.

Table 1. Summary of the identified barrier to the social acceptance of sandbag technology.

Code	Barriers	References
B1	Lack of sandbag databases and information	[37]
B2	Lack of interest from the government	[26,37,44,45]
B3	Lack of sandbag policy and regulations	[9,26,41,42]
B4	Lack of building code	[17,20,24,37]
B5	Lack of promotion of sandbag by government	[43]
B6	Lack of courses and training on sandbag	[43]
B7	Negative effects on human health	[24]
B8	Lack of interest from clients	[2,46]
B9	Lack of existing sandbag machines and technologies	[20,43]
B10	lack of professional knowledge and expertise	[2,26,43]
B11	Professionals resistant to change from the use of conventional technologies	[2,47,48]
B12	Lack of awareness of sandbag and their benefits	[2,5]
B13	Deficiency in sandbag construction techniques	[17,20]
B14	Durability issue	[20,46]
B15	Technical limitations	[17,26,49,50]
B16	Lack of standard design method for sandbag technology	[51]
B17	Inexperienced labour	[20,37,45]
B18	Lack of financing schemes (bank loans, grants)	[47,52,53]

Previous research suggests that most construction professionals (architects, engineers, and construction managers) lack appropriate knowledge, competence, and understanding of the ABTs [2,26]. Some experts view ABTs as more expensive than traditional construction methods and skills [2]. Previous research posited that because people are more familiar with conventional building materials and technology, most experts choose to use them in building construction [2,47]. Professionals are not confident in the earthbag's capacity to sustain the proper weights with little deformation; hence, the technical limitations of these alternative building systems are a significant barrier to professional adoption [17,49].

According to researchers [2], most individuals lack appropriate awareness and comprehension of the ABTs. Ordinary South Africa has a cultural propensity for houses made of concrete and brick [46] because many South Africans feel that ABTs are just for the impoverished [2]. Many investors are unaware of the technology and efficiency of ABTs. As a result of the lack of awareness, it is difficult to obtain a house loan or insurance from financial organisations to construct a house with ABTs [43]. The above literature study indicates the impediment to widespread deployment and acceptance of alternative construction and sandbag technologies. None of the studies have statistically and empirically analysed specific barriers to the social acceptance of sandbag technology in housing construction. Therefore, an investigation of the barriers to the social acceptance of SBTs in housing construction that incorporates the perspectives of all stakeholders is valuable.

3. Research Method

This research examines the barriers to the social acceptance of alternative construction technologies in housing construction in South Africa. To collect the necessary data for the study, the researchers used a quantitative research approach using empirical questionnaire surveys, employed in previous research [54]. In addition, the questionnaire data were gathered using a framework drawn from literature—journal articles, government gazettes, libraries, and online sites. According to Olatunji et al., the data collecting technique is critical in reaching the study goal, as is the composition of the question from [55].

Purposive sampling and snowball sampling techniques were used to target the appropriate respondents for the research. According to Wilkins, this strategy is suitable for choosing respondents based on their desire to engage in research [56]. Snowball approaches have been utilised in prior construction management research to acquire an appropriate and effective total sample size [57,58]. The survey respondents were consultants, contractors, developers, government officials (National Home Builders Registration Council), and end-users with good knowledge of alternative building and sandbag technologies. The researcher gave brief information to the respondent on what the alternative and sandbag building technologies entail. Respondents received the questionnaire survey using online survey forms; the researcher delivered the personal emails and URLs on the survey questionnaire to the targeted respondents.

Two hundred and twenty-eight survey responses were received across nine provinces in South Africa. Determining the questionnaire return rate was difficult as snowball sampling techniques were used. An international expert (a professor with over ten years of experience in alternative building technologies) pre-tested and evaluated the questionnaire before distributing it. The professor was selected because of their combined academic research track record and hands-on experience in alternative construction projects, as employed in previous construction management studies [57]. On the other hand, the expert was left out of the final questionnaire survey. The respondents were provided with some background information via the questionnaire survey. Following that, respondents were asked to rank the criticality of the identified impediments to the social acceptance of sandbag building technology in housing construction in South Africa on a 5-point Likert scale (1 = not critical, 2 = less critical, 3 = neutral, 4 = critical, 5 = extremely crucial).

3.1. Methods of Data Analysis Statistical Tools

To examine the data, the researchers used various statistical techniques and approaches. Among them are Cronbach's alpha, reliability analysis, mean and standard deviation, inferential analysis including ANOVA, Pearson correlation, and factor analysis and groupings.

3.1.1. Cronbach's Alpha and Reliability Analysis

Before performing more analysis on data collection, it is critical to assess its reliability [58]. In this study, the Cronbach alpha reliability test evaluates internal consistency across survey questionnaire variables and confirms that the questionnaire measures the correct construct [57,58]. Cronbach's alpha values vary from 0 to 1. The greater the alpha value, the more reliable the scale used. This study's Cronbach alpha reliability for the questionnaire items tested is 0.939, more than the 0.7 minimum, implying internal consistency among survey questionnaire variables [59,60].

3.1.2. Mean Score Ranking

The arithmetic mean is a qualitative analysis tool that displays the average value of a set of items and may be used to rank the relevance of variables [61]. A mean score was utilised in this study to measure the criticality of the 18 identified barriers in decreasing order. The standard deviation (SD) is another measure of variability and the difference between each result from the mean. If two or more barriers have the same mean value, the ordering is determined by the standard deviation, with the barrier with the lowest SD ranking higher [55]. By computing the normalised value of the mean score, the study determined the critical barriers among the 18 identified barriers.

3.1.3. Agreement Analysis Techniques

The study used ANOVA (analysis of variance) to determine whether there was a significant difference in the respondents' (contractors, consultants, developers, clients, and government officials) views of the barriers to the social acceptance of SBTs in the housing construction based on their work affiliations. ANOVA is an inferential statistical procedure used to determine whether or not there is a statistically significant difference between the means of two or more independent data groups [58]. In ANOVA, a normally distributed data point is required [55]. Olawumi and Chan [58] and Chan et al. [57] employed ANOVA in earlier construction management studies.

3.1.4. Factor Analysis

By studying the relationships between the factors, the study used factor analysis to discover the underlying grouping impediments to the social acceptance of SBTs in housing construction [62,63]. There are two types of factor analysis in quantitative research: the Promax rotation approach and Principal component analysis (PCA) [64]. The principal component analysis is used in this investigation (PCA). Factor analysis (PCA) is a statistical approach for identifying a small number of grouped factors to indicate correlations between numerous connected variables. PCA is also a useful technique for explaining complicated subjects. It is also used to minimise and recombine large components into a small number of factor scores and sizes [65,66]. However, before using Principal component analysis, it is necessary to confirm the sufficiency of the factor analysis for factor extraction (PCA). Therefore, the Kaiser–Meyer–Olkin (KMO) sample adequacy measure and Bartlett's sphericity test assess the factor analysis's appropriateness.

The Kaiser-Meyer-Olkin (KMO) ratio, defined by Field [67], is the ratio of squared correlation between variables to squared partial correlation between variables. It is used to measure the sampling appropriateness of variables. The Kaiser–Meyer–Olkin (KMO) scale ranges from 0 to 1. According to Norusis [63], Factor analysis is invalid when the value is zero since partial correlations are huge compared to the sum of correlations. This also shows that the connection pattern is shifting. On the other hand, according to Field [67], if the Kaiser–Meyer–Olkin (KMO) is close to above 0.5, the FA would give a reliable and

distinct factor. Hence, before a factor analysis is carried out, the KMO value should not be less than 0.50 [63,67]. According to Chan et al. [57], there are variabilities in the level of acceptance of KMO.

Bartlett's test of sphericity is a statistical test that assesses whether or not there are correlations between variables [64]. When doing Bartlett's test of sphericity, Pett et al. [68] concluded that if the original correlation matrix is an identity matrix, there is no link between the variables. As a result, FA will be ineffective. On the other hand, FA would be suitable if the correlation matrices are not identity matrices and if the significant level is low with a high sphericity value [69].

3.2. Respondents' Demographic Information

This section presents the background details of the 228 respondents who took part in this survey (see Figure 2). The responses came from South Africa's nine provinces. Gauteng has the slight majority of respondents (48, 21.05 percent), followed by Kwazulu Natal (45, 19.74 percent), Western Cape (38, 16.67 percent), Eastern Cape (34, 14.91 percent), Limpopo (20, 8.77 percent), Free State (13, 5.70 percent) and North West (12, 5.26 percent), Northern Cape (10, 4.39 percent) and Mpumalanga has the fewest participants (8, 3.51 percent). The respondents worked in various organisations, with the majority of them being contractors (96, 42.11 percent), followed by client participants (38, 16.66 percent), developers (37, 16.23 percent), and consultants (32, 14.04 percent), with government officials having the fewest participants (25, 10.96 percent). Profession-wise, the finding revealed a slight majority as project and construction managers (47.96 percent), academia and others (38.46 percent), structural and civil engineers (11.76 percent), and architects (1.81 percent).

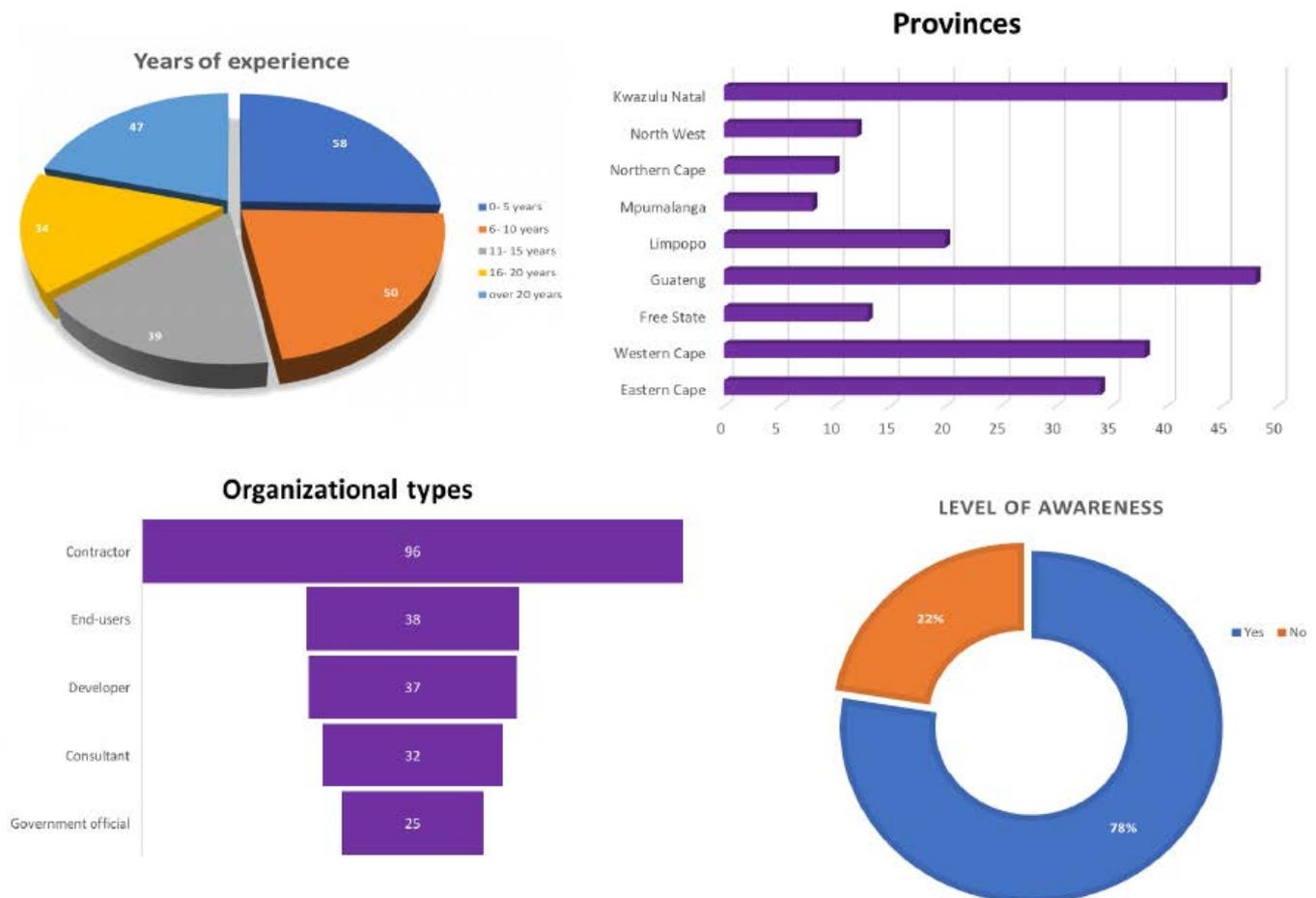


Figure 2. Demographic information of the respondent.

The respondents' awareness of alternative and sandbag building technologies suggested that most participants (177, 77.63 percent) had a high degree of awareness of sandbag building technologies, whereas 51 respondents (22.37 percent) had a low understanding of the technique. The survey participants had extensive professional experience in the sector, with 52.63 percent of the respondents (120) having at least 11 years of industry experience. A total of 21.93 percent of the respondents (50) had six to ten years of industry experience.

4. Result of Statistical Analysis

The section includes a summary of the data acquired via a questionnaire survey and the findings of the statistical methods used in the study.

4.1. Descriptive Statistical Tests

Table 2 summarises the findings of the ranking study on the barriers to the social acceptance of sandbag technology in housing construction. The mean value for the 18 identified impediments ranges from $M = 3.25$ ($SD = 1.125$) for "B7—Negative effect on human health" to $M = 4.0$ ($SD = 1.039$) for "B12—Lack of awareness of sandbag and its benefits," with a variance of 1.08. Furthermore, based on a comparable benchmark used by Chan et al. [57], critical barriers were identified as those with normalised values greater than 0.5.

Table 2. Barriers to the social acceptance of sandbag technology uptake in housing construction; intergroup comparisons.

Code	Contractors		Consultants		Developers		Client		Government Officials		All Respondents			ANOVA	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	SD	Rank		Normalisation ^a
B12	4.01	1	4.11	4	3.89	9	4.14	1	3.73	10	4.00	1.039	1	1 ^b	0.818 ^c
B6	3.92	2	4.06	6	4.11	3	3.86	7	4.00	1	3.95	1.038	2	0.93 ^b	0.958 ^c
B10	3.87	5	4.11	3	3.78	10	4.29	2	3.87	6	3.93	1.031	3	0.91 ^b	0.604 ^c
B5	3.92	3	3.94	11	4.11	4	3.71	10	4.00	2	3.92	1.068	4	0.89 ^b	0.926 ^c
B3	3.86	6	4.17	1	4.22	2	3.57	14	3.60	15	3.87	1.018	5	0.83 ^b	0.303 ^c
B18	3.89	4	3.89	13	4.00	6	3.86	6	3.60	16	3.87	1.159	6	0.83 ^b	0.916 ^c
B2	3.82	8	3.83	14	4.44	1	3.71	12	3.93	5	3.86	1.071	7	0.81 ^b	0.529 ^c
B4	3.83	7	4.06	9	3.78	11	3.57	15	3.73	11	3.82	1.096	8	0.76 ^b	0.801 ^c
B9	3.78	9	3.89	12	3.89	7	4.07	4	3.60	13	3.81	1.031	9	0.75 ^b	0.783 ^c
B11	3.73	10	4.06	5	3.67	13	3.79	9	4.00	3	3.79	1.097	10	0.72 ^b	0.734 ^c
B13	3.58	14	4.17	2	3.56	14	4.07	3	3.80	9	3.72	1.054	11	0.63 ^b	0.146 ^c
B16	3.63	12	4.00	8	4.00	5	3.79	8	3.40	8	3.69	1.072	12	0.59 ^b	0.445 ^c
B1	3.61	13	3.78	16	3.89	8	3.64	13	3.93	4	3.68	1.116	13	0.57 ^b	0.811 ^c
B15	3.57	15	4.06	7	3.56	15	3.29	17	3.80	7	3.63	1.082	14	0.51 ^b	0.298 ^c
B17	3.67	11	3.56	17	3.00	17	3.57	16	3.60	14	3.60	1.233	15	0.47	0.650 ^c
B8	3.54	16	3.78	15	3.67	12	3.71	11	3.47	17	3.58	1.085	16	0.44	0.884 ^c
B14	3.38	17	4.00	10	3.11	16	4.00	5	3.67	12	3.52	1.124	17	0.36	0.065 ^c
B7	3.26	18	2.89	18	3.00	18	3.14	18	3.80	18	3.25	1.125	18	0	0.198 ^c

Note: SD = Standard Deviation. ^a Normalized value = (mean – minimum mean)/(maximum mean – minimum mean). ^b the normalised value suggests that the barrier (normalised value ≥ 0.50) is a critical barrier. ^c at the 0.05 significant level (significance level > 0.05), the ANOVA result is insignificant.

According to Table 2, 14 of the initial 18 obstacles had normalised values of more than 0.50 and are classified as critical. Expectedly, "lack of awareness of Sandbag and its benefits" was ranked #1, with the highest mean value, $M = 4.0$ ($SD = 1.039$), showing that awareness is the most crucial obstacle impeding the social acceptance of sandbag technology in housing construction. The respondents ranked "B6—absence of sandbag courses and training" ($M = 3.95$, $SD = 1.038$) second, "B10—lack of professional knowledge and expertise" ($M = 3.93$, $SD = 1.031$) third, and "B5—lack of sandbag promotion by government" ($M = 3.92$, $SD = 1.068$) fourth. The fifth most critical obstacle to the social acceptance of sandbag building technologies was identified as "B3—the absence of sandbag policies and regulations" ($M = 3.87$, $SD = 1.018$). According to the research findings, low awareness is still a key barrier to the social acceptance of sandbag technologies in South Africa, combined with inadequate training programs, knowledge and expertise, and a low level of government support.

The data obtained from respondents based on organisational affiliation suggest that contractors and clients respondents regarded "B12—lack of awareness of sandbag and its

benefits" ($M = 4.0$ $SD = 1.039$) as the most critical barrier to social acceptance of sandbag building technologies in housing construction. This may imply that most contractors and clients are not fully aware of sandbag building technology and its benefit. However, the barrier was rated by respondents who are developers as the ninth most critical barrier, who ranked "B2—Lack of interest from government" ($M = 3.86$ $SD = 1.071$) as the critical barrier. The consultants perceived "B3—lack of sandbag policies and regulations" ($M = 3.87$ $SD = 1.018$) as the most critical barrier. However, Government officials rated "B6—lack of courses and training on Sandbag" ($M = 3.95$, $SD = 1.038$) as the most critical barrier to accepting sandbag building technologies in South Africa. This explains why the government has invested so much in training programmes and workshops on alternative building technologies, including sandbags, through various agencies such as National Home Builder Registration Council (NHBRC) [2,31].

All the various organisational setup (consultants, contractors, developers, Government officials and clients) regards "B7—Negative effect on human health" ($M = 3.25$ $SD = 1.125$) as the least significant barrier. Hence, these barriers have little impact on the social acceptance of sandbag building technologies in South Africa.

4.2. Inferential Statistical Tests

To investigate whether there are perception disparities among various respondents from various organisational backgrounds (consultants, contractors, developers, government officials, and clients, the 18 identified barriers were analysed using ANOVA. The significance values of 18 barriers were more than 0.05 based on the ANOVA findings (Table 2). The findings show no statistically significant variations in consultants', contractors', developers', government officials, and clients' assessments of the importance of these barriers.

4.3. Grouping of the Critical Barriers Based on Factor Analysis

The 14 critical barriers (variables) identified in this study were subjected to FA to classify the barriers to the social acceptance of sandbag technology in housing construction according to Factors. Before subjecting the critical barriers to factor analysis, as recommended by Xu et al. [65], a Pearson correlation analysis was performed on the 14 crucial barriers to minimise any multiplier effects among the variables. Consequently, the results shown in Table 3 demonstrate that the 14 critical barriers were substantially correlated.

Using the varimax rotation approach, a PCA was performed on the 14 critical barriers from 228 samples of responses (an orthogonal rotation method). Table 3 displays the factor analysis results, and each analysis explains the total variance. Previous research suggested that the sample size is in the 1:5 (number of variables: sample size) before it could be regarded as adequate for component analysis [70–72]. Fourteen crucial barriers multiplied by five samples necessary for each component equals at least 70 samples required to proceed with factor analysis. As a result, with 228 samples, the study met these requirements.

The KMO score for this study is 0.929, which is greater than the acceptable threshold of 0.50 [73] and also shows an "outstanding degree" of common variance [54,67]. Variables with KMO values near one, according to Chan and Hung [64], reflect a tight correlation pattern. It indicates that the PCA is quite likely to provide more trustworthy clusters. According to Chan and Choi [72], Bartlett's test of sphericity analysis yields a statistical test result ($\chi^2 = 1377.913$) and a tiny significant value ($p = 0.000$, $df = 91$), indicating that the correlation matrix is not an identity matrix. As a result, the condition to proceed with the factor analysis has been satisfied.

The study used the principal component analysis approach to identify the underlying grouping obstacles for factor extraction. PCA was used to identify four underlying groups (components) with eigenvalues greater than one, which account for 74.51 percent of the total variance in responses after varimax rotation (see Table 3), which is more than the minimum criteria of 60 percent [70,74].

Table 3. Varimax rotation factor structure on the critical barrier.

Code	The Barrier to the Social Acceptance of Sandbag Technology	Factor Loading	Eigenvalue	Percentage of Variance Explained	Cumulative Percentage of Variance Explained
Factor 1-	Policy and knowledge-related barrier		6.752	56.894	56.894
B3	Lack of sandbag policies and regulations	0.730			
B11	Professionals resistant to change from the use of conventional technologies	0.708			
B4	Lack of building code	0.692			
B10	Lack of professional's knowledge and expertise	0.678			
B6	Lack of courses and training on sandbag	0.624			
Factor 2-	Government-investor related barriers		2.849	7.409	64.303
B18	Lack of financing schemes (bank loans, grants)	0.843			
B9	Lack of existing sandbag machines and technologies	0.540			
B5	Lack of promotion of sandbag by government	0.518			
B2	Lack of interest from the government	0.458			
Factor 3-	Technical-related barrier		1.788	5.655	69.958
B15	Technical limitations	0.841			
B16	Lack of standard design method for sandbag tech	0.786			
B13	Deficiency in sandbag construction techniques	0.753			
Factor 4-	Information-related barrier		1.636	4.553	74.511
B1	Lack of sandbag databases and information	0.841			
B12	Lack of awareness of sandbags and their benefits	0.630			

Each of the fourteen barriers is represented by one of the four underlying barrier groups (component)—policy and knowledge, government-investor, technical, and information-related barriers; the factor loading for each group is larger than 0.5, which demonstrates the consistency and reliability of the study's findings and interpretation of the extracted individual component. Variables with factor loadings larger than or equal to 0.50, as indicated by Matsunaga [75] and Akintoye [76], will contribute considerably to the interpretation of the group factor.

5. Discussion of Survey Findings

5.1. Discussion of Grouped Barriers after Factor Analysis

In Figure 3, the grouped barriers are studied in descending order of importance to interpret the individual barriers. Sato [77] suggested assigning a collective or recognisable label to each aggregated barrier with a strong correlation. The authors, however, select the label, according to Chan and Hung [64], because it is subjective, and the researcher may come up with a different label. However, Olawumi and Chan [58] and Chan [70] used the barrier scale rating to rank the barrier components (groups) in similar construction management studies. The ratio of the mean of individual barriers inside a cluster divided by the number of obstacles in the cluster determines the barrier scale rating [58,70]. The focus of the discussion of grouped barriers will be on all four of the ranking barrier categories (component). The main goal of using barrier scale rating analysis is to determine which barrier group is more important, i.e., which barrier group has a higher-ranking value for future discussion [64].

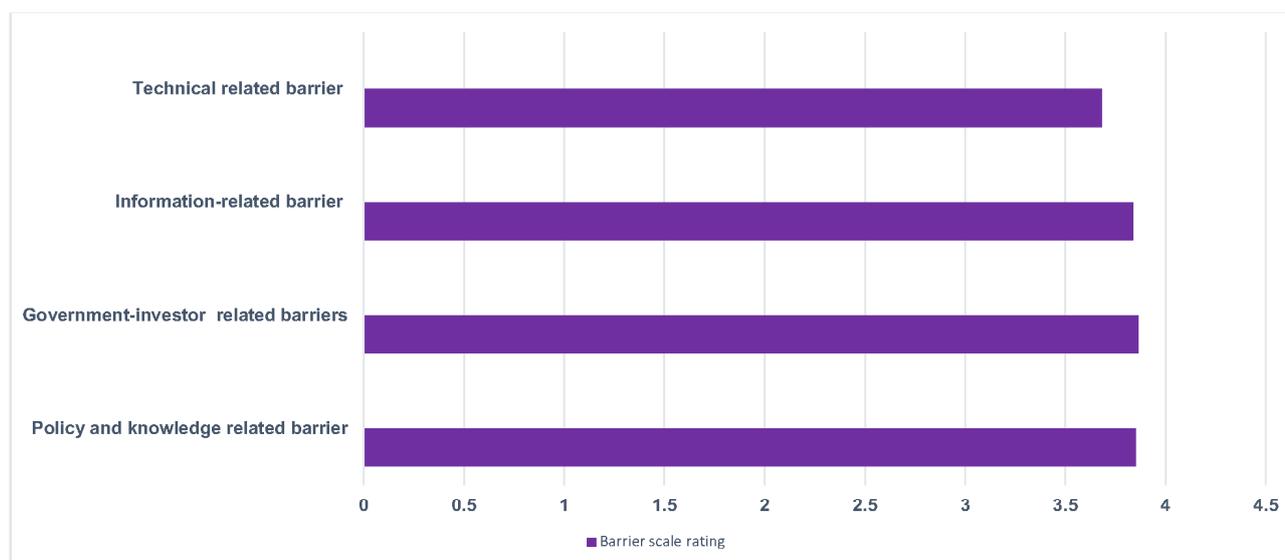


Figure 3. Ranking result of the barrier scale rating for the critical barriers.

5.1.1. Policy and Knowledge Related Barrier

Group (component) 1 comprises five barrier-related components and has the highest barrier scale rating of $M = 3.872$. The group is related to a lack of sandbag policy and regulations, a lack of Building codes, professionals' aversion to changing from conventional technologies, a lack of professional knowledge and skills, and a lack of sandbag courses and training. The lack of Sandbag policy and regulations is one of the major hurdles to the general use of Sandbag technology in South Africa.

The lack of Sandbag policy and regulations has hampered its widespread use and social acceptability. In contrast to traditional construction methods, alternative construction methods, such as sandbags, have no set policy or regulation [17,20,78]. Government rules and regulations are effective tools for boosting sandbag usage. Establishing sandbag building rules and standards at the national and international levels is critical to the acceptability of earthbag construction methods [37,41]. This is also supported by Gou et al. [79], who found that government rules and regulations significantly promote innovative technologies in the building sector. This finding implies that stakeholders and the general public will cooperate if sandbag uptake expectations are established in the form of legal requirements. Mpakati-Gama et al. [42] and Hadjri et al. [41] found similar results in research conducted in Sub-Saharan Africa (SSA). The findings suggest that the South African government should take a more active role in the construction industry's pursuit of sustainability by adopting rules and regulations to encourage social acceptability and uptake of alternative building technologies like sandbag technology.

It emerged that the most significant impediment to the social acceptance of SBTs is the lack of a well-established building code. Despite the development of earthbag and superadobe construction techniques, general guidelines and building rules are still lacking, with no mention in building codes [20,37]. Meanwhile, according to Cataldo-Born et al. [17], earthbag technology has been included in the building standards of California, USA, after it was established that these earthbag constructions surpassed the rules' criteria.

Another critical barrier to sandbag technologies' social acceptance and uptake is the resistance to a move from the use of conventional technologies, which stems from stakeholders deeply ingrained traditional notions. Uguchukwu et al. [47] and MacDougall [48], in their work, established that many experts in the conventional building sector are reticent to accept new inventive approaches that are not widely used. Contractors in South Africa prefer to employ conventional building materials and technologies because they are familiar with them [2]. As a result, low-income house development in the country has become homogeneous. This corresponds to a lack of professional knowledge and abilities.

Another major impediment to the social acceptance and adoption of sandbag technologies is a lack of professional knowledge and abilities. Previous research indicates that most construction stakeholders lack appropriate knowledge, competence, and understanding of the ABTs [2,26]. A lack of knowledge, ability, and understanding among experts, the government, donors, and consumers of alternative construction technologies constitutes a significant impediment to their societal acceptance and uptake. Santos and Beiro [26] and Zami and Lee [43] found that some construction professionals and stakeholders resist employing alternative building technologies because they believe they are more expensive than conventional building methods. This study's findings are consistent with Zami and Lee's [43]. These findings show that the number of construction professionals and stakeholders who understand the building process of sandbag technologies is low. On the other hand, the lack of people with the essential skills, expertise, and understanding would make it impossible for a company to use Sandbag technology. Lack of knowledge and skill, which are inextricably linked, are more significant barriers to sandbag social acceptance than a professional aversion to shifting from the employment of traditional technologies.

The lack of training and courses on sandbag technologies impedes the social acceptability and adoption of sandbag technologies [43]. According to Succar et al. [80], stakeholder training is critical for implementing new technology and applications. The techniques, design, materials, and technologies used in alternative technologies differ from conventional building methods indicating that a lack of training for stakeholders on what alternative construction is all about and how to construct a sandbag building effectively might negatively influence the successful adoption of sandbag technology.

5.1.2. Government-Investor-Related Barrier

One of the most significant impediments to the general acceptability of Sandbag technology in South Africa is the absence of finance options (bank loans, grants). The barrier group with the second-highest barrier scale rating of $M = 3.865$ is Group (component) 2, consisting of four barrier-related elements. The Group is related to the government's lack of promotion of sandbags and the government's lack of interest, lack of existing sandbag machines and technologies, and finance schemes (bank loans, grants).

Many investors and financial organisations are unfamiliar with the technology and efficiency of ABTs, according to Grady et al. [2]. Therefore, it is difficult to obtain a house loan or insurance from financial organisations [43,52,53]. This demonstrates that financial backing is critical to sandbag technology's public acceptance. Experts and individuals may be hesitant to embrace or implement this alternative technology without adequate financial support (grants and loans) from investors and the South African government [81]. It is also imperative that the Government of South Africa learn from the developed countries like Australia, Hong Kong, and the United States. According to Gou et al. [79], obtaining financial support through grants and bank loans for innovative technologies and sustainable projects in developed countries is easier.

According to Ben-Alon et al. [37] and Santos and Beiro [26], developing-country leaders and governments resist using earthen materials such as sandbag technology because they are hesitant to build dwellings with ordinary soil. While Zami and Lee [43] note that most new innovative building technology promotion is done by foreign organisations while developing country governments are uninterested in ABTs. According to this report, the government's lack of attention is a significant impediment to the societal acceptance of sandbag technology in housing construction. The study's findings correspond with Potbhare et al. [82] and Sameh [83]. They claimed that when a country's leaders and government approve a technology, it confirms the technology's efficacy in the eyes of the general public. As a result, public acceptability is dependent on the government's acceptance and interest in technology. This barrier is analogous to the government's failure to promote Sandbag.

The lack of existing sandbag machines and technologies is also a significant barrier to its acceptance. According to Potbhare et al. [82], the lack of established technologies

or demonstration projects might stymie the application of new technologies. Existing technologies will give people a sense of how the building will seem and raise public knowledge about the technologies, increasing public acceptability. Also, the absence of current sandbag equipment is a major stumbling block to its uptake. In their work, Adetooto et al. [31] demonstrate that the sandbag manufacturing method necessitates a significant amount of labour and effort. As a result, designing a machine that would improve the sandbag building process will be vital to its critical adoption.

5.1.3. Information-Related Barrier

The barrier group with the third-highest barrier scale rating of $M = 3.84$ is Group (component) 4, consisting of two barrier-related elements. The Group is related to a lack of sandbag databases and information and technologies and a lack of awareness of sandbags and their benefits.

The lack of awareness of sandbag technology and its benefits is the most significant impediment to the social acceptance of SBTs in housing construction. According to the Human Settlements Review [5], most government housing authorities and the general public are unaware of the advantages of alternative building technologies, which is aligned with the findings of this study, that there is a lack of understanding of the benefits of sandbag technology by South African practitioners and the general public. This outcome is consistent with earlier studies on alternative construction technologies in South Africa [2,5,31,84].

A lack of databases and information is another important barrier to social acceptance and deployment of sandbag technology. Sandbag adoption relies heavily on having access to appropriate information. According to Ben-Alon et al. [37], more information and technical data are required for sandbag adoption, which is aligned with the findings of this study, that the lack of sandbag databases and information is impeding sandbag uptake in South Africa. This demonstrates how difficult South Africa's present building sector practitioners are to get information on the technical properties of sandbags.

5.1.4. Technical Related Barrier

The barrier group with the least barrier scale rating of $M = 3.68$ is Group (component) 3, consisting of three barrier-related elements. The Group is related to a deficiency in sandbag construction techniques, a lack of standard design methods for sandbag technology, and technical limitations.

It emerged in this study that the deficiency in sandbag construction techniques is a major hindrance to the social acceptance and implementation of sandbag technology by stakeholders in the South African building sector. This finding is consistent with the results of previous research by Cataldo-Born et al. [17], who uncovered a defect in sandbag building procedures that impacts the bonding of sand and cement in their investigation is consistent with the studies by Windapo et al. [15] and Adetooto et al. [31]. Sharma [20] agrees, adding that it is difficult to grasp the sandbag building style when looking at how it is built. The study by Sharma [20] revealed that a lack of standard design methods and sandbag building procedures cause insufficiency, deficiency, and inconsistency in sandbag construction techniques and recommends that the government and interested construction stakeholders invest in further research on enhancing the current sandbag building technology.

Another major barrier found in this study to impede the social acceptance and adoption of sandbag building technologies is a lack of standard design methods for sandbag technology. This aligned with previous findings by Adetooto et al. [31] and Windapo et al. [16]. Canadell et al. [51] discovered a lack of a standard design technique for sandbag technology; unlike conventional construction methods, there is no standard design strategy or building methodology for SBTs. In South Africa, for example, most sandbag buildings are erected using short bags and eco beams [31]; yet, in other countries such as India and Egypt, long continuous bags are used without eco beams [20].

Another major impediment to the social acceptance and adoption of sandbag technologies by construction stakeholders in the housing construction market is the technical limitations of SBTs. Existing research shows that most construction professionals and engineers are hesitant to use sandbag technology because they lack faith in the earthbag's capacity to sustain suitable loads with minor deformation [17,26]. In their studies, Barros and Imhoff [49], Vardy et al. [85], and Gutiérrez and Manco [50] found that sandbag building technology has poor tensile strength and is considered a weak material with many flaws. As a result, most construction professionals are sceptical of sandbag technology's technical integrity.

6. Practical Implications for ABT and SBT Practitioners

This research draws on the many perspectives and hands-on experience of ABT professionals and stakeholders in the South African housing sector to provide a broad framework for implementing sandbag technology in housing projects. This study's findings have significant implications for ABT and SBT implementation practice and praxis. Furthermore, the study is the first and only attempt to compare the viewpoints of experts and housing market stakeholders in South Africa on the challenges to social acceptance of sandbag technology. It identified certain best practices that policymakers and practitioners may use to mitigate the barrier. Second, the research prioritised the concomitant impediment, defining the key barriers that must be addressed to ensure the successful implementation of sandbag technology. Finally, the factor analyses produced a framework of four main areas necessary for successfully implementing sandbag technology.

7. Conclusions and Recommendations

The research examined the barriers to the social acceptance of SBTs in housing construction. The study adopted a quantitative research approach that employed a questionnaire survey of respondents with significant experience of ABTs. A total of 18 barriers to social acceptance were identified through a desktop literature review.

The study found that 14 of the 18 barriers were critical to the social acceptance of sandbag building technology. The most critical barriers are a lack of awareness of sandbags and their benefits, a lack of Sandbag courses and training, a lack of professional knowledge and expertise, and Sandbag policy and regulations. The research findings also found no statistically significant differences in stakeholder perception of the critical barriers to the social acceptance of sandbags in housing construction. Further categorisation of the 14 barriers by Factor analysis revealed four clusters with a minimum of two variables in each cluster and a maximum of five.

Based on these findings, the following recommendations are made to mitigate the identified barriers to the social acceptance of ABTs such as sandbags in housing construction: (1) More research that gives specific information on sandbag technology to professionals and construction stakeholders should be promoted. (2) The government should enact laws and regulations to promote social acceptance and use of alternative building technologies such as sandbag technology. (3) Sandbag technology construction standards should be established and implemented into the country's building codes (4) There should be adequate resources available to sponsor training and educate stakeholders and the general public about using sandbag technologies and other alternative technologies. (5) Access to financial incentives and support, such as bank loans and grants, should stimulate the use of sandbag technology in line with what is obtainable in countries like Australia, Hong Kong, and the USA (6) Promotion teams should be organised, and techniques should be developed to improve public acceptance of sandbag technology. (7) More studies should be conducted to improve sandbag technology's structural and technical integrity and building procedures. Future research that investigates the interrelationships between the barriers, drivers, and strategies to the social acceptance of SBTs is recommended. A limitation of this study is that only sandbag technology was investigated among alternative construction technologies, although it is critical to provide inexpensive and sustainable housing. Section 1 contains

the justification behind this, as sandbag is the most readily accessible unknown alternative construction method.

This study's assessment of significant barriers to the social acceptance of SBTs is intended to provide a framework for government agencies and construction stakeholders to make realistic and well-informed decisions. Furthermore, the findings of this study will fill a knowledge gap regarding barriers to the social acceptance of SBTs in South Africa and serve as a valuable reference for policymakers and practitioners in taking appropriate measures to mitigate the barriers. Furthermore, the findings can be used as a policy tool and useful guidelines for government agencies, international organisations, and advocates interested in promoting ABTs such as sandbags in South Africa to achieve more sustainable and affordable housing delivery.

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