

**AN INVESTIGATION OF THE UTILISATION AND BARRIERS TO THE SOCIAL  
ACCEPTANCE OF ALTERNATIVE BUILDING TECHNOLOGY IN HOUSING  
CONSTRUCTION IN SOUTH AFRICA**

**By**

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## **ABSTRACT**

Social acceptance and the adoption of Alternative Building Technology (ABT), with a focus on Sandbag Building Technology (SBT) in housing delivery, are imperative to bridging the ever-increasing deficit in housing provision in South Africa, which stands at about 2.2 million units. However, ABT's adoption is influenced by issues, and its promotion is a difficult task in South Africa. This dissertation investigates the extent of use and the barrier to the social acceptance of ABT, focusing on SBT in housing construction in South Africa. It develops a framework to promote the social acceptability of ABT in housing delivery in South Africa. Specifically, this study has five objectives: (1) to determine the actor's perceptions of SBT as a sustainable and affordable housing solution in South Africa; (2) to identify and establish the critical drivers of social acceptance of SBT in South Africa; (3) to identify and establish the concomitant impediment to the social acceptance of SBT in South Africa; (4) to identify and establish the major strategies for the social acceptance of SBT in South Africa, and (5) to develop a framework for the uptake and social acceptance of SBT in South Africa.

The objectives were achieved through a mixed research method that began with two focus group sessions with thirteen (13) randomly selected South African housing market players and end-users. Also, a questionnaire survey was conducted across South Africa's nine provinces and yielded 228 valid responses. The data were analysed using various methods such as inductive content analysis with NVivo, the Shapiro-Wilk test and Cronbach's Alpha, a mean score rating, the Kruskal-Wallis H Test, the Kaiser-Meyer-Olkin (KMO) sample adequacy measure and Bartlett's sphericity, and factor analysis. The hypotheses developed for the study were tested using the Partial least squares structural equation modelling (PLS-SEM) analysis technique.

The findings revealed that the government-investor-related barrier, comprised of the government's lack of promotion of sandbags, their lack of interest and lack of finance schemes (bank loans, grants), is significant in impeding the social acceptance and use of SBT in South Africa. The study revealed that to promote the social acceptance of SBT there is a need for stakeholder integration; and that the government and the other South African housing market players need to support the adoption of SBT through the formation of strategic policy. More so, there is a need for effective education, training, availability of sandbag demonstration projects in all provinces, and knowledge sharing among South African housing stakeholders and end-users. The major benefits of SBT, which include its economic, construction and health-

related benefits, should be communicated to South African housing stakeholders and the general public to promote its acceptance.

This study provides a comprehensive framework for the social acceptance and adoption of sandbag technology in housing projects by drawing on the diverse opinions and practical experience of ABT experts and housing industry stakeholders in South Africa. In addition, this is the first and only effort to establish a framework for effectively adopting sandbag technology in South Africa, to provide inexpensive and sustainable housing. If completely implemented and approved, the framework will contribute to resolving South Africa's housing shortfall problem. Furthermore, the findings can be used as a policy tool and useful guidelines for government agencies, international organisations, and advocates interested in promoting a variety of ABTs such as sandbags in South Africa, to achieve more sustainable and affordable housing delivery.

## DECLARATION STATEMENT

This study is my work and is written in my own words (except where I have attributed the writing to others). I have utilised the sixth version of the APA manual for citations and references. Each contribution to and quote from the work(s) of others in this study has been credited, cited, and referenced. Any part borrowed from an online source has been cited accordingly. I realise it is unethical to replicate someone else's work or a portion of it and declare that this is my work.

Signed by candidate

---

Johnson Adetooto

(ADTJOH001)

## **DEDICATION**

This dissertation is dedicated to God, my Lord and Saviour Jesus Christ, and the Holy Spirit, who has been my inspiration, best friend and wisdom, and has spared my life and given me the grace to accomplish this work. Further to my parents, the late Prince R. A. Adetoto and Deaconess E. O. Adetoto. To my Grandma the late Mrs. E. Adetoto, and to my siblings Taiwo and Kehinde Adetoto for their assistance throughout my MPhil studies.

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## **PUBLICATIONS ARISING FROM THE THESIS**

Following is a list of the research articles produced by the author of this thesis throughout his MPhil studies. This study produced (four journal nine research publications articles, four conference papers, and one textbook). Leading publications and conferences in Construction Management were engaged for helpful and pertinent comments. The peer-review and direct comments from journal and conference articles and the textbook supplied the author with valuable insights that assisted with advancing the research goals.

The author, Adetooto Johnson conceived the concept for the journal and composed the original versions of the published articles under the full supervision of Professor Abimbola Windapo. In addition, the author modified and improved the article based on input from his supervisor. Other experts in this field were requested to collaborate by co-authoring articles for some of this paper and providing general feedback, which the applicant revised and enhanced to produce a comprehensive work. Furthermore, the candidate served as the corresponding author for all publications and was accountable for all revisions and responses to journal reviewer comments.

### **LIST OF PUBLICATIONS**

#### **Journal articles**

1. **Adetooto, J.**, and Windapo, A. (2022). Concomitant impediments to the Social Acceptance of Sandbag Technology for Sustainable and Affordable Housing Delivery: The Case of South Africa. *Buildings*. 12(6), 859. (Impact Factor: 3.324, Q1: Architecture) <https://doi.org/10.3390/buildings12060859>
2. **Adetooto, J.** Windapo, A., Pomponi, F.; Fabio, C. and Alade K. (2022). Strategies to the use of Sandbag Technology as a Sustainable Affordable Housing Solution: Perspectives from South Africa. *Journal of Engineering Design and Technology*. (Impact Factor: 2.48, Q2: Engineering) - accepted for publication
3. **Adetooto, J.;** Windapo, A.; Pomponi, F. (2022). The use of Alternative Building Technologies as a Sustainable Affordable Housing Solution: Perspectives from South Africa. *Journal of Engineering Design and Technology*. (Impact Factor: 2.48, Q2: Engineering) - accepted for publication

4. **Adetooto, J.;** Windapo, A.; Olawumi T. (2022). Drivers to the use of Sandbag Technology as a Sustainable Affordable Housing Solution: Perspectives from South Africa. *Habitat*. (Impact Factor: 5.205 Q1: Engineering) - under review

### **Textbook**

1. Windapo, O.A.; **Adetooto, J.D.;** Pomponi. F.; Emuze, F. Sandbag Building Technologies. *Construction Business and Management Research Group*; Department of Construction Economics and Management, University of Cape Town: Cape Town, South Africa, 2022; ISBN 978-1-998962-05-1.

### **Published Conference Papers**

1. **Adetooto, J.;** Windapo, A.; Pomponi, F. (2022). Barrier to the use of Sandbag Material Technologies as a Sustainable Affordable Housing Solution: Perspectives from South Africa. *EPiC Ser. Built Environ.*, 3, 722–730. <https://doi.org/10.29007/nqpb>.
2. Windapo, A.; Jarratt, N.; Adetooto, **J. A;** Pomponi, F.; Emuze, F. Assessing the Structural properties of the Sandbag wall for alternative housing construction. *EPiC Ser. Built Environ.* 2022<sup>b</sup>, 3, 795–803. <https://doi.org/10.29007/w511>.
3. **Adetooto, J.;** Windapo, A.; Pomponi, F. (2022). Strategies to the use of Sandbag Technology as a Sustainable Affordable Housing Solution: Perspectives from South Africa. *Construction Business and Project Management Conference (CPBM) 2022*, Cape Town, South Africa (Conference proceedings)
4. **Adetooto, J.;** and Windapo, A. (2022). A partial least squares structural equation modelling (PLS-SEM) of barriers to the social acceptance of sandbag building technology in South Africa. African Built Environment Researchers Association (ABERA) Conference, 15-18 November 2022, Lagos, Nigeria.

### **LIST OF AWARDS**

The author received the following award in the last year of his MPhil studies.

1. International Student Merit Award, 2022. University of Cape Town, South Africa.

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## LIST OF ABBREVIATION AND ACRONYMS

ABT – Alternative Building Technology	GHG – Greenhouse Gases
SEM – Structural Equation Modelling	PLS-SEM – Partial least squares structural equation modelling
SBT – Sandbag Building Technology	ANOVA – Analysis of Variance
NHBRC – National Home Builder’s Registration Council	KMO – Kaiser-Meyer-Olkin
MSDF – Municipal Spatial Development Framework	SPSS – Statistical Package for the Social Sciences
IBTs – Innovative Building Technologies	SD – Standard Deviation
ACMs – Alternative Construction Methods	PCA – Principal Component Analysis
FNB – First National Bank	CFA – Confirmatory Factor Analysis
NHF – National Housing Forum's	CB-SEM – Covariance based structural equation modelling
RDP – Reconstruction and Development Programme	AVE – Average Variance Extracted
BNG – Breaking New Ground	EFA – Exploratory factor analysis
HSDG – Human Settlement Development Grant	CEO – Chief Executive officer
LSM – Lightweight Sandwich Membrane	RI – Relative Importance
SAH – Sustainable, Affordable Housing	PKRB – Policy and Knowledge Related Barrier
NASA – National Aeronautics and Space Administration	GIRB – Government-Investor -Related Barriers
PVC – PolyVinyl Chloride	TRB – Technical Related Barrier
MS – Mean Score	IRB – Information-Related Barrier
RK – Rank	CHRD – Construction and Health Related Driver
FA – Factor analysis	ERD – Environmental Related Driver
PCA– Pearson Correlation Analysis	ECRD – Economic Related Driver
SA – Social Acceptance	MCRD – Material and Cost Related Driver
TRB – Technical-Related Barrier	AARD – Aesthetics and Acoustic Related Driver
PKRB – Policy-Knowledge-Related Barrier	SIPF – Stakeholders Integration and Policy Formation
GIRB – Government-Investor-Related Barrier	EEKS– Effective Education and Knowledge Sharing
IRB – Information-Related Barrier	GAI – Grassroots Advocacy and Incentives
AVE – Average Variance Extracted	CHRD – Construction and Health Related Driver
AARD – Aesthetics and Acoustic Related Drivers	MCRID – Material and Cost Related Driver
ECRD – Economic Related Drivers	

# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 Chapter overview**

This dissertation investigates the extent of use and the barrier to the social acceptance of Alternative Building Technologies (ABTs), focusing on Sandbag Building Technology (SBT) in housing construction in South Africa. It develops a framework to promote the social acceptability of ABTs in housing delivery in South Africa. This chapter presents the study's background, problem statement, research question, aim and objectives, research hypotheses, the significance of the study, scope, and limitations.

### **1.2 Background to the study**

#### **1.2.1 The context of South Africa housing market**

Humans naturally yearn for shelter because it fulfils their fundamental needs for security, safety, and protection. However, more than 20 percent of the world's population, or more than 1.6 billion people, still need sufficient shelter, with an estimated 100 million homeless (Adabre et al., 2020). Existing research (Grady et al., 2019; Ncube, 2017) has shown that a lack of suitable and affordable housing is a major concern for many people, resulting in homelessness and slum extension over time. Consequently, Africa has the biggest number of slum inhabitants, with more than 199,500,000 people living in slums in Sub-Saharan Africa alone (Alaazi & Aganah, 2020; Golubchikov & Badyina, 2012).

In addition, the National Home Builder's Registration Council (2020) estimates that 12.5 million South African families live in slums without adequate housing. Consequently, previous studies estimated South Africa's housing backlog now stands at around 2.2 million units (National Home Builder's Registration Council, 2020; Ncube, 2017). This suggests that traditional building techniques and materials cannot handle the housing shortage hence, the need for alternative building materials (Adetooto & Windapo, 2022a; Ncube, 2017). In Cape Town, for instance, the Cape Metropolitan Municipal Spatial Development Framework (MSDF) of 2018 predicted a housing need of 500,000 units over the next 20 years (2012–2032) (City of Cape Town, 2018). Based on present resources, clearing Cape Town's current housing backlog is expected to take more than seventy years (City of Cape Town, 2018).

### **1.2.2 The need for Alternative Building Technology (ABT)**

The South African government and academics view alternative building technologies (ABTs), also known as innovative building technologies (IBTs) or alternative construction methods (ACMs), as a viable option for constructing higher-quality low-income housing faster, more sustainably, and at a lower cost (City of Cape Town, 2018; Dosumu & Aigbavboa, 2019; National Home Builder's Registration Council, 2020; Ncube, 2017). According to previous research (Ballerino, 2002; Theart, 2014), ABTs were adopted as a type of intervention in the country's housing problem after it became evident that the government could not solve the large housing backlog. According to Mbambo, Agbola, and Ayodeji (2021) ABTs are non-conventional building technologies with characteristics that differ from those involved in the use of regular brick and mortar. Their implementation is anticipated to improve the construction process considerably. For example, Burger, Swilling, and Lengkeek (2010) estimate that a 43m<sup>2</sup> house can be built in four to seven days utilising alternative methods, as opposed to the 30 days required for typical brick-and-mortar construction. ABTs have evolved in South Africa over time. They have been employed in many construction projects, such as student hostels, dwellings, health facilities, schools, public or institutional structures, and motorways (Mphahlele, 2015; National Home Builder's Registration Council, 2020). Most ABTs are built with locally available materials, although others rely solely on imported components (Mbambo et al., 2021). In South Africa, alternative building technologies such as the power wall, Abod, Solbric, sandbag, and so on are available (National Home Builder's Registration Council, 2020). However, the focus of this research is on sandbag building technologies.

### **1.2.3 Sandbag Building Technology**

SBT consists of the application of polypropylene bags or polymers containing granular elements, to building construction projects. SBT is one of the alternative construction technologies used in South Africa and is sometimes referred to as the use of "earthbags" or "soil bags" in construction.

SBT emerged from the 17th-century concept of using sand-filled bags for military defence and flood control (Cataldo-Born, Araya-Letelier, & Pabón, 2016). Moreover, sandbags are used in soil retention walls and barriers to increase the carrying capacity of the foundation. SBT was conceived in the early 1990s in response to the need to provide inexpensive accommodation for millions of refugees and victims of conflict and natural catastrophes (Hunter & Kiffmeyer,

2004). SBTs were a viable option for building dwellings for the underprivileged and on the moon (Khalili & Outram, 2008; Sharma, 2015). Sandbag construction techniques include curved, linear, and dome walls with varied wall colours, lengths, and textures.

#### **1.2.4 Why focus on Sandbag Building Technology?**

SBT is gaining popularity as one of the best answers to the global housing crisis (Kamal & Rahman, 2018). In many developed and developing nations, it has been considered a viable alternative to conventional building techniques, providing economic and environmental benefits in delivering affordable housing (Cataldo-Born et al., 2016).

The use of sandbags as a construction technique has been promoted as a low-cost, eco-friendly, recyclable, and economical solution that may provide housing access (Cataldo-Born et al., 2016). SBT is the most widely available alternative building technology in South Africa that is unknown (Windapo, Pomponi, & Fidelis, 2022c). If completely implemented, SBT is capable of contributing significantly to resolving the housing crisis in South Africa (Adetooto & Windapo, 2022a; Adetooto, Windapo, & Pomponi, 2022c).

According to existing research, sandbag dwellings utilise less energy during construction and operation than traditional building techniques. (Cataldo-Born et al., 2016; Hunter & Kiffmeyer, 2004). Several studies (Rincón, Carrobé, Martorell, & Medrano, 2019; Santos & Beirão, 2016; Shaker et al., 2017) have shown that sandbag buildings mediate the interior temperature of a structure and offer a pleasant indoor atmosphere during hot and warm weather, at a lower cost than that of traditional approaches. Further, researchers (Cataldo-Born et al., 2016) indicated that 15,000 sandbag houses were erected globally in 2016; both developed and developing nations have embraced the technology due to its sustainability and affordability. In countries such as the United States, Australia, Brazil, India, Iran, Haiti, and Chile, SBTs have produced low-income, sustainable, and contemporary housing (Rincón et al., 2019). In addition, the US building code significantly permits the usage of sandbag technology (Geiger & Zemskova, 2015).

#### **1.2.5 Social acceptance of Sandbag Building Technology**

Burningham (2000) describe social acceptance as societal opposition to new technologies that must be overcome in order for smooth adoption of the technology to occur. However, rather than focusing solely on overcoming local resistance, Wüstenhagen, Wolsink, and Bürer (2007) and Heidenreich, Köhler, and Andersen (2022) define social acceptance as a multidimensional

approach, including adoption, opposition, and other actions and initiatives related to the level of technological progress. For this research, social acceptance of sandbag building technology is defined as a multidimensional approach, including *"all dynamic positions and actions — taking initiatives, adoption, support, resistance, opposition, apathy, tolerance, uncertainty, and indifference — that are relevant to the degree of sandbag technology innovation"* (Heidenreich et al., 2022; Wolsink, 2018)

Adoption and social acceptance of ABT are very low among South African housing stakeholders and the general public (Mbambo et al., 2021; Olojede, Agbola, & Samuel, 2019). The problem of social acceptance of SBT and ABT in South Africa is multidimensional. It involves many actors and South African housing stakeholders, including the government, building professionals, end-users, and investors (Adetooto & Windapo, 2022a). Most South Africans feel that any alternative to traditional brick-and-mortar technology is inferior. (Mbambo et al., 2021; Olojede et al., 2019). According to Kulshreshtha et al. (2020) and Olojede et al. (2019) the social acceptability of sandbag technology is a significant barrier that has prevented the widespread worldwide adoption of sandbag technology. In addition, existing studies (Adetooto, Windapo, & Pomponi, 2022b; Bosman & Van der Westhuizen, 2014) have shown that low-income families living in traditional sandbag buildings see sandbags as a non-durable and unpleasant material and prefer to live in a brick or concrete home. Olojede et al. (2019) also observed that South African financial institutions have not effectively promoted and supported alternative technologies. One example is the lack of financial support for the shipping container alternative technology from two of South Africa's largest banks, Nedbank and FNB (Mbambo et al., 2021).

### **1.2.6 Gap in knowledge**

In South Africa, the level of use of sandbag technology and the number of individuals employing it to construct houses are still relatively low, even though this technology may generate structures that are both inexpensive and environmentally beneficial (Windapo, Pomponi, & Fidelis, 2022d). However, research into sandbag building technology in South Africa is relatively scarce.

Furthermore, several studies on sandbag building technologies have been conducted outside of South Africa. There has been substantial study into design approaches and thermal behaviour for sandbag house (Barnes, Kang, & Cao, 2006; Canadell, Blanco, & Cavalaro, 2016; Daigle, Hall, & MacDougall, 2011; Rincón et al., 2019), challenges and motivation of sandbag

technology (Cataldo-Born et al., 2016), comparative cost analysis of sandbag technology (Geiger & Zemskova, 2015), and other topics. Despite all this research, the usage of sandbag technology is still quite uncommon internationally, as only 15,000 sandbag houses were documented by Cataldo-Born et al. (2016) worldwide in 2016. Research into the social acceptance of sandbag technology is still uncommon. The context of social acceptance of sandbag building technology in housing delivery has not been adequately and specifically addressed in the existing literature. This thesis attempts to fill the gap that currently exists.

### **1.3 Problem statement**

South Africa is infamous for its housing shortage. Scholars believe that alternative technologies, such as sandbag building technology, may provide affordable and sustainable housing and address the enormous housing need. However, the social acceptability or adoption of the sandbag technology in residential buildings is quite limited. In addition, there are insufficient studies on the societal acceptance of sandbag building technology in housing construction. In light of this, conducting a study to investigate the extent of use and the barrier to the social acceptance of Alternative Building Technologies (ABTS), focusing on Sandbag Building Technology (SBT) in housing construction in South Africa, is worthwhile.

### **1.4 Research question**

The main question to be addressed in this research is: What constraints impede the social acceptance and use of sandbag building technology in South African housing construction?

### **1.5 Research aim and objectives**

This study aims to investigate the factors impeding the use and social acceptance of the sandbag building technology in South African housing construction, towards developing a framework to promote the social acceptance of SBT. The study has the following precise objectives:

1. Determine the actor's perceptions of sandbag building technology as a sustainable and affordable housing solution in South Africa.
2. Identify and establish the concomitant impediment to the social acceptance of sandbag technology in South Africa.
3. Identify and establish the critical drivers to the social acceptance of sandbag technologies in South Africa.

4. Identify and establish the major strategies for the social acceptance of sandbag technologies in South Africa.
5. Develop a framework for the uptake and social acceptance of sandbag technologies in South Africa.

### **1.6 Significance of the study**

The results of this research have practical consequences for implementing and adopting alternative building technologies in South Africa. The results of each of this study's objectives have crucial implications for the social acceptance and implementation of sandbag building technologies in South Africa. First, this study examined the actors' perspectives of sandbag construction technology in South Africa as a sustainable and affordable housing alternative. A clear understanding of the actors' perception of SBT and the developed SBTs social acceptance framework may assist the South African housing stakeholders in implementing SBT to resolve the housing deficit problem in South Africa. This finding may also apply to other countries with similar environmental characteristics to South Africa.

Second, the research is the first and only effort to benchmark the drivers, challenges, and strategies for the social acceptance and adoption of SBT to generate sustainable and affordable housing, towards expanding the global knowledge of sandbag building technologies. It recommended specific best practices that policymakers and practitioners might adopt to promote societal acceptability of ABT and SBT. The research prioritized key strategies, drivers, and barriers that must be implemented concurrently to ensure the efficient deployment of sandbag technology. The research ultimately produced a framework for effectively adopting and accepting sandbag technology. It contributes significantly to the limited knowledge of the social acceptability of sandbag building technology. The results are also valuable for international and foreign organisations promoting SBT to provide cheap and sustainable housing. Overall, this research is very relevant for South Africa, and other emerging nations, since South Africa and several others confront a significant housing deficit problem. Lastly, this research has implications for the construction industry's utilisation of alternative building technologies to provide sustainable and affordable housing.

### **1.7 Limitations of the study**

Despite the weight of significance of this research, there are limitations to this research that must be addressed. First, the questionnaire survey used for evaluation and assessment in the

research was largely subjective; results might be affected by respondents' expertise, opinions, and experience. However, the impact of this limitation was significantly decreased by structuring the questions according to the study objectives, asking questions that engaged the research participants — keeping the questionnaire survey anonymous — and selecting research participants with substantial knowledge of alternative building and sandbag technologies in South Africa. Second, the emphasis of this study was only on the social acceptability and adoption of SBTs in South Africa; hence, generalisations about ABT may be limited.

## **1.8 Outline of the thesis**

Chapter One provides a summary of the thesis. It starts with an introduction to the research, the study's context, a description of the problem, the research question, and the aims and objectives. It also covers research limitations, significance, and an outline of the study. Chapter Two covers the relevant and noteworthy literature review for the investigation. This summarises the housing context and application of alternative construction technologies. It also includes a historical overview of South African housing challenges, and the drivers, challenges, and strategies for achieving the social acceptance competence of SBT. Chapter Three explains the conceptual framework adopted for the research, based on known theoretical viewpoints and literature-based findings. Chapter Four explains the methods used to do the research for the study. Presented are the research methodology, philosophy, paradigm, and strategy. Chapter Five provides a qualitative and quantitative result presentation and analysis of the objectives 1-5, and the testing of hypothesis developed for the study. Chapter Six concentrates on the quantitative component of the investigation. Chapter Six also discusses the findings acquired from the research, using the study objectives as the foundation. The chapter emphasises the similarities and contrasts between the study's variables and then relates the results to current literature. Chapter Seven discusses the development and validation of the Framework to the social acceptance of SBT. Chapter Eight gives an overview of the study's results. It reaffirms the research objectives and describes how each was attained. In addition, the consequences of the study results for theory, practice, and policy are discussed. Finally, the chapter concludes with prospective areas for further research.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Chapter overview**

This chapter presents relevant and noteworthy literature review for the investigation. It summarises the housing context and application of ABTs. It also includes a historical overview of South African housing challenges, a discussion of the perception and implementation of sandbag building technology in South Africa, and the drivers, challenges, and strategies for achieving the social acceptance competence of SBT.

#### **2.2 Housing context and the use of Alternative Building Technology**

##### **2.2.1 Historical overview of South African housing challenges**

Housing inequities and deficiencies persist due to ongoing effects of South Africa's apartheid-era policies across the country (Clark, 2019). Race-based policies were used in South Africa under apartheid to deny racial minorities their rights (Grady et al., 2019). A person of mixed ancestry in South Africa is referred to as "coloured" rather than "black," whereas a black person is considered an original African in the country (Grady et al., 2019). Less than 10% of South Africa's land was designated black "reserves" under the Native Property Act of 1913. It prohibited the acquisition of land by black people outside of these reservations (Wood, 2019). Since less than ten percent of the country's available land was allotted to black South Africans, this severely limited their ability to build and own houses (Smith, 2003). As a result of apartheid, black and coloured South Africans had their property rights severely restricted, and many were forcibly evicted from their homes starting in the 1950s. According to legislation passed in 1950, municipalities were divided into residential and business zones (Wood, 2019). South Africa's government forcibly relocated millions of non-white residents from white-only neighbourhoods between 1950 and 1994, demolishing their houses, businesses, and educational institutions. As a result, there was an insufficient housing supply for those thrown out of their homes due to reclassification (Wood, 2019).

Apartheid ended in 1994; however, the South African government has been working to improve the housing conditions that millions of South Africans were forced to live in during that time. Consequently, the new South African government implemented several housing laws, programmes, and initiatives to alleviate the country's housing crisis. In 1996, the South African government established in Section 26 of the Constitution, Act 108 that everyone has

the right to have access to sufficient housing, and affordable housing supply (Department of Housing, 1994). In addition, the Housing White Paper of 1994 was published due to the National Housing Forum's (NHF) attempts to establish a new housing strategy (Mackay, 1996). Further, the Programme for Reconstruction and Development was approved. The subsidy programme implementation began, and the National Home Builders Registration Council (NHBRC) was created (South African Housing & Infrastructure Fund, 2020b). The Housing Act (Act No.107 of 1997), among other initiatives, was enacted. Figure 1 depicts the numerous housing initiatives launched by the South African government since 1994.

Timeframe	Housing Policy changes
1992 - 1994	<ul style="list-style-type: none"> <li>National Housing Forum negotiation commenced on the formulation of housing policy in South Africa, birthing the white paper</li> </ul>
1994	<ul style="list-style-type: none"> <li>Reconstruction and Development Programme adopted</li> <li>The Housing Subsidy Programme launched; National Housing Accord signed; Housing White Paper promulgated</li> </ul>
1995	<ul style="list-style-type: none"> <li>Implementation of the subsidy programme commenced and the National Home Builders Registration Council was established</li> </ul>
1996	<ul style="list-style-type: none"> <li>The Constitution of the Republic of South Africa finalised</li> </ul>
1997	<ul style="list-style-type: none"> <li>The Housing Act (Act no.107 of 1997) promulgated</li> </ul>
Early 2000's	<ul style="list-style-type: none"> <li>We saw the commencement and implementation of new industry codes of practise wherein the entire value chain of both the built sector and sales side had standards to comply with. These were followed by mega integrated project deliveries.</li> </ul>
2004 - 2014	<ul style="list-style-type: none"> <li>Shift from building houses to building human settlements</li> </ul>

**Figure 1:** South Africa Housing initiatives 1994-2014 (South African Housing & Infrastructure Fund, 2020b)

### 2.2.1.1 Reconstruction and Development Programmes (RDP)

Government introduced Reconstruction and Development Programmes as one initiative to address South Africa's growing housing shortfall. Since its inception in 1994, the Reconstruction and Development Program (RDP) has provided low-cost homes to previously impoverished South Africans (Corder, 1997; Gabula, 2012; Mnisi, 2012). Families where the lone breadwinner earns less than R3500 per month or is jobless got free RDP dwellings from the government (Greyling, 2009). In addition, the government prioritises families with children, regardless of whether the children are theirs or not, when allocating RDP housing

(Gabula, 2012). Additionally, in 2004 the RDP was upgraded and renamed the Breaking New Ground (BNG) programme (Cloete, Venter, & Marais, 2009; Pithouse, 2009). "BNG housing" and "RDP housing" are often used interchangeably because of their similarity. The study's term "RDP/BNG housing" refers to government-built low-income housing unless otherwise noted.

Between 1994 and 2016, the government constructed over three million RDP/BNG dwellings for South African inhabitants, according to previous studies (Grady et al., 2019; Scheba & Turok, 2020). Excluding the accompanying land and infrastructure costs, the public cost of RDP has been calculated as around \$30 billion at current rates, or 13 percent of the present national budget (Mbambo et al., 2021; Olojede et al., 2019)

Despite the initiative's excellent intentions and advantages, the official housing backlog climbed to 1.5 million in 1996, 1.8 million in 2001, and 2.1 million between 2010 and 2013 (Theart, 2014; Van Wyk, 2010), with 1.1 million families living in informal settlements (Del Mistro & Hensher, 2009). It was anticipated in 2013 that R800 billion would be required to house every family in South Africa by 2020 (Olojede et al., 2019; Pillay, 2017)

#### **2.2.1.2 Deficiency of RDP/BNG programmes**

RDP/BNG housing has a history of being badly constructed and leaving many occupants unsatisfied (Grady et al., 2019). They are costly, inefficient, badly built, and unsustainable (Mqikela, 2021; Nokulunga, Didi, & Clinton, 2018). Further, more than 40,000 RDP houses were destroyed owing to poor quality and dissatisfied occupants. In addition, millions of rands have been spent on rebuilding and repairing faulty RDP houses in South Africa over the first 15 years after the program's inception, with the government having to repair 131,000 substandard homes at the cost of R836.9 million (Amoah, Kajimo-Shakantu, & van Schalkwyk, 2020). Between 2011 and 2014, the South African government spent over 2.1 billion rands repairing poorly constructed RDP/BNG homes (Olojede et al., 2019). It is important to note that seventy-eight percent of BNG/RDP houses were constructed from bricks, while approximately twenty percent were built from concrete blocks (Marais, Sefika, Ntema, Venter, & Cloete, 2014).

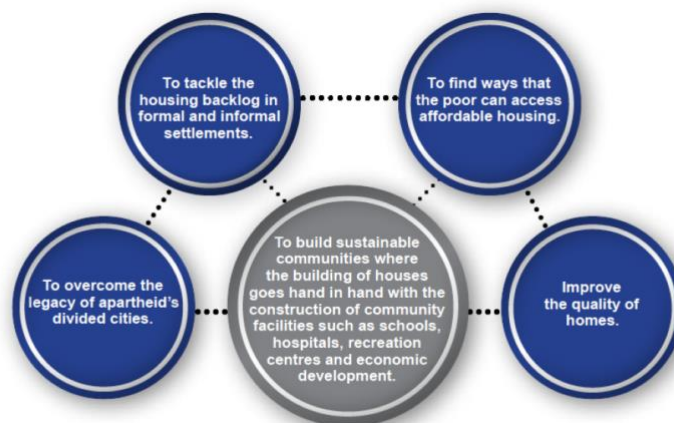
Numerous authors believe that these faults and poor-quality housing provisions are attributable to the construction materials and methods utilised to provide the structure and may be remedied through the application of ABTs (Dosumu & Aigbavboa, 2019; Grady et al., 2019; Mbambo et al., 2021; Ncube, 2017; Windapo, Johnson, Pomponi, & Fidelis, 2022b). Further, more than

sixty percent of total housing delivery costs may be linked to engineering design and building materials (Ballerino, 2002). In addition, Renaud (1984) pointed out, conventional construction techniques (Brick and Block) have several drawbacks, including a high price tag, making the pursuit of alternative technologies crucial for future sustainability. Therefore, all the aforementioned justifies exploring and implementing more cost-effective solutions to improve financial resources. Consequently, a natural agreement grew between the South African housing stakeholders that ABT should be developed to resolve the nation's housing crisis (Adetooto & Windapo, 2022a; Adetooto et al., 2022c; Grady et al., 2019; Windapo et al., 2022c).

### 2.2.2 Alternative Building Technology

Alternative building technologies (ABT) include environmentally friendly and economically effective building materials and technique (South African Housing & Infrastructure Fund, 2020a). While some rely on locally sourced materials, others rely on imported ones (Adetooto & Windapo, 2022a).

In this study, ABTs are regarded as non-conventional building methodologies that utilise economically valuable and environmentally friendly local building materials and technology to deliver affordable houses. Further, the use of ABT in housing delivery is expected to significantly improve the construction process and deliver affordable and sustainable housing solutions (National Home Builder’s Registration Council, 2020). As a result, the South African government allocates 10% of its Human Settlement Development Grant (HSDG) yearly to ABT to improve service delivery and reduce the housing deficit (Centre for Affordable Housing Finance in Africa, 2018). The characteristics of ABT are shown in Figure 2 below.

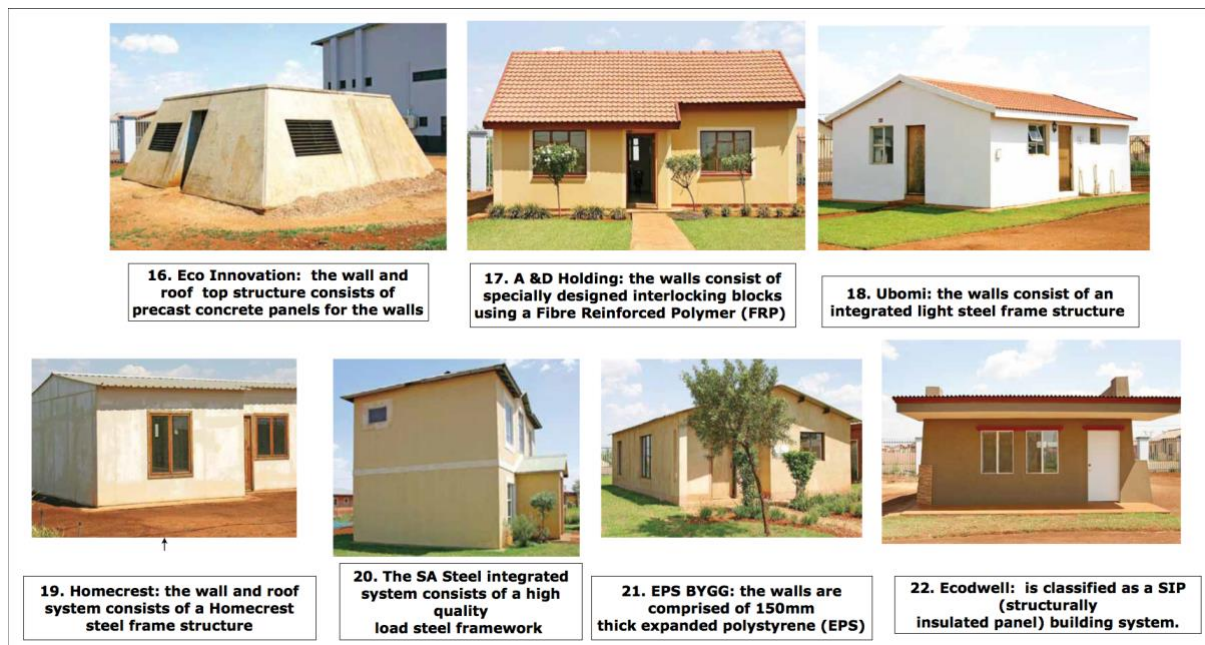


**Figure 2:** Characteristics of ABT (National Home Builder’s Registration Council, 2020)

Given South Africa's enormous housing backlog and the speed required to meet the enormous demand, ABT is beneficial since it produces speedier and more affordable housing (Tighe & Mueller, 2013). It improves construction by decreasing construction time and cost by up to 35% and 41%, respectively (Olojede et al., 2019). ABT reduces material waste to an absolute minimum (Mbambo et al., 2021). Further, Van Wyk (2015) stated that ABT has the potential to establish an exciting and gratifying working environment that might draw young people to the industry, considering that South African youth are often averse to construction employment (Haupt & Harinarain, 2016).

### 2.2.3 Available Alternative Building Technology in South Africa

ABTs have been utilised in many South African buildings, including dwellings, hospitals, residence halls, governmental or corporate structures, and highways (Mbambo et al., 2021; Olojede et al., 2019). Twenty-two ABTs were built at the Eric Molobi Housing Innovation Hub in Soshanguve, Pretoria, by the National Home Builders Registration Council (NHBRC), which recognises up to forty different varieties of ABT (Mbambo et al., 2021; Olojede et al., 2019). Figure 3 and 4 below contains a list of ABTs constructed at the Eric Molobi Housing Innovation Hub and have received significant coverage in published works.



**Figure 3:** ABTs at Eric Molobi Housing Innovation Hub (National Home Builder's Registration Council, 2020)

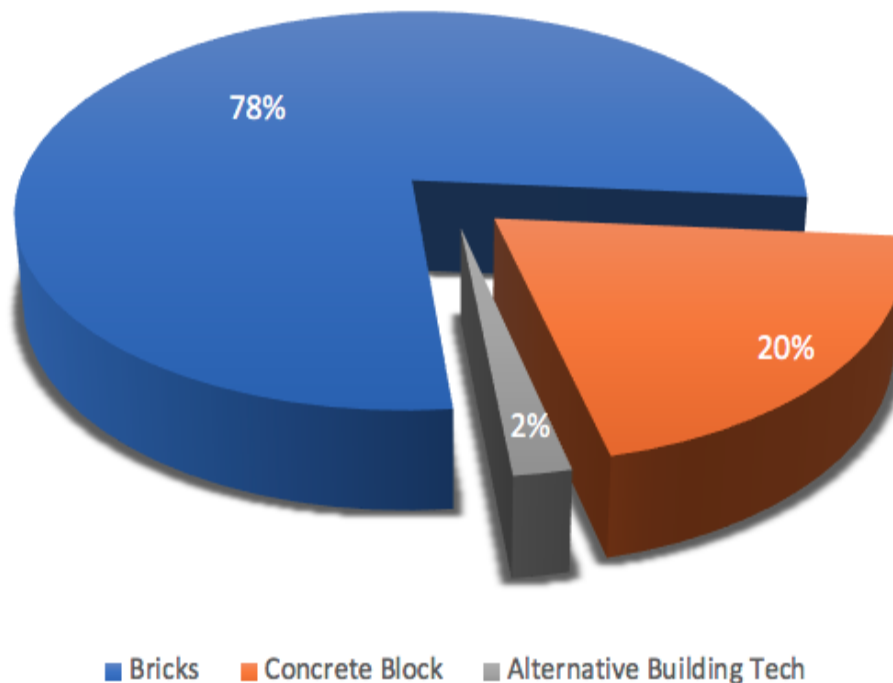


**Figure 4:** ABTs at Eric Molobi Housing Innovation Hub (National Home Builder's Registration Council, 2020)

## 2.2.4 Perceptions and implementation of Alternative Building Technology in South Africa

Despite the benefits and variety of ABTs and their potential to address the housing need in South Africa, their use in home construction is limited. Since 1994, the government has provided 2.8 million residences, but just 17,000 have used alternative technology (Olojede et al., 2019). Perceptions about alternative technologies are often highlighted as a significant barrier to the widespread adoption of ABT housing (Grady et al., 2019).

According to Botes (2013) and Nokulunga et al. (2018) typical brick, concrete, and steel homes are the most desired and seen as contemporary by the ordinary individual. South Africans believe that ABT-built homes are exclusively intended for the impoverished. They prefer to reside in a home constructed of traditional materials, such as brick, concrete blocks, and mortar (Grady et al., 2019). This is obvious as most South African buildings are constructed using standard materials such as bricks, concrete blocks, and mortar (Dlamini, 2020; Schmidt & Msinjili, 2014). Seventy-eight percent of government-built homes were constructed using bricks, while almost twenty percent were built with concrete blocks (Marais et al., 2014). Bosman and Van der Westhuizen (2014) indicates that adopting alternative construction materials contributed to little more than two percent of the total consumption (Figure 5).



**Figure 5:** South Africa: Building material statistics (Marais et al., 2014)

### 2.2.5 Existing research on Alternative Building Technology

Given the global climate problem, the need for affordable housing, low-cost and low-carbon solutions, and the high and ever-increasing cost of current building materials, a growing number of individuals are investigating methods to achieve less expensive construction approaches (Dosumu & Aigbavboa, 2019; Ncube, 2017; Nokulunga et al., 2018). The utilization of alternative construction technologies has garnered a greater focus of study.

In Portugal, Mateus, Neiva, Bragança, Mendonça, and Macieira (2013) conducted a sustainability assessment of alternative building technology (lightweight sandwich membrane) for partition walls and compared it to conventional technologies. The study concluded that ABT (LSM) is more functional and sustainable than conventional technology. D'Ayala and Fodde (2008) also found a variety of ABTs accessible in Nigeria and revealed that the alternative materials are less costly than traditional ones. Further, in China, Ge, Zhao, Luo, and Lin (2020) established a multi-objective assessment methodology based on several indices (i.e., economy, environmental quality, and load and maturity) to assess the suitability of alternative building technologies for the numerous needs of green, affordable housing.

Further, many studies have been conducted on ABT in South Africa. For instance, Grady et al. (2019) analysed the cost-feasibility of alternative building technologies compared to conventional construction methods. They chose the most appropriate alternative building technologies for future Department of Human Settlements projects. In addition, Haselau (2013) found many impediments to using ABT in South Africa, including shoddy craftsmanship, corruption, tender fraud, lack of knowledge, ineffective government legislation, and poor management.

The research by Mbambo et al. (2021) also focuses on the application of AV Light Steel and how it may be used to mitigate housing backlog and other associated issues in post-apartheid South Africa. More so, Olojede et al. (2019) examine the usage of ABT in South Africa and its implications for the Fourth Industrial Revolution in their paper. The research by Ncube (2017) examines the viability of adopting Moladi building technology to enable in-situ upgrading in informal settlements and produce affordable homes.

Clearly, a many studies have been conducted on alternative building technology internationally and in South Africa, but the majority have focused on the performance and use of alternative building technology. Little or no research has been conducted in the area of social acceptability and adoption of alternative building technologies, despite the fact that it is evident that the level of adoption is extremely low, and numerous studies have indicated that the level of social acceptance and perception is one of the major obstacles to the widespread adoption of ABT. Therefore, this study determines the extent of use and barrier to the social acceptance of alternative building technologies in South Africa.

Further, even though a great deal of ABT is accessible worldwide and in South Africa, this study will solely concentrate on one of the ABT. The author chose to concentrate on sandbag building technology (SBT) above other alternative technologies since SBT has been rediscovered in South Africa as a viable ABT and alternative to concrete, steel, and glass. Further, past research has shown that SBT offers more economic and environmental benefits than other alternative construction technologies for delivering low-income housing in many countries (Cataldo-Born et al., 2016; Hadjri, Osmani, Baiche, & Chifunda, 2007). For at least 10,000 years, sand has been the most common construction material, and at least one-third of the world's population still resides in sand-built buildings (Rincón et al., 2019). In addition, the previous study has shown that it is the most widely used, but least understood native construction material technology in South Africa (Adetooto et al., 2022c; Windapo et al., 2022c)

## **2.3 Perception and use of Sandbag Building Technology as a method for sustainable and affordable housing (SAH)**

### **2.3.1 Concept of sustainable and affordable housing (SAH)**

The definition of sustainable, affordable housing (SAH) is "housing that satisfies the requirements and expectations of the current generation without jeopardising future generations' capacity to satisfy their own housing needs and demands" (Pullen et al., 2010). SAH delivers an economic advantage, enhanced occupant health, comfort, energy and water efficiency, and cost savings (Golubchikov & Badyina, 2012; Sullivan & Ward, 2012). It is possible to achieve an 80% reduction in energy through a suitable practice (Adabre & Chan, 2019; Adabre et al., 2020). Affordable housing is defined as housing that costs less than 30% of a household's income (Friedman & Rosen, 2019). A house is sustainable if it is of excellent quality, in a desirable location for a lower-middle-income family, and the price is modest enough to enable the household to cover other basic living needs on a long-term (Adabre & Chan, 2019; Adabre et al., 2020). Sandbag building technology has been presented as a sustainable and affordable housing solution in South Africa (Adetooto et al., 2022c)

### **2.3.2 Overview and use of Sandbag Building Technology as a method of Sustainable and Affordable Housing (SAH)**

Sandbag Building Technology (SBT), also known as the use of the earthbag or soil bag, has been proposed as one of the sustainable, low-cost housing options globally and in South Africa

(Adetooto et al., 2022c). SBT is a style of earthen architecture that uses locally sourced soil packed in woven bags and layered to construct a structure (Rincón et al., 2019).

SBTs have been used in nations such as the United States, Australia, Brazil, India, Iran, Haiti, and Chile to offer low-income, modern, and sustainable housing (Cataldo-Born et al., 2016). In addition, sandbag technology has been utilised in the construction of a low-income residential building in Rwanda, an emission training medical centre in Ouagadougou, Burkina Faso (Rincón et al., 2019), a one-bedroom prototype building in Egypt (Shaker et al., 2017), a pavilion and low-cost houses in South Africa (Grady et al., 2019; Santos & Beirão, 2016). Figure 6 is an example of SBT construction.



**Figure 6:** Sandbag house construction including a swimming pool

### **2.3.3 Historical innovation of Sandbag Building Technology**

Since the 17th century, sandbags have been frequently used for military defence and flood control. Before World War I, the military utilised sand-filled bags to form bunkers and barriers for defence because they were readily erected and efficiently deflected bullets (Cataldo-Born et al., 2016)

Innovation in Sandbag Building Technology (SBT) for building houses and permanent structures was pioneered by Architect Nadar Khalili of the California Institute of Earth Art and

Architecture in 1990 (Kennedy, 2002). In 1986, Architect Nadar Khalili started research focussing on finding ways to build a house on the moon, using local building materials (Khalili 1989) in response to the call from the National Aeronautics and Space Administration (NASA).

Khalili later broadened the scope of his work to include solving the social housing deficit by building houses for the homeless in the United States with local building materials - earth, sand, and mud (Hunter & Kiffmeyer, 2004; Minke, 2021). This innovation was borne out of a passion for providing affordable housing for millions of refugees and victims of wars and disasters in the early 90s (Kennedy, 2002). Khalili identified Sandbag Building Technology as a good option for building houses for the poor and on the moon (Khalili & Outram, 2008; Sharma, 2015). Khalili developed a sandbag building prototype, presented to NASA as “Velcro-adobe”. The patented (U.S. Patent #5,934,027) and trademarked (#3,195,445) technology is offered free and licensed for commercial use (Zhao, Lu, & Jiang, 2015). This prototype won the Aga Khan Award in 2004 (Khalili & Outram, 2008). Khalili's research served as a model for other research institutions and has received growing research attention in the past decade. Kamal and Rahman (2018) noted that SBT is slowly gaining worldwide recognition as an optimum solution to the global epidemic of housing shortages. The sandbag building technologies are available in various shapes - curvy, linear, and dome walls, with a variety of wall colours, lengths, and textures.

#### **2.3.4 Method of Construction and varieties of Sandbag Building Technology**

The varieties of Sandbag Building Technology can be classified based on the size of the bags, according to Windapo et al. (2022d). Earthbag is a form of sandbag building technology that uses a short, regular degradable bag to contain soil (Rincón et al., 2019). Another variety, super adobe is a form of sandbag building technology that uses a long continuous bag to contain soil (Cataldo-Born et al., 2016). A typical example of super adobe construction is shown in Figure 7.



**Figure 7:** Example of the construction of a super adobe sandbag house.

Windapo et al. (2022d) provide an outline of the procedure for constructing SBT utilising smaller biodegradable bags, which includes the following steps:

- a. **Marking out:** This entails basic setting out of the SBT foundation, and the procedure is almost to the same as for the conventional building methods, depending on the structural engineer's specification.
- b. **Construction of Eco-beam (timber) frame walls:** Eco-beam is a frame construction made of wood and steel bars that is the primary support for holding sandbags. The eco-beams are fastened to the top and bottom beams with two No. 100 mm ring-shank nails at 900 mm intervals (Figure 8). The specific construction project determines the length of the frame.



**Figure 8:** Example of sandbag house with eco-beam (timber) frame walls

- c. **Sandbagging:** This entails filling the bags with sand, which must be free of chlorides (such as sea sand) and other contaminants that might cause galvanised metal components to rust. Sand is put into a prefabricated tube or PVC pipe (trimmed to size) so that each sandbag has the same quantity of sand (Figure 9).



**Figure 9:** The process of sandbagging

- d. **Bonding:** this requires fastening the packed sandbags to the eco-beam and to each other. Using a "stretcher bond" stacking technique is recommended to strengthen the wall's stability as it is constructed (Figure 10).



**Figure 10:** A typical example of SBT bonding

A study by Windapo et al. (2022d) study revealed that after bonding and cladding, most sandbag technology's other construction processes are similar to traditional methods. Figure 11 below shows a typical sandbag-constructed house in South Africa.



**Figure 11:** (a) SBT house under construction; (b) SBT house post-construction

### **2.3.5. Perception of the use of sandbags as a method of sustainable and affordable housing (SAH)**

In several countries throughout the globe, sandbags have been recommended as sustainable and inexpensive housing. In Burkina Faso, for example, Rincón et al. (2019) demonstrated SBT as a sustainable, practicable, inexpensive, and pleasant means of enhancing thermal comfort. Comparing the yearly thermal performance of two low-cost earthen constructions, an SBT residence and a typical Burkinabe adobe dwelling, the researchers determined that SBT performs better. In addition, SBT was promoted in Chile as a viable and sustainable alternative for alleviating the country's housing needs because of its increased habitability and environmental advantages (Cataldo-Born et al., 2016). In Bangladesh, SBT was likewise seen as a viable and cost-effective technique for constructing energy-efficient, sustainable buildings (Kamal & Rahman, 2018).

However, despite the potential of SBT in delivering sustainable and affordable housing worldwide, its widespread implementation is still very low. The acceptability of SBT construction is predominantly low in South Africa. This is recognised as the primary barrier to the rise of SBT and its application as a sustainable and affordable housing solution (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c). Moreover, in India, Kulshreshtha et al. (2020) revealed that earthen building in India and other developing nations has a poor social image; instead of a preferring a house that appears as if it belongs in the village, people in the rural areas prefer something that would be more at home in the city. Zami and Lee (2011) also determined that SBT is seen as a transient structure and a sign of poverty by the general public and professionals, which has impeded its widespread deployment.

Clearly, the question of societal acceptability is a major impediment to the widespread adoption of SBT. However, research on the adoption and acceptance of sandbag building technologies is uncommon in the academic literature, so this study was conducted. It evaluates stakeholders'

perceptions regarding the drivers, barriers, and strategies for the uptake and social acceptance of sandbag material technology to provide sustainable housing in South Africa.

## 2.4 Drivers of the social acceptance and adoption of the Sandbag Building Technology

This section provides a detailed literature assessment of the factors influencing the societal acceptability and implementation of Sandbag Building Technology. A prior study by Darko, Chan, Owusu-Manu, and Ameyaw (2017) stated that the drivers for adopting technology combined the advantages of the technology and activities outside of the benefits. Nonetheless, this study expanded on this definition to define drivers of SBT social acceptance and adoption as "the persuasions that encourage the social acceptance and adoption of SBTs and include the benefits of SBTs and actions outside of the benefits, that can lead or motivate individuals to accept SBTs." Considering such a wide definition, the author examined 42 relevant peer-reviewed journal articles. Consequently, 24 drivers for the societal acceptance of the sandbag construction technique have been identified as illustrated in Table 1.

**Table 1:** Summary of the identified drivers for the uptake and social acceptance of sandbag technology

<b>Code</b>	<b>Drivers</b>	<b>Related sources of data</b>
D1	A better alternative to adobe	Cataldo-Born et al. (2016); Rincón et al. (2019) and Santos and Beirão (2016)
D2	High energy efficiency	Cataldo-Born et al. (2016); Christoforou, Kylili, Fokaides, and Ioannou (2016); (2014) and Sharma (2015)
D3	Reduce environmental impacts	Cataldo-Born et al. (2016); Geiger and Zemskova (2015); Shaker et al. (2017) and Sharma (2015)
D4	Better thermal comfort	Cataldo-Born et al. (2016); Santos and Beirão (2016); Shaker et al. (2017) and Sharma (2015)
D5	Diversity of forms and styles	Ben-Alon, Loftness, Harries, Hameen, and Bridges (2020); Daigle et al. (2011); Racusin and McArleton (2012) and Sharma (2015)
D6	Affordability	Cataldo-Born et al. (2016); Geiger and Zemskova (2015); Rincón et al. (2019) and Sharma (2015)
D7	Low maintenance cost	Ben-Alon et al. (2020); Santos and Beirão (2016) and Sharma (2015)

<b>Code</b>	<b>Drivers</b>	<b>Related sources of data</b>
D8	Less transportation cost	Daigle et al. (2011); Geiger and Zemskova (2015); Shaker et al. (2017) and Sharma (2015)
D9	Fireproof	Cataldo-Born et al. (2016) and Sharma (2015)
D10	Ease of construction	Barnes et al. (2006); Cañizio (2006); Daigle et al. (2011); Geiger and Zemskova (2015) and Sharma (2015)
D11	Required little expertise	Cataldo-Born et al. (2016); Geiger and Zemskova (2015) and Shaker et al. (2017)
D12	Fast mode of construction	Barnes et al. (2006); Canadell et al. (2016); Cañizio (2006) and Santos and Beirão (2016)
D13	Erosion and flood control	Geiger and Zemskova (2015) and Sharma (2015)
D14	Good acoustic insulation	Bestraten Castells, Hormias Laperal, and Altemir Montaner (2011); Cataldo-Born et al. (2016); Shaker et al. (2017) and Sharma (2015)
D15	Improved indoor environmental quality	Barnes et al. (2006); Ben-Alon et al. (2020); Cataldo-Born et al. (2016) and Hall, Lindsay, and Krayenhoff (2012)
D16	Job creation opportunity	Ben-Alon et al. (2020); Daigle et al. (2011); Shaker et al. (2017) and Sharma (2015)
D17	Material availability	Daigle et al. (2011) and Rincón et al. (2019)
D18	Improved occupant health	Ben-Alon et al. (2020); Bestraten Castells et al. (2011); Cataldo-Born et al. (2016); Sameh (2014) and Sharma (2015)
D19	Reduced condensation and fungal growth	Ben-Alon et al. (2020); Daigle et al. (2011) and Little and Morton (2001)
D20	Resist environmental hazard	Geiger and Zemskova (2015) and Shaker et al. (2017)
D21	Reusable and recyclable	Barnes et al. (2006); Ben-Alon et al. (2020); Santos and Beirão (2016) and Shaker et al. (2017)
D22	Waste reduction	Sharma (2015)

<b>Code</b>	<b>Drivers</b>	<b>Related sources of data</b>
D23	Wind resistant and bulletproof	Shaker et al. (2017)
D24	Aesthetics	Sharma (2015)

Previous research by Ben-Alon et al. (2020), Cataldo-Born et al. (2016) and Geiger and Zemskova (2015) confirmed that sandbag technology is one of the least expensive construction technologies globally. It has been established that it utilises naturally occurring materials and cheap labour, and that a typical sandbag house might cost \$7.55 per m<sup>2s</sup>, compared to \$20.75 per m<sup>2</sup> for a concrete block in India.

Shaker et al. (2017) determined that sandbag technologies have distinctive characteristics because they manage the building's interior temperature, collect surplus heat during the day, and release it at night. The technology has been determined to provide a comfortable interior atmosphere during hot and warm weather (Ben-Alon et al., 2020; Cataldo-Born et al., 2016; Daigle et al., 2011; Rincón et al., 2019; Santos & Beirão, 2016; Shaker et al., 2017; Sharma, 2015). Further, existing research indicates that buildings produced using the sandbag technique utilise less energy during construction and operation (Cataldo-Born et al., 2016). Throughout its life cycle, sandbag building produces fewer greenhouse gases (GHG) than conventional construction methods, according to several studies (Ben-Alon et al., 2020; Christoforou et al., 2016; Freney, 2014). Also, according to Daigle et al. (2011) sandbag technology has a lower embodied energy than other construction technologies. Further, SBT consumes less energy in the winter, and reduces heat costs (Sharma, 2015)

#### **2.4.1 Gap in knowledge**

After a thorough literature study of sandbag building technology's social acceptability and adoption, its benefits and drivers were identified. Evidently, SBT provides several advantages that might promote its acceptance and encourage people to embrace it.

However, research on the drivers influencing the social acceptance and implementation of Sandbag Building Technology in developing nations is lacking. Specifically, it is absent in the setting of South Africa. This research intends to overcome this deficiency by examining the drivers of societal acceptability and adoption of Sandbag Building Technology in South Africa, using a thorough empirical questionnaire survey given to industry experts. The results may

assist housing stakeholders and end-users in South Africa by promoting the societal acceptability and implementation of SBT.

## 2.5 Barriers to the social acceptance and adoption of Sandbag Building Technology

This section presents a comprehensive literature review of the impediments to Sandbag Building Technology's social acceptance. Adetooto and Windapo (2022a) reviewed 31 relevant publications from peer-reviewed journals. As shown in Table 2, 18 obstacles to the social acceptability of the sandbag building technology have been found.

**Table 2:** Summary of the identified barriers to the uptake and social acceptance of sandbag

Code	Barriers	References
B1	lack of sandbag databases and information	Ben-Alon et al. (2020)
B2	Lack of interest from the Government	Ben-Alon et al. (2020); Cañizio (2006); Lyamuya and Alam (2013) and Santos and Beirão (2016)
B3	lack of SBT policy and regulations	Dosumu and Aigbavboa (2019); Hadjri et al. (2007); Mpakati-Gama, Wamuziri, and Sloan (2012) and Santos and Beirão (2016)
B4	Lack of building code	Ben-Alon et al. (2020); Cataldo-Born et al. (2016); Rincón et al. (2019) and Sharma (2015)
B5	Lack of promotion of SBT by Government	Zami and Lee (2011)
B6	Lack of courses and training on SBT	Zami and Lee (2011)
B7	Negative effects on human health	Rincón et al. (2019)
B8	Lack of interest from clients	Daigle et al. (2011) and Grady et al. (2019)
B9	Lack of existing sandbag machines and technologies	Sharma (2015) and Zami and Lee (2011)
B10	Lack of professional knowledge and expertise	Grady et al. (2019); Santos and Beirão (2016) and Zami and Lee (2011)
B11	Professionals resistant to change from the use of conventional technologies	Grady et al. (2019); MacDougall (2008) and Ugochukwu and Chioma (2015)

<b>Code</b>	<b>Barriers</b>	<b>References</b>
B12	Lack of awareness of sandbags and their benefits	Grady et al. (2019)
B13	Deficiency in sandbag construction techniques	Cataldo-Born et al. (2016) and Sharma (2015)
B14	Durability issue	Daigle et al. (2011) and Sharma (2015)
B15	Technical limitations	Barros and Imhoff (2010); Cataldo-Born et al. (2016); Gutiérrez Aliaga and Manco Rivera (2006) and Vardy, MacDougall, Magwood, and Spick (2006)
B16	Lack of standard design method for sandbag technology	Canadell et al. (2016)
B17	Inexperienced labour	Ben-Alon et al. (2020); Cañizio (2006); Daigle et al. (2011) and Sharma (2015)
B18	Lack of financing schemes (bank loans, grants)	Adegun and Adedeji (2017); Norton (1997) and Zami and Lee (2011)

One of the greatest obstacles to the social acceptability of sandbag technology, according to previous studies, is that the leaders of developing nations do not encourage the use of earthen materials, such as sandbags, since they do not want to build their homes with ordinary soil (Santos & Beirão, 2016; Zami & Lee, 2011). Consequently, no regulations are in place to promote the use of alternative building materials such as sandbags (Daigle et al., 2011; Dlamini, 2020). Therefore, international groups are promoting sandbag technology in most developing nations since these nations' governments are not interested in SBTs (Zami & Lee, 2011). In contrast to traditional technologies, there are no existing construction standards and regulations or recommendations for alternative building technologies, including the use of sandbags, as stated by earlier studies (Cataldo-Born et al., 2016; Sharma, 2015).

Furthermore, construction professionals are unfamiliar with ABT and SBT; therefore, it is not socially recognised or embraced by these professionals. Extant studies, for example, said that most construction professionals lack proper knowledge, competency, and comprehension of the ABTs (Grady et al., 2019; Santos & Beirão, 2016). In South Africa, construction professionals are more experienced with traditional building materials and technology (Grady et al., 2019). Many experts believe that SBTs are more costly than traditional construction

techniques; hence they choose to utilise traditional construction methods in their building projects (Grady et al., 2019; MacDougall, 2008). Furthermore, most construction professionals are sceptical of SBT's ability to support optimum weights with little deformation; hence, the technical constraints of these alternative building systems constitute a substantial impediment to professional acceptance (Barros & Imhoff, 2010; Cataldo-Born et al., 2016).

Furthermore, many individuals do not accept sandbag technology since most people lack a clear grasp of the benefits of sandbag technology (Grady et al., 2019; MacDougall, 2008). This is obvious since most South Africans believe that sandbag homes are for the poor and would prefer a house constructed using traditional techniques (Grady et al., 2019). Further, many investors do not accept sandbag technology because they are unaware of the quality and effectiveness of SBTs. Due to this lack of understanding, obtaining a home loan or insurance from financial institutions to build a house using SBTs is difficult (Gutiérrez Aliaga & Manco Rivera, 2006).

### **2.5.1 Gap in knowledge**

The above literature review identifies the impediment to the broad adoption and deployment of alternative building and sandbag technologies. However, no study has statistically and empirically examined particular challenges to the societal acceptability of sandbag technology. In addition, there is a lack of study on the obstacles to societal acceptability and application of Sandbag Building Technology in developing countries. Specifically, it is missing in South Africa's environment. This study aims to address this shortcoming by investigating the challenges to social acceptance and adoption of the Sandbag Building Technology in South Africa using a comprehensive empirical questionnaire survey of industry professionals. The findings may aid South African housing stakeholders and end-users in boosting the social acceptance and implementation of SBT.

## **2.6 Strategies to boost the social acceptance and adoption of Sandbag Building Technology**

This research employs Mintzberg (1987) definition of strategy: "strategy is a plan, some form of a continuous planned course of action, a guideline (or collection of guidelines) to cope with a problem." SBT is not widely accepted in South Africa (Grady et al., 2019). Adetooto and Windapo (2022a)'s research outlines the present state of social acceptance of SBT in South Africa. However, given the degree of acceptability of SBT in South Africa, it is vital to create ways to enhance social acceptance of SBT. Therefore, a study of relevant published material

was done to determine the strategies to promote the SBT's social acceptability. Consequently, 13 strategies to the societal acceptance of the sandbag construction technique have been identified as illustrated in table 3.

**Table 3:** Summary of the identified strategies to the uptake and social acceptance of sandbag technology

<b>Code</b>	<b>Strategies</b>	<b>Related sources of data</b>
S1	A financial incentive for sandbag uptake	Dosumu and Aigbavboa (2019)
S2	Public sandbag awareness creation through workshops, seminars, and conferences	Ben-Alon et al. (2020) and Grady et al. (2019)
S3	Approved sandbag building code	Ben-Alon et al. (2020) and Hadjri et al. (2007)
S4	Availability of the competent promotion teams and grassroots supporters	Belofsky and Zemskova (2018); Ben-Alon et al. (2020) and Grady et al. (2019)
S5	Availability of sandbag demonstration projects across all provinces	Grady et al. (2019) and Hadjri et al. (2007)
S6	Availability of standard design methods for earthbag	Rincón et al. (2019)
S7	Availability of sandbag research centre	Ben-Alon et al. (2020); Dosumu and Aigbavboa (2019) and Hadjri et al. (2007)
S8	Support from executive management	Belofsky and Zemskova (2018)
S9	Formulation of sandbag policies and regulations	Hadjri et al. (2007)
S10	Inclusion of sandbag technology in the curriculum of technical training colleges	Lyamuya and Alam (2013)
S11	Reformed tendering process	Grady et al. (2019)
S12	Standardisation of the material and components	Adegun and Adedeji (2017)
S13	Educational training for investors, professionals and end-users	Belofsky and Zemskova (2018)

Prior research has shown that establishing earthbag construction codes and standards at the national and international levels is crucial for the widespread adoption of earthbag building techniques (Ben-Alon et al., 2020; Hadjri et al., 2007). In addition, Hadjri et al. (2007) suggested the development of national initiatives to encourage and expand the usage of earth building. They advise that advertising, research, development, training, and pilot projects should be used to promote the use of earth as a construction material in creating sustainable policies. Grady et al. (2019) suggested that individuals become more receptive to ABTs after physically seeing an ABT-built home; therefore, it is necessary to construct a model earthbag home for community members to examine prior to actual construction to promote acceptance of these alternative building techniques. Moreover, engaging community members in the construction of SBT houses will teach them about the building material and its unique construction process, therefore fostering its social acceptability (Hadjri et al., 2007).

Previous research indicated that the community would embrace ABTs such as earthbags more easily if there were more published research findings on the technical performance of ABTs, such as earthbags (Dosumu & Aigbavboa, 2019; Hadjri et al., 2007). Moreover, it could foster collaboration, innovation, and integration among stakeholders (Ben-Alon et al., 2020). In addition, the literature identifies several other strategies for societal acceptance of SBT, including financial incentives for sandbag use (Dosumu & Aigbavboa, 2019), reformed tendering processes (Grady et al., 2019), standardisation of materials and components (Adegun & Adedeji, 2017), and educational training for investors, professionals, and end-users (Belofsky & Zemskova, 2018). In addition, Belofsky and Zemskova (2018) and Grady et al. (2019) stated that the availability of effective promotion teams and grassroots supporters is essential for SBT acceptability.

### **2.6.1 Gap in knowledge**

To effectively and efficiently increase the societal acceptability of SBTs, it is necessary to develop measures that overcome housing market obstacles. However, a few efforts have been made by extant researchers to comprehend the strategies for SBTs' social acceptance and adoption in underdeveloped nations. Specifically, no effort has been made within the ecosystem of South Africa. In addition, most of the prior research advocates sandbag technology's social acceptance and adoption strategies without empirical data or support. Given the limits of prior research, it would be worthwhile to do an empirical study on the SBT social acceptance and adoption strategies in South Africa.

In addition, although the research describes a range of social acceptance and adoption strategies for SBTs, these strategies may not be appropriate to South Africa owing to cultural, economic, and legislative variations across nations. Consequently, it is necessary to do research focusing exclusively on the emerging nation of South Africa. Further, this study's results help to address a knowledge gap for SBT societal acceptability strategies in South Africa. In addition, it will be a great resource for policymakers and practitioners in outlining the critical strategies and giving a general framework that must be devised to guarantee the effective application of sandbag technology.

## **2.7 Chapter summary**

This review has highlighted the prior and current debates in the literature and the significant areas of doubt about the societal acceptability of SBT. Numerous research works on the housing context and the implementation of alternative construction technologies were also explored. This research has also sparked academic discourse about the perception and implementation of sandbag building technology in South Africa, as well as the drivers, barriers, and strategies for obtaining SBT's societal acceptability. In response, the next chapter provides theoretical underpinnings and constructs a conceptual framework in preparation for the research process.

## **CHAPTER THREE**

### **THEORETICAL AND CONCEPTUAL FRAMEWORK**

#### **3.1 Chapter overview**

This chapter explains the rationale behind this study. It describes the theoretical perspectives and the conceptual framework used in this study.

#### **3.2 Theoretical basis**

This research's conceptual framework has a theoretical foundation, since it depends heavily on acceptance theory, change theory, and field theory (force field approaches).

##### **3.2.1 Theory and concept of social acceptance**

Acceptance refers to how willingly individuals embrace and adopt new technology for usage (Louho, Kallioja, & Oittinen, 2006). According to Dillon (2001), public adoption of new technology is defined as the visible desire of a group to employ new technology to achieve a goal that had previously been attained differently. Thus, acceptance may be understood as a consequence of user participation in technology applications. Acceptance is the decisive element in the success or failure of any technology, and it has been characterised as an outcome variable in a psychological process that users undergo, while making technology-related choices (Dillon & Morris, 1996).

Social acceptance is a multidimensional and multi-actor approach. According to Rogers (1995), there are numerous phases to the concept of acceptance or rejection of new technology. It begins with the learning stage, during which people, stakeholders, and decision-makers are introduced to the technology. It is followed by a validation phase (when the technology is used in the actual world), implementation stages, and acceptance. According to Upham, Oltra, and Boso (2015) a certain group must first embrace technology before it can be adopted. As a result, a study of sandbag construction technology's social acceptance is crucial for ensuring its broad implementation and adoption for SAH delivery. (Adetooto & Windapo, 2022a).

In addition, recent research (Adetooto & Windapo, 2022a; Upham et al., 2015; Wüstenhagen et al., 2007) identified three components/phases of social acceptance of new technology: socio-political acceptance, community acceptance, and market acceptance. Socio-political acceptance is a stage of acceptance that includes the acceptance of technology by society and the political class, particularly the government; in this stage, the government contributes to

technology's widespread adoption through legislation (Adetooto & Windapo, 2022a). Another stage of acceptance is community acceptance, which encompasses the adoption of technology by end-users and citizens. In this stage, the general public embraces and accepts the technology by building it with it (Adetooto & Windapo, 2022a; Wüstenhagen et al., 2007). Another stage of acceptance is market/stakeholder acceptability, which includes the acceptance of the technology by experts, investors, and other stakeholders. At this stage, the South African housing stakeholders accept and embrace the technology by establishing policies that will facilitate the widespread implementation of the technology (Adetooto & Windapo, 2022a; Upham et al., 2015)

Therefore, South African housing market participants must first recognise and accept sandbag technology before it can be fully adopted/socially accepted. South African housing market participants include end-users, professionals, government housing authorities (National Home Builders Registration Council), housing investors, and financial institutions (Adetooto & Windapo, 2022a). As a result, the societal acceptability of sandbag technology in South Africa may be measured using these four components (end-user approval, government acceptance, professional acceptance, and investor/developer acceptance).

### **3.2.2 Change Theory**

The theoretical framework for this research is built on the theory of change. According to Kurt Lewin's theory of change, individuals and organisations are impacted by distinct restraining factors that strive to maintain the status quo, and also driving forces, or positive forces for change, that push in the direction that causes change to occur (Burke, 2017; Lewin, 1951; Manchester et al., 2014). Change theory has been used in previous construction management research (Marsh, 2020; Wu, Zhao, Baller, & Wang, 2018).

Change Theory is one of the first and most commonly utilised theories for comprehending acceptance and transformation (Lewin, 1951; Wan, Saade, & Wang, 2019). This model includes three processes in altering behaviour: unfreezing the current developmental stage, movement, and refreezing stages. The first step in Lewin's paradigm is the unfreezing stage. Unfreezing is described as bringing individuals from a state of being unprepared for change to one in which they are willing and able to take the first move (Lewin, 1951). Among the activities that may aid in the thawing phase are a motivational enhancement, trust-building, and problem-recognition involvement (White, 2019). The first part of this research is establishing trust and problem-recognition engagement, which will lead the public to shift from traditional

construction technology to realising the significance of implementing sandbag building technology.

The second step of Lewin's paradigm is the idea that change modifies equilibrium (Transition). During this phase, new attitudes, beliefs, values, and behaviours are developed due to receiving new knowledge (Lewin, 1951; Wan et al., 2019). After minimising the influence of the opposing forces and amplifying the impact of the driving forces, the change may be executed (Robbins, 2003). Therefore, the change is achieved by moving in the direction of the desired position by modifying the equilibrium position. South Africa's public and housing stakeholders must develop new attitudes, beliefs, and values regarding alternative and sandbag building technology and be aware of the benefits thereof. This will shift from traditional construction technology to realising the significance of implementing sandbag building technology.

Lewin's third phase is refreezing or creating routines for the new order. This stage is designed to maintain the system after the change has been implemented and blend the new values with the existing community values and traditions.

### **3.2.3 Field theory (Force field techniques)**

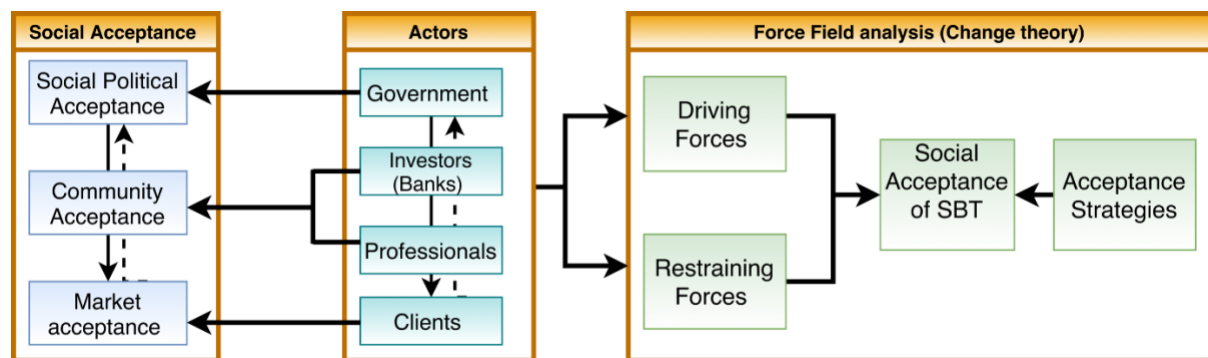
Field theory extends the change theory; it is useful for gaining a thorough grasp of the driving factors and restraining forces that drive change (Yang, Wang, Dai, Yang, & Huang, 2021). Brager and Holloway (1993) developed force field analysis to evaluate the likelihood of change. However, this approach for this research requires the assessment of change-influencing driving and constraining factors. The force field analysis has been used in previous construction management research (Darko et al., 2018)

### **3.3 Conceptual framework**

A research framework is beneficial for developing new knowledge (Agherdien, 2010) and may be grounded on theory or logic (Darko et al., 2018; Olawumi & Chan, 2021). This study's framework has a theoretical foundation. This framework intends to provide a better understanding of the societal acceptability and adoption process for SBT. In this suggested paradigm, restricting forces reflect issues that impede stakeholders from adopting SBT, while driving forces and strategies push stakeholders to embrace SBT.

Figure 12 depicts the path diagram that explains the conceptual paradigm for the study. This research proposed three degrees of societal acceptability (as described above). This

acceptability is heavily influenced by the government, investors, experts, and clients/users. Leveraging in the theoretical background, the study suggests that the four components can be used to measure the societal adoption/acceptance of the sandbag building technique (government, client, investors, and the construction professional). The research used change theory (force field method) to determine which forces impede or motivate the use and societal acceptability of sandbag building technology in South African house construction. This entails recognising the restraining factors that impede the usage and societal acceptability of the SBT and the pushing forces and acceptance strategies that counteract the restraining ones. The study further checks the impact of these forces (retraining, driving and strategies) on the social acceptance of sandbag technology.



**Figure 12:** Conceptual framework

### 3.4 Development of hypothesis

Based on the theoretical and conceptual underpinnings described above, the following hypotheses are formulated:

**Main hypothesis 1:** The restraining forces (barriers) have a significant impact on the social acceptance of SBT.

**Main hypothesis 2:** The driving forces (drivers) have a significant impact on the social acceptance of SBT.

**Main hypothesis 3:** The acceptance strategies have a significant impact on the social acceptance of SBT.

### **3.5 Chapter summary**

This chapter describes the conceptual framework and theoretical views used in this investigation. The study's conceptual framework has a theoretical basis since it mainly relies on acceptance theory, change theory, and field theory (force field approaches). This approach involves recognising the restraining factors that represent obstacles that prevent stakeholders from adopting SBT, as well as the driving forces and strategies that can motivate stakeholders to adopt SBT.

## CHAPTER FOUR

### METHODOLOGY

#### 4.1 Chapter overview

This chapter presents research methodologies for the study, stressing their merits and the arguments for their selection and also presenting the philosophical viewpoint of this study.

#### 4.2 Research philosophy

Philosophy is the foundation of scientific study, providing a framework for investigating research and developing knowledge. Philosophy offers a conceptual framework that enables the formation and enhancement of alignment between what individuals believe and what they do (Brown, Veen, & Finn, 2022). Research philosophy is a set of broad worldviews that generate beliefs influencing the researcher's activities. Research paradigms are philosophical assumptions or the fundamental set of views that underpin a researcher's perspective (Kaushik & Walsh, 2019). Philosophy leads to selecting a research strategy with varied knowledge structures for research design choices; failing to articulate the philosophical relationships between research problems may negatively impact research quality and design (Žukauskas, Vveinhardt, & Andriukaitienė, 2018). The following are some examples of philosophical thinking in research.

##### 4.2.1 Ontology in research

According to Merriam-Webster (2017) ontology is a field of metaphysics concerned with the nature and interactions of existence. It is a belief system that represents an individual's judgment of what constitutes reality, allowing the researcher to be assured of the nature and presence of their study (Lukyanenko, Larsen, Parsons, Gefen, & Mueller, 2019). It focuses on the types of existing items and the entities to which they belong. It makes assumptions about what exists, what it looks like, what components comprise it, and how these components interact. In summary, ontological assumptions concern what we think constitutes social reality (Khadir, Aliane, & Guessoum, 2021). The next section discusses several ontologies in research and how the researcher's ontological stance was decided.

**Objectivist/ Positivist ontology** stresses the independent existence and significance of social phenomena. Positivist ontology is philosophically tied to natural science and must work with observable social reality to produce law-like generalizations (Melnikovas, 2018). It provides

clear and accurate information and is often based on predetermined objectives. Based on this, researchers using this inquiry viewpoint examine a series of logically related processes and generate knowledge claims within the study process, using objectivity, standardization, deductive reasoning, and control (Kaushik & Walsh, 2019). According to realist ontology, the external world is composed of physical structures that exist independently; the latter concerns an individual's ability to learn knowledge and is seen as pragmatic, rather than abstract or ideological.

**Interpretivist Ontology** asserts that human brains socially generate and internally envision a reality. Everything is resolved by consensus. Everything is beneficial, but nothing is objective. According to constructivist ontology, social things and their meanings emerge through constantly changing social interactions (Ozturk & Berber, 2022). According to relativist ontology, the reality is influenced by socially transmitted conceptions that differ by language and culture (Ekpo, 2019). The same thing or event has several points of view. It is founded on the notion that reality is a social product that can only be understood by social actors (including academics) who produce and interpret it (Ozturk & Berber, 2022). Subjective perception and human consciousness are extensions of reality (Qureshi, 2020).

The ontological philosophy of pragmatism maintains that human acts can never be divorced from prior experiences and the ideas that result from those experiences (Kaushik & Walsh, 2019). For a pragmatist, research begins with a problem and ends with practical answers that influence future practice (Zellweger & Zenger, 2021).

#### **4.2.2 Epistemology in research**

Epistemology studies knowledge and the evidence a researcher uses to support their assertions (Creswell, 2021). Epistemology encompasses features of knowledge's validity, extent, and acquisition techniques (Moon, Cvitanovic, Blackman, Scales, & Browne, 2021). Positivism's epistemology aims to utilise observable phenomena to give trustworthy data and facts and construct law-like generalisations, using numbers. In critical realism, the researcher employs historically situated knowledge and socially constructed facts, while interpretivism relies on narratives, tales, perceptions, and worldviews to contribute to theory (Botha, 2021).

#### **4.2.3 Philosophical position of this research**

The research methodology addresses the methods used to explore the subject under investigation. This study used a positivist research methodology. This methodology facilitated

the scientific and statistical validation of SBT's social acceptability and adoption by South Africa's housing stakeholders and the general public. The research also used an interpretivist methodology to investigate the level of usage and barriers to societal acceptability of ABTs, focusing on SBT in South African house building. It follows a pragmatist ontological study that develops a framework to promote the social acceptability of Sandbag Building Technology. It gives background on affordability, sustainability, and social acceptability. Based on the study's philosophical stance and direction, a mixed-methods research design was chosen.

### **4.3 Research approach for this study**

Choosing the proper research approach is essential to assure the achievement of study goals (Moreira-Almeida & Lotufo-Neto, 2017). Appropriate research methodologies enable construction management research to provide important findings and substantially contribute to theory and practice (Kaushik & Walsh, 2019). Darko et al. (2018) noted that it is essential to use the expertise and experience of industry experts and stakeholders to improve a research project's results. This research relied heavily on housing market stakeholders' expertise, insight, experience, and perspectives to investigate the problems at hand. Previous studies (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c) examined the drivers, impediments, and promotion strategies of SBTs and practices adoption using a range of research techniques. Previous research in housing research often included a comprehensive literature review, interviews, case studies, and questionnaire surveys, mixed research among other methodologies (Fleury et al., 2021; Riazi & Emami, 2018).

The current study used a mixed research method to achieve the research objective. Mixed method research is a study strategy that combines quantitative and qualitative approaches in terms of question type, research methodology, data collecting and analysis techniques, or inference (Morse, 2016; Palinkas et al., 2015). In construction management, particularly in housing research, the mixed research approach has been used to offer a comprehensive knowledge of the study (Fleury et al., 2021; Riazi & Emami, 2018). It also lowers personal bias and maximizes research validity (Moreira-Almeida & Lotufo-Neto, 2017). Researchers use a mixed methodological approach to combine qualitative and quantitative research pragmatically, compensating for the limitations inherent in the two methodologies (Fleury et al., 2021)

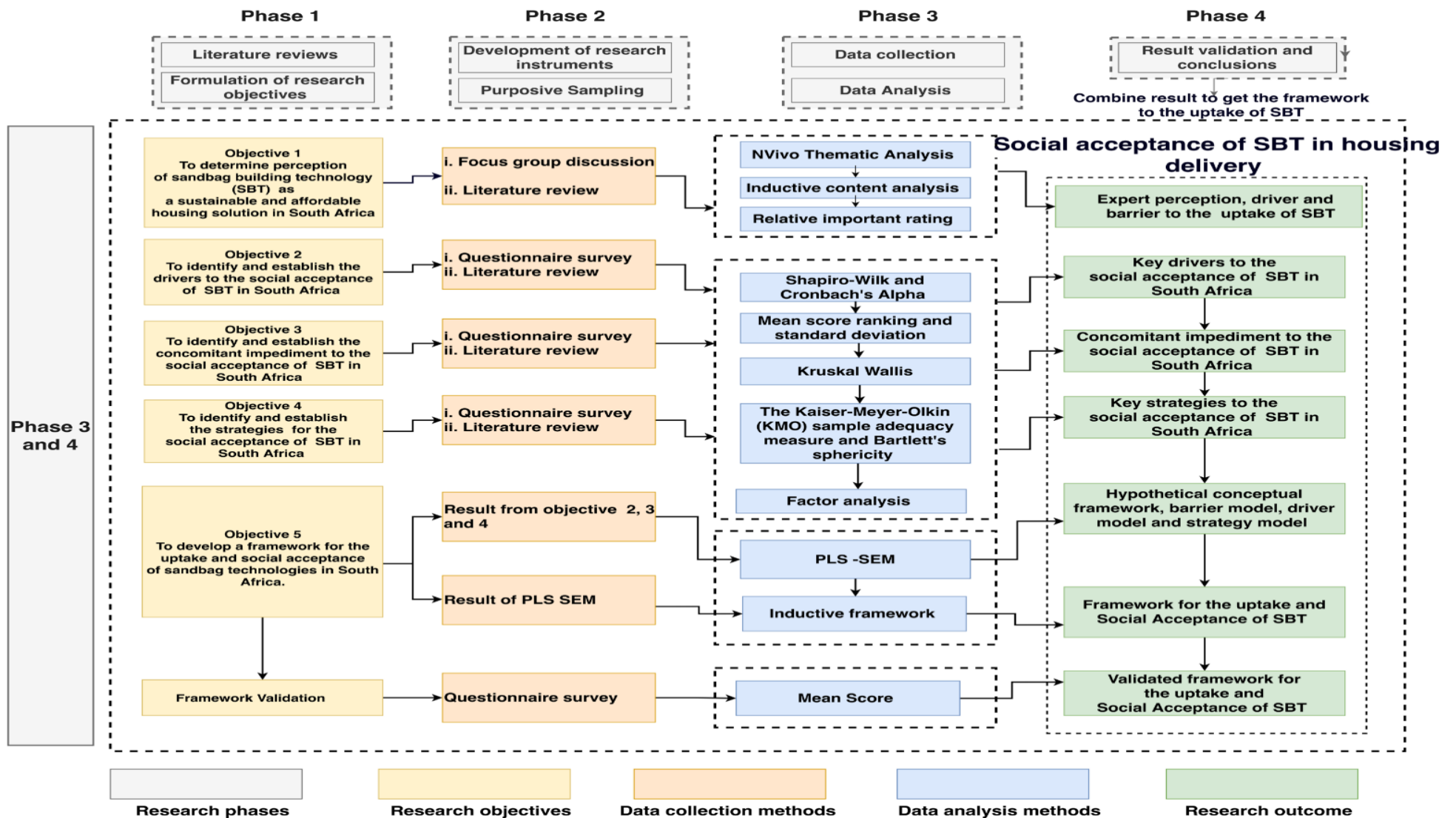


Figure 13: Methodological framework

Quantitative research comprises a variety of techniques for the systematic analysis of social phenomena through the use of statistical or numerical data (Watson, 2015). It is associated with positivism. It is logical, enables researchers to distance themselves from the subject of study, and promotes scientific impartiality (Hathaway, 1995).

The quantitative research method's development phase offers respondents unambiguous questions that elicit responses consistent with study goals (Watson, 2015). In addition, it entails measuring and analysing data for patterns and correlations to validate the measurements (Ekpo, 2019). Quantitative research methods have been used in earlier construction management research, particularly in housing (Adabre & Chan, 2019; Adabre et al., 2020). Therefore, this study employed a quantitative technique for objectives two, three, four, and validation of the framework, to provide a comprehensive understanding of the research

As shown in Figure 13, this study was divided into four phases, with the first phase consisting of a review of the relevant literature and the setting of research objectives. The second phase entails the creation of a research instrument, the third phase includes data collecting and analysis, and the last phase entails validating and constructing the results. The first objective was accomplished by qualitative research, and the second, third, and fourth objectives were accomplished through quantitative analysis.

#### **4.4 Sample population, sample size and sampling techniques**

For the quantitative approach, the population of this research consisted of all South African housing stakeholders and end-users who have knowledge and awareness of alternative building and sandbag technologies. Due to the sample population, this research lacked a sampling frame, hence the sample type was nonprobability (Zhao, Hwang, Pheng-Low, & Wu, 2015). Therefore, nonprobability sampling may be used to get a representative sample (Patton, 2014). It is suitable only when a random sampling approach cannot be utilised to choose respondents from the public, but respondents may also be chosen based on their desire to engage in a research project (Wilkins, 2011). Consequently, snowball sampling approaches were used in this investigation to get a valid and effective overall sample size. Leveraging snowball sampling approaches, overall, two hundred twenty-eight (228) completed surveys with valid responses were obtained (Table 8). Prior research in construction management has also used snowball methodologies to get a suitable and effective total sample size (Chan, Darko, Olanipekun, & Ameyaw, 2018; Darko et al., 2017; Darko et al., 2018; Olawumi & Chan, 2020; Olawumi & Chan, 2021). The survey participants included consultants, contractors,

developers, government authorities (National Home Builders Registration Council), and end-users who were well-versed in alternative construction and sandbag technologies.

#### **4.5 Instrument of data collection**

The research used literature review, questionnaires and semi-structured focus group interviews to gather data. The following sections describe data acquisition.

##### **4.5.1 Comprehensive literature review**

The literature review offers a strong basis for improving the knowledge base in a specific study field by examining and synthesising past relevant works (Okoli & Schabram, 2010). The researcher focused the literature review upon the goals of determining the housing context and application of alternative building technologies. The literature review also includes an overview of the perception and implementation of sandbag building technology in South Africa. Further, the factors (barriers, drives, and tactics) for societal acceptability of SBT were identified by a thorough literature analysis because it enables empirical investigations to build on existing studies and offers a theoretical foundation for future research (Wuni & Shen, 2020). The researcher compiled a preliminary list of drivers, impediments, and strategies based on the analysis. The tentative list was piloted with three ABT specialists in South Africa to validate the questionnaire as suggested by previous research of Wuni and Shen (2020), Chan et al. (2018) and Darko (2019). These professionals were selected based on their combined academic, research, and ABT experience, but they were not included in the final questionnaire. The experts evaluated the relevance and adequacy of the SBT social acceptability strategies, barriers and drivers. Based on the expert judgement, many variables (strategies, barriers and drivers) were rewritten, combined, modified, or eliminated.

##### **4.5.2 Questionnaire design and measurement instrument**

A prepared questionnaire was used as the survey tool for assessing SBT social acceptance variables (strategies, barriers and drivers), social acceptance indicator statement and framework validation. Despite their subjectivity, questionnaires are commonly employed in construction management research to collect quantitative data from practitioners and experts (Wuni & Shen, 2020). As a result, questionnaire survey techniques have been extensively employed in the alternative building technology research area (Darko et al., 2017; Darko et al., 2018).

The questionnaire was developed with the following goals in mind:

- i. To identify the concomitant impediment to the social acceptance of SBT (reported in (Adetooto & Windapo, 2022a)
- ii. To identify the key drivers to the social acceptance of SBT (reported in Adetooto and Windapo (2022b)
- iii. To identify the key strategies to the social acceptance of SBT (reported in Adetooto, Windapo, and Olawumi (2022a)
- iv. To evaluate the component to the social acceptance of SBT (It should be noted that this was required for the PLS-SEM, and the components were modified from (Upham et al., 2015) who measure the level of social acceptance by users of the technology, and also by investors, professionals, and the government). This statement was listed in Table 12.

#### **4.5.2.1 Structure of the questionnaire**

The administered questionnaire included five sections: section one requested background information from the respondent. The questionnaire was designed according to the objectives of the study. The factors described in the literature as objective two (impediment), objective three (drivers), and objective four (strategies) were assessed in the questionnaire in sections two, three, and four, respectively. Section five was developed to examine the component of social acceptability of SBT in South Africa. The factors assessed in sections two through five are referred to as measurement items (or observables) in the PLS-SEM.

The factors in sections two through five of the questionnaire were evaluated using a five-point Likert scale. The five-point Likert scale was used in this research because it provides precise results that may be analysed without difficulty (Ekanayake & Ofori, 2004).

The most practical method of gathering information from respondents was through an online survey (Chan et al., 2018; Darko et al., 2017). The researcher copied the URL from the Survey Monkey platform, which was utilised to build an online version of the questionnaire. The selected respondents received personal emails and Uniform Resource Locators (URLs) to the survey questionnaire. From nine South African provinces, 228 survey responses were obtained. The questionnaire return rate was difficult to calculate, since snowball sampling methods were utilised.

### **4.5.3 The use of Focus Groups**

This research adopted a qualitative approach that employed focus group meetings as the primary data collection method for this study. Qualitative research has been recognized as an excellent method for examining social perspectives in a housing-related study. (Nadal et al., 2018). The two primary methods of data collection used in qualitative research comprise participant observations: typically, through an interview or in focus groups (Gill, Stewart, Treasure, & Chadwick, 2008). The focus group can capture actors' perceptions toward gaining an in-depth understanding of the social issue (Nyumba, Wilson, Derrick, & Mukherjee, 2018). This speaks to the objective of this study, which seeks the perception of the stakeholders on the use of SBT in housing delivery. The respondent can share ideas on a particular problem through a focus group discussion, which can inform future decision-making and strategies (Nyumba et al., 2018). When conducting complex research requiring deep understanding, focus group methods will enable the researcher to generate rich and detailed data (Man, Chan, & Wong, 2017).

Exploiting pre-existing networks, where respondents have an in-depth undertaking and are participating in the same activities, may offer rich data and contribute to the success of the focus group (Kamberelis, Dimitriadis, & Welker, 2018). Given this precedent, the current study's focus group members included ABT professionals and end-users of ABT houses in South Africa, who were chosen using a convenient sampling approach. Table 4 indicates the demographics and skills of the focus group members. Table 4 shows that the chosen experts have a common interest in sustainable housing. According to Kamberelis et al. (2018), there is always an effective focus group when participants share a similar interest in the research problem and can comfortably talk to other participants.

Cape Town was determined to be the perfect site for the focus group talks (Adetooto et al., 2022c). A broader range of specialists from South Africa's construction industry attended in person, while others engaged online. Two focus group conversations with six and seven participants were held in Cape Town, a number which falls within the range of six to fifteen participants that Morgan (1996) recommends. In addition, the most often cited preceding research mandates at least two focus group sessions for studies that rely on focus group data (Guest, Namey, Taylor, Eley, & McKenna, 2017). However, this research fits the aforementioned condition. The two focus group meetings solicited the views and opinions of

experts and end-users on the research objectives by posing two main questions. Following are the general questions:

1. What are your perceptions of using alternative building technologies such as sandbag building technologies as one of the solutions to affordable housing in South Africa?
2. What are the barriers, and strategies to adopting ABTs such as sandbags, in South Africa?

Gathering information from the participants' conversations is the main objective of the focus group discussion, not to force agreement, and the two sessions were handled to accomplish this goal. The talk lasted 4-5 hours and was videotaped. In addition, several participants gave formal presentations to explain their views and points. The slides were collected and analysed. The video footage and various output formats from the focus group conversation were transcribed.

#### **4.6 Criteria for judging the quality of research design**

Cronbach's Alpha was used to check internal consistency among survey questionnaire variables and ensures that the questionnaire captures the right notion (Olawumi & Chan, 2020; Olawumi & Chan, 2021).

In addition, according to Anderson (2010), criticism of qualitative data has been substantial, including allegations of prejudice, anecdotal evidence, and a lack of rigour. However, these would only be true if the study was poorly conducted. As Fleming and Vanclay (2009) provided, the themes in this study were carefully validated against the data from which they were produced, to ensure relevance and validity. Furthermore, an NVivo word frequency analysis was performed to ensure word consistency. The research adheres to Rosenthal (2016) proposal that actual quotes from respondents be supplied to guarantee the data's reliability and validity. As a result, the themes were complemented by verbatim quotes from the focus group discussions of the respondents.

#### **4.7 Method of data analysis**

The NVivo 2.0, Statistical Package for the Social Sciences (SPSS) 28.0 and Partial Least Squares Structural Equation Modelling (PLS-SEM) statistical software were used to analyse the data acquired in the research. The data were analysed using inductive content analysis, mean and standard deviation, the Kruskal-Wallis H test, the Kaiser-Meyer-Olkin (KMO) sample adequacy measure and Bartlett's Test of Sphericity, and factor analysis.

#### **4.7.1 NVivo inductive content analysis**

The qualitative descriptive study followed Creswell and Clark's description of qualitative descriptive research (Creswell & Clark, 2004). In keeping with qualitative descriptive research, this study was conducted without regard for any preexisting theoretical or philosophical viewpoint. It is based on an inductive content analysis, in which code categories were constructed directly from text data. It is utilised when there is no existing research to aid data classification (Hsieh & Shannon, 2005).

The audio data were transcribed verbatim and analysed using NVivo 11 software. Nvivo was utilised to prevent bias while allowing for flexibility in defining codes and categories (Ozkan, 2004). Open coding was used, which involves a line-by-line or verbatim assessment of data in which qualitative data were chosen as the unit of meaning (Draucker, Martsolf, Ross, & Rusk, 2007). In addition, the different codes derived from the selected data were utilised to highlight the main point. These were classified into several concepts. The concept was then subdivided further into categories and subcategories. As a result, this strategy forms the foundation for creating a set of inductive coding frames comprising core categories and subcategories.

The number of repetitions of each code was used to determine the relative significance of each code. According to Chileshe, Rameezdeen, and Hosseini (2016), while analysing qualitative data in construction research, multiple references to codes are processed to show their relative weight and significance. According to Jackson and Bazeley (2019) the above-suggested inferences are true because "people repeat concepts that have meaning to them."

#### **4.7.2 Cronbach Alpha reliability test**

It is crucial to check the reliability of data collection before proceeding with further research (Olatunji, Olawumi, & Awodele, 2017; Olawumi & Chan, 2020; Olawumi & Chan, 2021). The Cronbach Alpha reliability test was used in this research to assess internal consistency among survey questionnaire variables and validate that the questionnaire captures the proper construct (Adabre et al., 2020; Chan et al., 2018). Cronbach's Alpha values range between 0 and 1. The higher the alpha value, the more reliable the scale. Cronbach Alpha reliability for the questionnaire items examined in this research is 0.939, which is more than the 0.7 minimum, showing internal consistency across survey questionnaire variables (Adetooto, Ijigah, Oseghale, & Oseghale, 2020).

### **4.7.3 Normality test**

For the quantitative data, Shapiro-Wilk testing was done to evaluate if the data was normal, parametric, or non-parametric (Wuni & Shen, 2020). The null hypothesis of the Shapiro-Wilk test is that "the data is not normally distributed" (Darko, 2019). The null hypothesis must be rejected if the test p-value is less than the alpha value of 0.05. The Shapiro-Wilk test revealed a P-value of less than 0.05 in this investigation, indicating that the data collected was not normally distributed. Given that the study's data set has less than 2000 sample sizes, this is to be anticipated (Adabre et al., 2020; Chan et al., 2018; Darko, 2019). Hence, the non-normal data distribution influences this study's choice of statistical analysis.

### **4.7.4 Mean score ranking**

The mean score was used in this research to establish the relative importance and ranking of the proposed strategies for SBT's acceptance. In construction management research, mean score ranking approaches are an excellent way to rapidly find key factors (Darko et al., 2018; Olawumi & Chan, 2020). The standard deviation (SD) is another measure of variability and the difference between each result from the mean. If two or more variables have the same mean value, the ordering is determined by the standard deviation, with the barrier with the lowest SD ranking higher (Olatunji et al., 2017).

### **4.7.5 Kruskal-Wallis H test**

Furthermore, since the responses were from various groups (consultants, contractors, end users, government officials, and experts), comparing the means and assessing the perceived differences in the responses across the group is necessary. ANOVA (analysis of variance) and Kruskal-Wallis are two important inferential statistical procedures that may be used to assess whether there is a statistically significant difference between the means of two or more independent data sets (Wuni & Shen, 2020). The data in ANOVA must be normally distributed (Olawumi & Chan, 2020). On the other hand, Kruskal-Wallis is a non-parametric test that may be applied with data that is not normally distributed (Darko, 2019). Given that this study's data is not normally distributed, the Kruskal-Wallis H test was employed to determine if there were statistically significant differences between the means of the various groups. The Kruskal-Wallis H test has also been widely employed in construction management research to compare the means of more than two groups of non-parametric data (Darko, 2019; Wuni & Shen, 2020).

#### **4.7.6 Factor analysis**

The research employed factor analysis (FA) to find the underlying grouping variables (barriers, drivers and strategies) for the social acceptance of SBTs by investigating the interactions between the components (Hair, 2010; Norusis, 2008). Principal component analysis (PCA) was utilised to decrease and recombine large components into a limited number of factor scores and sizes (Li, Chen, Chew, Teo, & Ding, 2011; Xu et al., 2010). Before employing PCA, it is necessary to confirm the adequacy of the factor analysis for factor extraction (PCA).

The Kaiser-Meyer-Olkin (KMO) sample adequacy measure and Bartlett's sphericity test examine the factor analysis's suitability. The KMO ratio, introduced by Field (2013), measures the sampling appropriateness of variables and runs from 0 to 1. Norusis (1993) suggested that if the KMO is over 0.5, the FA will produce a dependable and unique factor. Before a factor analysis is carried out, the KMO value should not be less than 0.50. Bartlett's test of sphericity is a statistical technique that examines correlations between variables (Chan, Lam, Chan, Cheung, & Ke, 2010). When completing Bartlett's test of sphericity, Pett, Lackey, and Sullivan (2003) stated that if the original correlation matrix is an identity matrix, there is no relationship between the variables. As a consequence, FA will be useless. FA would be acceptable if the correlation matrices are not identity matrices and the significance level is low with a high sphericity value (Pallant, 2020).

##### **4.7.6.1 Factor scale rating**

Each aggregated driver and barrier with a strong correlation was labelled with a collective or identifiable label, as advised by Sato (2005). The driver scale rating is determined by the ratio of the mean of individual driver/barrier within a cluster divided by the number of drivers in the cluster (Olawumi & Chan, 2020). The primary purpose of the driver scale rating study is to discover which driver group is more significant. The explanation of grouped drivers will centre on all five ranking driver categories (component).

#### **4.7.7 Partial least squares structural equation modelling (PLS-SEM)**

This research examined SBT social acceptability barriers, drivers, and techniques using structural equation modelling (SEM), a multivariate statistical analytical tool. SEM investigates hypotheses among measurement items and constructs and analyses a phenomenon-based structural hypothetical model, using a confirmatory approach (Hair Jr, Howard, & Nitzl, 2020)

SEM examines both direct and indirect correlations between independent and dependent variables. SEM was selected because it goes beyond multiple regression, ANOVA, and factor analysis (Janadari, Sri Ramalu, Wei, & Abdullah, 2016). In contrast to multivariate regression and factor analysis, SEM may simultaneously perform confirmatory factor analysis (CFA) and path analysis (Darko et al., 2018). A structural equation model (SEM) contains both measurement and structural models. A measurement model investigates the links between a construct and its measurement items, while a structural model illustrates construct linkages (Hair Jr et al., 2020). SEM was used to analyse the hypotheses in this study.

CB-SEM (Covariance based structural equation modelling) and PLS-SEM are two SEM methods. PLS-SEM performs better than CB-SEM with few samples and non-normal data (Hair, Risher, Sarstedt, & Ringle, 2019; Hair Jr et al., 2020). PLS-SEM is well-known in construction management research because of its advantages over CB-SEM. The present study employed PLS-SEM using SmartPLS 3.2.7 software to evaluate the study hypotheses and validate the hypothetical models. Chapter 5 discusses hypotheses and models based on Exploratory Factor Analysis (EFA) results.

CFA may investigate measurement item-construct relationships (Darko, 2019). Janadari et al. (2016) advocate examining the reliability and validity of the measurement items after explaining the measurement and structural models. Evaluating the measurement models assures that the constructions required to evaluate the structural model's assumed connections are consistently represented and measured, showing the measurement models' fitness for route analysis. Reliability refers to how successfully multi-item scales evaluate structures compared to error (Janadari et al., 2016). The composite reliability score and Cronbach's Alpha coefficient were utilised to investigate assessment item internal consistency reliability. The composite reliability score and Cronbach's Alpha coefficient value have the same meaning (Janadari et al., 2016) because composite reliability scores should be more than 0.70 and Cronbach's Alpha coefficient values should be greater than 0.70 (Hair, 2010).

Following reliability, validity (convergent and discriminant) must be evaluated. Factor loadings demonstrate bivariate correlations between measuring items and their respective constructs and relate the items to the concept (Hair, 2010). For convergent validity, the factor loading and average variance extracted (AVE) of each assessment item should be 0.50 or above (Hair et al., 2019; Hair Jr et al., 2020). The grand mean value of a collection of squared loadings equals the communality of a construct (Hair, 2010).

Discriminant validity examines whether a construct measures what it was intended to measure; it compares a concept to others. To assess discriminant validity, two methods were used. First, the Fornell and Larcker (1981) criterion was used, which demonstrates that a construct's variance with its measurement items is greater than that of any other construct. The AVE of each construct should be greater than the greatest squared correlation. Second, cross loadings were investigated in order to confirm discriminant validity. The construct loading of each measurement item must be greater than the cross loadings of other constructs (Chin, 1998). Path coefficients represent hypothetical construct relationships (Hair et al., 2019; Hair Jr et al., 2020). To assess structural model assumptions, path coefficient significance must be estimated after proving the reliability and validity of measurement models.

Bootstrapping was also utilised. Bootstrapping is a versatile strategy for forecasting the distribution of any statistic (Hair et al., 2019; Hair Jr et al., 2020). This research, like Hair (2010) employed 5,000 bootstrap subsamples with an equal number of cases and responses. Using numerous bootstrap subsamples provides consistent results. The required t-values for a two-tailed test were 1.65 (significance threshold = 10%), 1.96 (5%), and 2.58 (1%). (Hair et al., 2014b). The results of PLS-SEM are discussed in Chapter 6.

#### **4.8 Ethical considerations**

The researcher submitted an application to the Faculty of Engineering and the Built Environment at the University of Cape Town for ethical approval. Before the researcher began collecting data, the committee granted ethical clearance on October 21, 2021. The researchers ensured that study participation was voluntary throughout data collection. Before data collection, participants were asked for their informed consent and free to withdraw at any moment. All participants' anonymity was maintained, and members of focus groups and survey replies were coded to conceal their identities. The researcher verified that no information about the participants was divulged beyond the scope of the study. The outcomes of the data analysis accurately match the data obtained from respondents.

#### **4.9 Chapter summary**

This chapter outlines the philosophical stance and methodology of the study. Both qualitative and quantitative data collection and analysis were used in this study. The qualitative analysis was conducted using NVivo and a focus group. While SPSS 28.0 is used for quantitative analysis, a five-level analytical framework is implemented. Descriptive statistics, namely the

Kruskal-Wallis H test, KMO, Bartlett's test for sphericity, factor analysis and PLS-SEM are included. The following chapter analyses and interprets the qualitative data collected at this investigation stage.

## CHAPTER FIVE

### DATA PRESENTATION AND ANALYSIS

#### 5.1 Introduction

This chapter provides a qualitative, quantitative analysis and PLS-SEM analysis of the objectives of this study.

#### 5.2 Data Presentation

##### 5.2.1 Qualitative data presentation

##### 5.2.1.1 General profile of the focus group respondents

Table 4 displays the demographics and skills of the focus group participants. To preserve anonymity, the interviewees are represented by the letters C1 to C6 and D1 to D7, which correspond to the first and second focus groups. Table 4 demonstrates that the selected experts are interested in SAH.

Participants include leading researchers in the fields of sustainability and ABT, a SBT expert and the CEO of an SBT company, a United Nations researcher in infrastructure investment, green building, and biomimicry, representatives from the Centre for Research in Housing Innovation, the National Home Builders Registration Council (NHBRC), and SBT house occupants. The participants' expertise in sustainability and ABT ranged from 5 to 40 years, allowing them to contribute a lot of knowledge about the research context in particular.

**Table 4:** Profile of the focus group members

<b>ID</b>	<b>Position</b>	<b>Experience with ABT (Years)</b>	<b>Involvement in sandbag technologies</b>
C1	A leading research expert in sustainable, affordable housing	40	A leading researcher on sustainability and ABT.
C2	Architect	25	A sandbag technologies expert and the CEO of a sandbag construction company.

<b>ID</b>	<b>Position</b>	<b>Experience with ABT (Years)</b>	<b>Involvement in sandbag technologies</b>
C3	Member of the sustainable, affordable housing research group	20	United Nations researcher, in infrastructural investment, green building, and biomimicry.
C4	Member of the sustainability research group	15	A doctoral researcher on sustainable and affordable housing in South Africa.
C5	Architect	25	A quality assessor inspector at the Centre for Research in housing innovation
C6	End-user 1	3	An occupant of a sandbag technology house in South Africa
D1	A leading researcher on alternative housing	25	A leading researcher on ABT.
D2	A leading researcher on alternative housing	30	A leading researcher on ABT
D3	Member of the sustainable, affordable housing research group	5	A researcher on sustainable and affordable housing in South Africa.
D4	Engineer	25	A sandbag technologies expert and the CEO of a sandbag construction company.
D5	Collaborator on research on the sustainable,	13	An Associate Professor and an expert researcher on

<b>ID</b>	<b>Position</b>	<b>Experience with ABT (Years)</b>	<b>Involvement in sandbag technologies</b>
	affordable housing research group		sustainable construction
D6	Collaborator on research on the sustainable, affordable housing research group	8	A researcher on alternative construction
D7	End-user 2	3	An occupant of a sandbag technologies house in South Africa

### 5.2.1.2 Perceptions on the use of sandbag technology

Table 5 presents the respondent's perception of the use of sandbag technology in South Africa. Direct statements from the respondent on the use of Sandbag Technology in South Africa were presented.

**Table 5:** Respondent perception on the use of sandbag technology in South Africa

<b>Respondent</b>	<b>Direct statement</b>
<b>D2</b>	<i>They are a fantastic alternative to traditional building techniques. The concrete used in a sandbag house (columns and lintels) accounts for around 50% of its carbon footprint, and low-carbon concretes or alternative materials may greatly lower the carbon footprint of sandbag construction</i>
<b>D1</b>	<i>Over time, the manufacture of cement has a considerable carbon impact. According to research, every tonne of cement produced emits an equal amount of carbon dioxide into the environment. So, when it comes to sandbag housing, the sandbag is a sustainable building technique that utilises less cement, and I believe that everyone should embrace it</i>
<b>C1</b>	<i>Sandbag technology is the most extensively utilised unknown local building material in South Africa. It is less expensive than traditional materials and is one of the potential solutions to affordable housing</i>
<b>D4</b>	<i>Sandbag construction should be less expensive than traditional construction, but this relies on how you operate the site, the building specification, the type of sand and availability of sand, the geography of the land, and the market structure. For example, houses developed in Val de Vie will be more costly than those erected in Durbanville or Mossel Bay</i>
	<i>In 2014, we erected a sandbag school in Nepal. Six days later, a major earthquake struck Nepal, destroying all of the buildings in the town. The only structure that remained intact after the earthquake was the sandbag school</i>

<b>Respondent</b>	<b>Direct statement</b>
	<i>we had just completed." And the Nepalese government initiated an inquiry on why this structure is still intact when everything else has crumbled, as broadcast on BBC TV and CNN. Consequently, sandbag construction is now an officially recognised building method in Nepal</i>
<b>C5</b>	<i>It is typically a good and inexpensive method, especially in remote development, and it might be one of the answers to the question of human settlements</i>
<b>C3</b>	<i>Sandbag [technology] is labour-intensive and can generate employment</i>
<b>C2</b>	<i>I've trained many people over the years how to construct a sandbag house since it's simple to understand; they're still doing it and generating money from it</i>
<b>D5</b>	<i>We know that around 2,000 people each year are killed by fire because, in these shacks, when a fire breaks out, it quickly spreads over the whole town, but a sandbag home cannot burn up</i>

### 5.2.1.3 Perceptions of the challenges to the use of sandbag technology

Table 6 presents the respondent's perception of the challenges to the use of sandbag technology for SAH delivery in South Africa. Direct statements from the respondents on the challenges of using sandbag technology in South Africa were presented.

**Table 6:** Respondents' perception of the challenges of using sandbag technology in South Africa

<b>Respondent</b>	<b>Direct statement</b>
<b>D6</b>	<i>Social acceptance is a significant difficulty. People associate living in a sandbag house with poverty and prefer to reside in a masonry building</i>
<b>C2</b>	<i>In Frieda, we erected 600 houses out of polystyrene, and when the contractors finished, people have set fire to buildings because the community does not recognise and approve of alternative building technologies</i>
<b>D4</b>	<i>We attempted to construct SBT houses in townships like Khayelitsha, but we were stoned and forced to leave. If I had remained there for another five minutes, I would have been murdered</i>
<b>D3</b>	<i>One of the problems is that South Africans have a natural preference for brick-and-concrete dwellings, and many fear alternative building technology would label them as impoverished</i>
<b>C3</b>	<i>People assume that since a house is made of sand, it is of inferior quality and has a short lifespan. When the community does not accept a notion, it will not be implemented</i>

<b>Respondent</b>	<b>Direct statement</b>
<b>C2</b>	<i>We've never been able to implement SBT in South Africa, despite our efforts since the impression is negative and the government is unwilling to accept it</i>
<b>D1</b>	<i>Only until the performance of sandbag housing is made public can the government have faith in its effectiveness</i>
<b>C5</b>	<i>Construction experts should understand the process of building with sandbags and what must be done to avoid difficulties such as cracking</i>
<b>C1</b>	<i>The major concern is that banks will not fund it</i>
<b>5</b>	<i>Banks have no trouble lending money to construct a sandbag home as long as the government has authorised SBT</i>

#### **5.2.1.4 Perceptions on the strategies for the use of sandbag technology**

Table 7 presents the respondent's perception of the strategies for the use of sandbag technology for SAH delivery in South Africa. Direct statements from the respondent on the strategies for using Sandbag Technology in South Africa were presented

**Table 7:** Respondents' perception of the strategies to the use of Sandbag Technology in South Africa

<b>Respondent</b>	<b>Direct statement</b>
<b>D6</b>	<i>There is a need to conduct more tests and publish more results to educate people on the performance integrity of sandbag technology to assure its widespread adoption</i>
<b>D1</b>	<i>One approach to get it accepted is to bring that technology into our cities, so people can witness it from start to finish, rather than just building it in rural areas</i>
<b>D4</b>	<i>One essential strategy to sell out this technology is to create prototype buildings in cities</i>
<b>C3</b>	<i>I believe raising awareness is one of the most important techniques for promoting the widespread adoption of alternative technology</i>
<b>C2</b>	<i>Training is one strategy to promote the ABT system</i>

#### **5.2.2 Quantitative data presentation**

##### **5.2.2.1 General profile of the survey respondents**

This section provides background information about the 228 respondents to this survey (see Figure 14 and Table 8). The responses came from the nine provinces of South Africa. Gauteng had the most 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

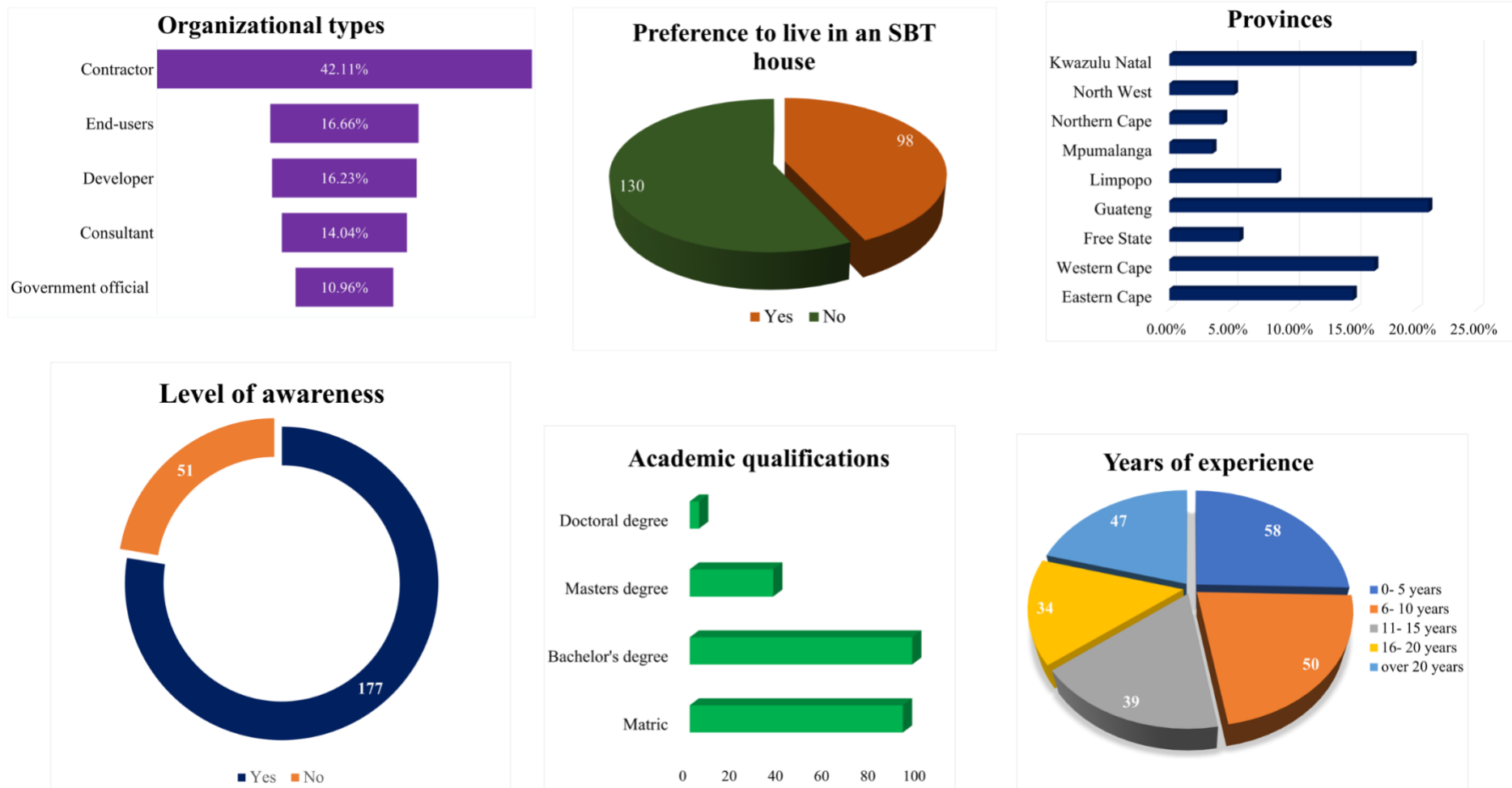
percent), Free State (13, 5.70 percent), North-West (12, 4.39 percent), Northern Cape (10, 21.05 percent), and Mpumalanga had the fewest participants (10, 4.39 percent) (8, 3.51 percent). The bulk of respondents were contractors (96, 42.11 percent), followed by customer participants (38, 16.66 percent), developers (37, 16.23 percent), and consultants (32, 14.04 percent), with government officials being the smallest proportion of respondents (25, 10.96 percent). A small majority of respondents were project and construction managers (47.96%), followed by academics and others (38.46%), structural and civil engineers (11.76%), and architects (1.81 percent). The respondents' awareness of alternative and sandbag construction technologies indicated that the majority of participants (177, 77.63 percent) had a high level of awareness of SBT, whilst 51 respondents (22.37 percent) had a poor comprehension of the approach.

52.63 percent of respondents (120) had at least 11 years of industry experience, indicating that the survey participants had substantial professional expertise in the field, and 21.93 percent of respondents (50) had six to ten years of industry experience. The majority of respondents had a bachelor's degree (96, 42.11 percent), followed by a matriculation certificate (92, 40.35 percent), a master's degree (36, 15.79 percent), and a doctorate (4, 1.75 percent). Most participants (130, 57.02 percent) were hesitant to live in a sandbag construction technology home, while 98 respondents (42.98 percent) were eager to do so. This is still a reasonable figure with the level of social acceptance of SBT in the literature.

**Table 8:** Demographic information of the respondents

<b>Answer choices</b>	<b>Response number</b>	<b>Response percent</b>
<b>Organizational types</b>		
Contractor	96	42.11
End-users	38	16.66
Developer	37	16.23
Consultant	32	14.04
Government official	25	10.96
<b>Provinces</b>		
Eastern Cape	34	14.91
Western Cape	38	16.66
Free State	13	5.70
Gauteng	48	21.05
Limpopo	20	8.77
Mpumalanga	8	3.51
Northern Cape	10	4.38

<b>Answer choices</b>	<b>Response number</b>	<b>Response percent</b>
North West	12	5.26
KwaZulu Natal	45	19.76
<b>Years of experience</b>		
0-5 years	58	25.44
6-10 years	50	21.93
11-15 years	39	17.11
16-20 years	34	14.91
Over 20 years	47	20.61
<b>Awareness</b>		
Yes	177	77.63
No	51	22.37
<b>Academic qualifications</b>		
Matric	92	40.35
Bachelor's degree	96	42.11
Master's degree	36	15.79
Doctoral degree	4	1.75
<b>Preference to live in an SBT house</b>		
Yes	98	42.98
No	130	57.02



**Figure 14:** Demographic information of the respondents

### 5.2.2.2 Barriers to the social acceptance of SBT

Table 9 summarises the data collected through a questionnaire survey on the barriers to the social acceptance of sandbag technology in housing construction. A five-point Likert scale was used, which ranges from 1 (not critical) to 5 (very critical). “Lack of awareness of Sandbag Technology and its benefits” was ranked #1, with the highest mean value,  $M = 4.0$  ( $SD = 1.039$ ). 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 technology 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 technology policies and regulations” ( $M = 3.87$ ,  $SD = 1.018$ ). More so, Based on a comparable benchmark used by Adetooto and Windapo (2022a) critical barriers were identified as those with normalised values greater than 0.5. Therefore, 14 of the initial 18 obstacles had normalised values of more than 0.50 and are classified as critical (Table 14).

**Table 9:** Descriptive statistics and Frequency of response for the barriers to the social acceptance of sandbag building technology

Code	Barriers	Frequency % (1 = not critical, 5 = very critical).					MS	SD	RK
		1	2	3	4	5			
B1	Lack of sandbag technology databases and information	6.06	7.88	20.61	40.00	25.45	3.68	1.116	13
B2	Lack of interest from the Government	4.24	3.64	24.85	33.94	33.33	3.87	1.159	6
B3	Lack of sandbag technology policy and regulations	3.05	4.88	23.7	36.59	31.71	3.87	1.018	5
B4	Lack of building codes	2.50	6.25	24.38	33.13	33.75	3.82	1.096	8
B5	Lack of promotion of sandbag technology by Government	3.07	5.52	20.86	36.20	34.3	3.92	1.068	4

Code	Barriers	Frequency % (1 = not critical, 5 = very critical).					MS	SD	RK
		1	2	3	4	5			
B6	Lack of courses and training on sandbag technology	3.05	4.88	18.90	35.9	37.20	3.95	1.038	2
B7	Negative effects on human health;	7.98	11.66	39.88	24.54	15.95	3.25	1.125	18
B8	Lack of interest from clients;	4.97	4.35	33.54	34.16	22.98	3.58	1.085	16
B9	Lack of existing sandbag machines and technologies	3.66	4.27	28.05	34.15	29.88	3.81	1.031	9
B10	Lack of professional knowledge and expertise	11.84	6.75	22.09	30.06	39.26	3.93	1.031	3
B11	Professionals resistant to change from the use of conventional technologies	2.47	8.02	25.31	32.10	32.10	3.79	1.097	10
B12	Lack of awareness of sandbag technology and its benefits	2.44	5.49	20.12	32.32	39.63	4.00	1.039	1
B13	Deficiency in sandbag construction techniques	2.48	4.97	33.54	31.68	27.33	3.72	1.054	11
B14	Durability issue	4.94	9.88	32.72	27.16	25.31	3.52	1.124	17
B15	Technical limitations	3.75	5.63	33.75	31.25	25.62	3.63	1.082	14
B16	Lack of standard design method for sandbag technology	5.52	4.91	25.15	40.49	23.93	3.69	1.072	12

Code	Barriers	Frequency % (1 = not critical, 5 = very critical).					MS	SD	RK
		1	2	3	4	5			
B17	Inexperienced labour	7.41	9.26	21.60	33.95	27.78	3.60	1.233	15
B18	Lack of financing schemes (bank loans, grants)	2.48	9.32	20.50	28.57	39.13	3.87	1.159	6

### 5.2.2.3 Drivers of the social acceptance of SBT

Table 10 summarises the data collected through a questionnaire survey on the drivers of the social acceptance of sandbag technology in housing construction. A five-point Likert scale was used which ranges from 1 (strongly disagree) to 5 (Strongly agree). The mean value ranges from M= 3.90 (SD= 0.928) for "D16- Job creation opportunities" to M= 3.45 (SD= 0.922) for "D24- Aesthetics." The five most important drivers of the social acceptance of SBT include D16- Job creation opportunity (M= 3.06 SD= 0.928); D17- Material availability (M= 3.82 SD= 1.030); D22- Waste reduction (M= 3.81 SD= 0.936); D3- Reduce environmental effects (M= 3.81 SD= 0.984); and D6- Affordability (M= 3.78 SD= 1.014). The minimal important criterion is 3.00, based on the linguistic variables given to the five-point grading scale (Wuni & Shen, 2020), indicating that all the drivers evaluated were important (key) to SBT social acceptance. All of these drivers are covered in the following sections of the study.

**Table 10:** Descriptive statistics and frequency of response for the drivers of the social acceptance of SBT

Code	Drivers	Frequency % (1 = strongly disagree, 5 = strongly agree).					MS	SD	RK
		1	2	3	4	5			
D1	A better alternative to adobe	2.12	4.76	47.62	30.16	15.34	3.47	0.873	22
D2	High energy efficiency	3.16	3.16	35.26	42.63	15.79	3.61	0.885	15
D3	Reduces environmental impacts	3.70	3.17	22.75	45.50	24.87	3.81	0.984	4
D4	Better thermal comfort	3.70	3.70	30.16	43.92	18.52	3.69	0.922	10

Code	Drivers	Frequency % (1 = strongly disagree, 5 = strongly agree).					MS	SD	RK
		1	2	3	4	5			
D5	Diversity of forms and styles	2.66	5.85	31.91	41.49	18.09	3.61	0.957	14
D6	Affordability	3.70	4.76	22.22	43.92	25.40	3.78	1.014	5
D7	Low maintenance cost	2.65	10.05	28.57	34.39	24.34	3.64	1.043	13
D8	Lower transportation cost	4.19	10.47	26.70	37.17	21.47	3.59	1.070	18
D9	Fireproof	1.06	5.82	33.33	37.57	22.22	3.71	0.911	9
D10	Ease of construction	3.16	10.00	23.68	41.05	22.11	3.67	1.022	12
D11	Required little expertise	2.63	15.26	25.26	42.11	14.74	3.50	0.998	20
D12	Fast mode of construction	3.16	6.32	23.68	41.58	25.26	3.77	0.999	6
D13	Erosion and flood control	2.13	11.70	36.70	28.72	20.74	3.49	1.036	21
D14	Good acoustic insulation	1.60	5.85	29.26	43.09	20.21	3.69	0.916	11
D15	Improved indoor environmental quality	1.59	7.41	34.39	38.62	17.99	3.60	0.929	16
D16	Job creation opportunity	1.05	5.76	22.51	41.36	29.32	3.90	0.928	1
D17	Material availability	2.14	7.49	20.86	38.50	31.02	3.82	1.030	2
D18	Improved occupant health	2.12	7.94	38.62	30.16	21.16	3.60	0.982	17
D19	Reduced condensation and fungal growth	2.13	10.11	39.36	33.51	14.89	3.46	0.952	23

Code	Drivers	Frequency % (1 = strongly disagree, 5 = strongly agree).					MS	SD	RK
		1	2	3	4	5			
D20	Resist environmental hazards	1.59	7.41	38.10	35.45	17.46	3.57	0.932	19
D21	Reusable and recyclable	3.16	5.79	24.74	42.11	<sup>2</sup> 4.21	3.74	0.991	8
D22	Waste reduction	1.58	5.79	24.74	43.16	24.74	3.81	0.936	3
D23	Wind resistant and bulletproof	1.58	6.84	27.89	39.47	24.21	3.77	0.961	7
D24	Aesthetics	1.61	9.14	38.71	36.56	13.98	3.45	0.922	24

#### 5.2.2.4 Strategies for the social acceptance of SBT

Table 11 summarises the conclusions of the ranking research on the strategies for social acceptance of sandbag technology in housing construction. A five-point Likert scale was used which ranges from 1 (not important) to 5 (very important). The mean value for the 13 identified strategies varies from M= 4.06 (SD= 0.933) for "ST11- Reformed tendering procedure" to M= 4.30 (SD= 0.836) for "ST5- Availability of sandbag demonstration projects throughout all provinces," with a variance of 0.699. Based on the mean score and standard deviation, the five most important strategies for SBT'S acceptance include ST5- Availability of sandbag demonstration projects across all provinces (M = 4.30 SD = 0.836); ST3 - Approved sandbag building code" (M= 4.30, SD= 0.878); ST6 - Availability of standard design methods for earthbag (M= 4.26, SD=0.849); S2 - Public sandbag awareness creation" (M= 4.22, SD=0.854) and S13 - Educational training for investors, experts, and end-users (M= 4.21, SD=0.977). Furthermore, based on comparable standards used by Olawumi and Chan (2020), who used a mean value of 4 on a 5-point Likert scale to consider a factor significant, all 13 strategies (factors) are considered significant based on the mean score.

**Table 11:** Descriptive statistics and Frequency of response for the strategies to the social acceptance of SBT

Code	Strategies	Frequency % (1 = not important, 5 = very important).					MS	SD	RK
		1	2	3	4	5			
S1	A financial incentive for sandbag technology uptake	1.33	4.00	15.33	42.67	36.67	4.08	0.903	12
S2	Public sandbag technology awareness creation through workshops, seminars, and conferences	1.33	2.00	13.33	39.33	44.00	4.22	0.854	4
S3	Approved sandbag building code	1.33	1.33	11.3	37.33	48.67	4.30	0.878	2
S4	Availability of the competent promotion teams and grassroots supporters	1.33	2.00	16.00	38.67	42.00	4.17	0.878	8
S5	Availability of sandbag technology demonstration projects across all provinces	0.67	4.00	14.00	30.00	51.33	4.30	0.836	1
S6	Availability of standard design methods for sandbag technology	1.33	1.33	13.33	38.67	45.33	4.26	0.849	3
S7	Availability of sandbag technology research centre	1.34	3.3	16.78	34.90	43.6	4.12	0.960	9

Code	Strategies	Frequency % (1 = not important, 5 = very important).					MS	SD	RK
		1	2	3	4	5			
S8	Support from executive management	2.00	2.67	19.33	33.33	42.67	4.11	0.961	11
S9	Formulation of sandbag technology policies and regulations	2.00	2.67	15.33	34.67	45.33	4.18	0.936	7
S10	Inclusion of sandbag technology in the curriculum of technical training colleges	2.00	1.3	18.00	33.33	45.33	4.18	0.930	6
S11	Reformed tendering process	2.00	2.67	22.67	35.33	37.33	4.04	0.933	13
S12	Standardisation of the material and components	1.33	2.00	19.3	39.33	38.0	4.11	0.863	10
S13	Educational training for investors, professionals and end-user	2.03	0.68	15.54	31.76	50.00	4.21	0.977	5

#### 5.2.2.5 Component of the social acceptance of sandbag building technology

Table 12 summarises the conclusions of the research on the ranking of the social acceptance of sandbag building technology. A five-point Likert scale was used which ranges from 1 (not important) to 5 (very important). Based on the mean score, C1- Members of the community construct their houses using sandbag construction technique (M = 4.11); C2- Government officials promote the use of sandbag technology in construction (M= 4.22); C3 - Investors and financial institutions encourage the usage of sandbag technology (M= 4.33); and C4 - Professionals in construction endorse the usage of sandbag technology (M= 4.78)

**Table 12:** Descriptive statistics and frequency of response for the component of the social acceptance of to the social acceptance of SBT

Code	Component	Frequency % (1 = not important, 5 = very important).					MS	RK
		1	2	3	4	5		
C1	Members of the community construct their houses using sandbag construction technique	0.00	0.00	11.11	66.67	22.22	4.11	4
C2	Government officials promote the use of sandbag technology in construction	0.00	0.00	22.22	33.3	44.44	4.22	3
C3	Investors and financial institutions encourage the usage of sandbag technology	0.00	0.00	11.11	44.4	44.44	4.33	2
C4	Professionals in construction endorse the usage of sandbag technology	0.00	0.00	0.00	22.22	77.78	4.78	1

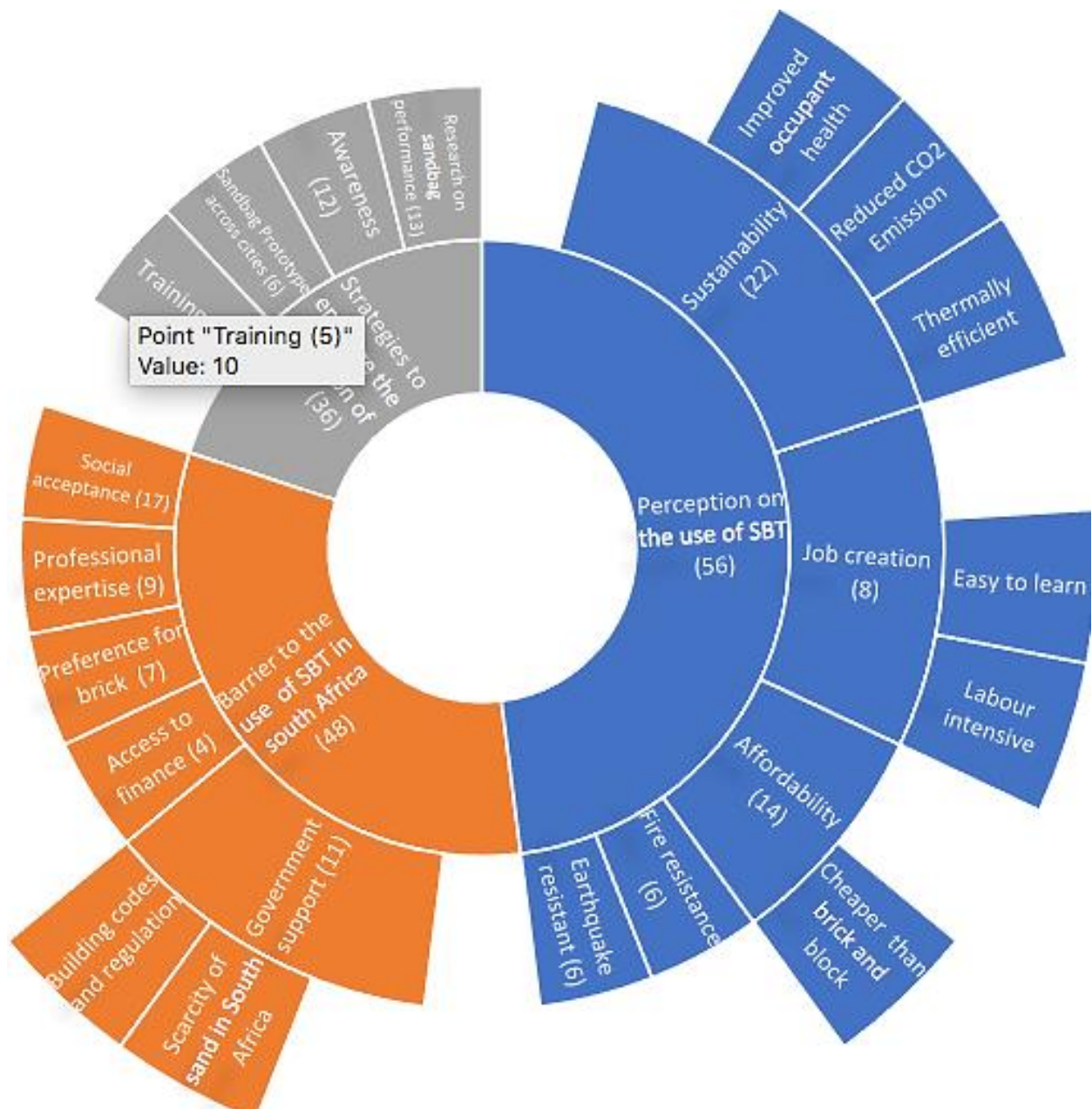
### 5.3 Data Analysis

#### 5.3.1 Qualitative data analysis

##### 5.3.1.1 Test of expert perceptions of the use of sandbag technology as a SAH solution in South Africa

The first research objective sought to determine the perception by actors of the use of SBT as a SAH solution in South Africa. NVivo was used to assess the perceptions of experts about the usage, barriers, and strategies for utilising SBT in South Africa to deliver SAH. Prior to thematic analysis using NVivo, a word frequency analysis (Figure 15) was performed in NVivo to validate the data and establish its consistency. Based on the word frequency analysis, the most frequent word is "sandbag", indicating that the analysed transcript is valid and consistent with the research objective.





**Figure 16:** NVivo Sunburst diagram of the perception of sandbag technology

Theme 1 (Perception of the usage of SBT) consists of five codes and has the highest relative importance (RI) of 56; it is associated with Sustainability (22), Affordability (14), Job Creation (8), Earthquake Resistance (6) and Fire Resistance (6). Theme 2 (barriers to the use of SBT in South Africa) consists of five codes and has the second-highest relative importance (RI) value of 48. The theme relates to Social Acceptance (17), Governmental Support (11), Professional Expertise (9), Brick and Block Preference (7), and Financial Access (4). Theme 3 (Strategies to increase the social acceptance of SBT (36) consists of four codes and has the lowest rated relative importance (RI) score of 36. This theme pertains to Adequate research on sandbag

performance (13), Awareness (12), Building sandbag prototypes throughout cities (6), and Training (5)

**Table 13:** NVivo thematic classification

<b>Themes</b>	<b>Codes (references)</b>	<b>Sub-Codes</b>
Perception of the use of SBT (56)	1. Affordability (14)	• Cheaper than brick and block
	2. Sustainability (22)	• Thermally efficient • Reduced CO2 emission
	3. Job creation (8)	• Improved occupant health • Labour intensive
	4. Earthquake resistant (6)	• Easy to learn
	5. Fire resistance (6)	
The barrier to the use of SBT in South Africa (48)	1. Social acceptance (17)	
	2. Support from Government (11)	• Building codes and regulation • Scarcity of sand in South Africa
	3. Professional expertise (9)	
	4. Preference for brick and block (7)	
	5. Access to finance (4)	
Strategies to enhance the social acceptance of SBT (36)	1. Adequate research on sandbag performance (13)	
	2. Awareness (12)	
	3. Building sandbag prototypes across cities (6)	
	4. Training (5)	

### 5.3.2 Quantitative data analysis

#### 5.3.2.1 Test of difference in the respondent's perception of the barriers and grouping of the barrier into factors: intergroup comparison

Objective 2 sought to determine the expert perception on the concomitant impediment to the social acceptance of sandbag building technology in South Africa. However, towards establishing the concomitant impediment, the study sought to check the intergroup comparison and test if there were perception differences across the group. Table 14 summarises the data obtained from respondents based on organisational affiliation, which suggest that contractors and clients respondents regarded “B12—lack of awareness of sandbag technology and its benefits” (M = 4.0 SD = 1.039) as the most critical barrier to social acceptance of SBT in

housing construction. 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 technology” (M= 3.95, SD = 1.038) as the most critical barrier to accepting sandbag building technologies in South Africa. “B7—Negative impact on human health” (M = 3.25, SD = 1.125) is seen as the least major barrier by all organisational structures (consultants, contractors).

The 18 identified impediments were analysed using the Kruskal-Wallis H test to see whether there are perceived differences among respondents from different organisational backgrounds (consultants, contractors, developers, government officials, and clients). Based on the Kruskal-Wallis H test results, the significance levels of 18 impediments were more than 0.05. (Table 14). There are no statistically significant differences in consultants', contractors', developers', government officials, and clients' perceptions of these impediments' importance.

**Table 14:** Barriers to the social acceptance of sandbag technology uptake in housing construction; intergroup comparisons.

Code	Contractors		Consultants		Developers		Client		Government officials		All respondent			Kruskal Wallis (P-value)	
	MS	RK	MS	RK	MS	RK	MS	RK	MS	RK	MS	SD	RK		Normalisation <sup>a</sup>
B12	4.01	1	4.11	4	3.89	9	4.14	1	3.73	10	4.00	1.039	1	1 <sup>b</sup>	0.725 <sup>c</sup>
B6	3.92	2	4.06	6	4.11	3	3.86	7	4.00	1	3.95	1.038	2	0.93 <sup>b</sup>	0.994 <sup>c</sup>
B10	3.87	5	4.11	3	3.78	10	4.29	2	3.87	6	3.93	1.031	3	0.91 <sup>b</sup>	0.621 <sup>c</sup>
B5	3.92	3	3.94	11	4.11	4	3.71	10	4.00	2	3.92	1.068	4	0.89 <sup>b</sup>	0.784 <sup>c</sup>
B3	3.86	6	4.17	1	4.22	2	3.57	14	3.60	15	3.87	1.018	5	0.83 <sup>b</sup>	0.384 <sup>c</sup>
B18	3.89	4	3.89	13	4.00	6	3.86	6	3.60	16	3.87	1.159	6	0.83 <sup>b</sup>	0.941 <sup>c</sup>
B2	3.82	8	3.83	14	4.44	1	3.71	12	3.93	5	3.86	1.071	7	0.81 <sup>b</sup>	0.413 <sup>c</sup>
B4	3.83	7	4.06	9	3.78	11	3.57	15	3.73	11	3.82	1.096	8	0.76 <sup>b</sup>	0.691 <sup>c</sup>
B9	3.78	9	3.89	12	3.89	7	4.07	4	3.60	13	3.81	1.031	9	0.75 <sup>b</sup>	0.695 <sup>c</sup>
B11	3.73	10	4.06	5	3.67	13	3.79	9	4.00	3	3.79	1.097	10	0.72 <sup>b</sup>	0.767 <sup>c</sup>
B13	3.58	14	4.17	2	3.56	14	4.07	3	3.80	9	3.72	1.054	11	0.63 <sup>b</sup>	0.146 <sup>c</sup>
B16	3.63	12	4.00	8	4.00	5	3.79	8	3.40	8	3.69	1.072	12	0.59 <sup>b</sup>	0.431 <sup>c</sup>

Code	Contractors		Consultants		Developers		Client		Government officials		All respondent			Kruskal Wallis (P-value)	
	MS	RK	MS	RK	MS	RK	MS	RK	MS	RK	MS	SD	RK	Normalisation <sup>a</sup>	
B1	3.61	13	3.78	16	3.89	8	3.64	13	3.93	4	3.68	1.116	13	0.57 <sup>b</sup>	0.694 <sup>c</sup>
B15	3.57	15	4.06	7	3.56	15	3.29	17	3.80	7	3.63	1.082	14	0.51 <sup>b</sup>	0.343 <sup>c</sup>
B17	3.67	11	3.56	17	3.00	17	3.57	16	3.60	14	3.60	1.233	15	0.47	0.701 <sup>c</sup>
B8	3.54	16	3.78	15	3.67	12	3.71	11	3.47	17	3.58	1.085	16	0.44	0.837 <sup>c</sup>
B14	3.38	17	4.00	10	3.11	16	4.00	5	3.67	12	3.52	1.124	17	0.36	0.053 <sup>c</sup>
B7	3.26	18	2.89	18	3.00	18	3.14	18	3.80	18	3.25	1.125	18	0	0.245 <sup>c</sup>

Note: MS = Mean Score, RK= Rank, SD = Standard Deviation.

<sup>a</sup>Normalized value = (mean – minimum mean) / (maximum mean – minimum mean).

<sup>b</sup> the normalised value suggests that the barrier (normalised value  $\geq 0.50$ ) is a critical barrier.

<sup>c</sup> at the 0.05 significant level (significance level  $> 0.05$ ), the Kruskal-Wallis result is insignificant.

### Grouping of the barrier into factors

Towards establishing the concomitant impediment, the study sought to group the critical barriers into factors. The 14 critical impediments (variables) discovered in this research were submitted to FA to classify the barriers to the social acceptance of sandbag technology in housing construction. A Pearson correlation analysis (PCA) was done on the 14 critical barriers to minimise any multiplier effects among the variables, before submitting the critical barriers to factor analysis. Consequently, the data provided in Table 14 reveal that the 14 critical barriers were significantly correlated.

A PCA was done on the 14 critical barriers from 228 response samples, using the varimax rotation technique (an orthogonal rotation method). The findings of the factor analyses are shown in Table 15, and each analysis explains the whole variance. According to previous research, the sample size should be in the 1:5 (number of variables: sample size) range before it can be considered acceptable for component analysis. Fourteen critical barriers multiplied by five samples required for each component yield at least 70 samples needed to go on with factor analysis. As a consequence, the research fulfilled these conditions with 228 samples.

**Table 15:** Varimax rotation factor structure on the critical barrier.

Code	Critical barriers	Factor loading	Eigen value	Percentage of variance explained	Cumulative Percentage of variance explained
<b>Factor 1</b>	<b>Policy and knowledge related barrier (PKRB)</b>		6.752	56.894	56.894
PKRB1	Lack of sandbag technology policy and regulations	0.730			
PKRB2	Professionals resistant to change from the use of conventional technologies	0.708			
PKRB3	Lack of building code	0.692			
PKRB4	Lack of professional's knowledge and expertise	0.678			
PKRB5	Lack of courses and training on sandbag technology	0.624			
<b>Factor 2</b>	<b>Government-investor-related barriers (GIRB)</b>		2.849	7.409	64.303
GIRB1	Lack of financing schemes (bank loans, grants)	0.843			

Code	Critical barriers	Factor loading	Eigen value	Percentage of variance explained	Cumulative Percentage of variance explained
GIRB2	Lack of existing sandbag machines and technologies	0.540			
GIRB3	Lack of promotion of sandbag technology by Government	0.518			
GIRB3	Lack of interest from the Government	0.458			
<b>Factor 3</b>	<b>Technical related barrier (TRB)</b>		1.788	5.655	69.958
TRB1	Technical limitations	0.841			
TRB2	Lack of standard design method for sandbag technology	0.786			
TRB3	Deficiency in sandbag construction techniques	0.753			
<b>Factor 4</b>	<b>Information-related barrier (IRB)</b>		1.636	4.553	74.511
IRB1	Lack of sandbag databases and information	0.841			
IRB2	Lack of awareness of sandbag technology and its benefits	0.630			

This study's KMO score is 0.929 (Table 16), which is higher than the permissible threshold of 0.50 and demonstrates an "excellent degree" of common variation. Variables with KMO values close to one, show a strong correlation. It suggests that the PCA is quite likely to provide more reliable clusters. The correlation matrix is not an identity matrix, according to the results of Bartlett's test of sphericity analysis (chi-square = 1377.913) and a miniscule significant value ( $p = 0.000$ ,  $df = 91$ ). Consequently, the prerequisite for moving further with the factor analysis has been met.

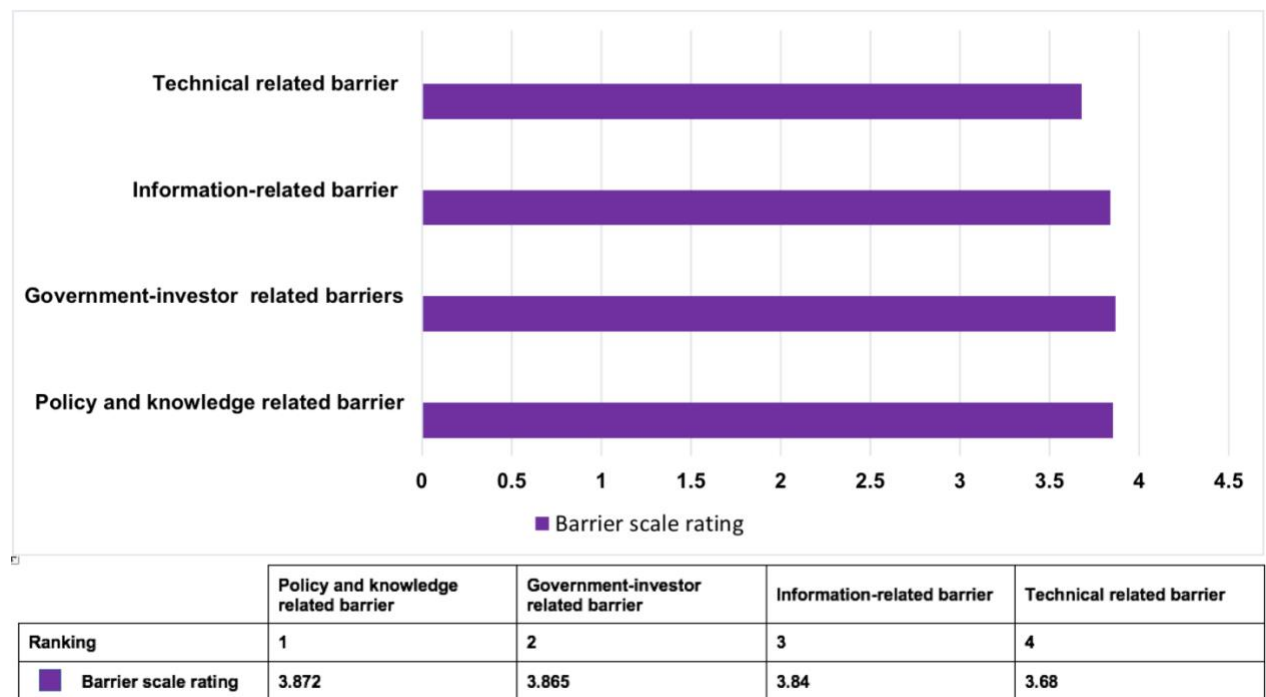
The principal component analysis method was employed to discover the underlying grouping impediments for factor extraction. PCA was used to uncover four underlying groups (components) with eigenvalues larger than one, which account for 74.51 percent of the total variance in responses after varimax rotation (see Table 16), which is more than the minimal criterion of 60%. 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 previous study will contribute considerably to the interpretation of the group factor.

**Table 16:** KMO and Bartlett’s Test for SBT barriers

<b>KMO and Bartlett’s Test</b>	<b>Value</b>
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.929
Bartlett's Test of Sphericity, Approx. Chi-Square	1377.913
df	91
Sig.	0.000

Furthermore, the barrier groups were ranked to determine which was more important. The discussion of grouped barriers in the next chapter will focus on all five ranking barrier groups (component).



**Figure 17:** Ranking result of the barrier scale rating for the critical barriers

### **5.3.2.2 Test of difference in the respondent's perception of the drivers and grouping of the driver into factors: intergroup comparison**

Objective three sought to determine the expert perception on the key drivers to the social acceptance of SBT in South Africa. However, towards establishing the key drivers, the study sought to check the intergroup comparison and test whether there were perception differences across the group. Table 17 summarises the data collected from respondents based on organizational affiliation. "D16— job creation opportunity" (M = 3.90 SD = 0.928) was identified as the most significant driver of social acceptance of SBT in housing construction by developers and clients. However, respondents who are contractors and consultants regarded the driver as the fourth most essential, while government officials placed it as the eighth most important. "D3— Reduce environmental effects" (M = 3.81 SD = 0.984) was identified as the most important driver by the contractors. "D23—Wind resistant and bulletproof" (M= 3.77, SD = 0.961) was deemed the most important driver by the consultants. On the other hand, government officials ranked "D17— Material availability" (M= 3.82, SD = 1.030) as the most significant driver of sandbag building technology acceptance in South Africa. Most organizational setups (contractors and clients) consider "D24— Aesthetics" (M = 3.45 SD = 0.922) to be the least significant driver. As a result, these factors have minimal bearing on the societal acceptability of SBT in South Africa.

The Kruskal-Wallis H test was used to examine the 24 key drivers to see if there were perception variations across varied respondents from various organizational backgrounds (consultants, contractors, developers, government officials, and clients). The significance levels of 24 drivers were above 0.05, according to the Kruskal-Wallis H test findings (Table 17). According to consultants, contractors, developers, government officials, and clients, there are no statistically significant variations in the relevance of these drivers.

**Table 17:** Drivers for the social acceptance of sandbag technology uptake in housing construction; intergroup comparisons

Code	Contractors		Consultants		Developers		Client		Government officials		All respondent			Shapiro-Wilk Test	Kruskal-Wallis P-value
	Mean	RK	Mean	RK	Mean	RK	Mean	RK	Mean	RK	Mean	SD	RK		
D16	3.78	4	3.72	4	4.30	1	4.04	1	4.00	8	3.90	0.928	1	0.00 <sup>a</sup>	0.126 <sup>b</sup>
D17	3.70	9	3.64	7	4.13	3	3.81	5	4.29	1	3.82	1.030	2	0.00 <sup>a</sup>	0.068 <sup>b</sup>
D22	3.71	7	3.84	2	4.22	2	3.77	6	3.82	14	3.81	0.936	3	0.00 <sup>a</sup>	0.249 <sup>b</sup>
D3	3.81	1	3.72	5	3.96	6	3.58	15	4.06	6	3.81	0.984	4	0.00 <sup>a</sup>	0.330 <sup>b</sup>
D6	3.80	2	3.60	11	3.96	5	3.81	3	3.65	18	3.78	1.014	5	0.00 <sup>a</sup>	0.750 <sup>b</sup>
D12	3.77	5	3.60	9	3.91	9	3.85	2	3.76	15	3.77	0.999	6	0.00 <sup>a</sup>	0.872 <sup>b</sup>
D23	3.73	6	4.00	1	3.74	17	3.50	20	4.06	5	3.77	0.961	7	0.00 <sup>a</sup>	0.192 <sup>b</sup>
D21	3.56	17	3.84	3	3.96	7	3.81	4	4.18	3	3.74	0.991	8	0.00 <sup>a</sup>	0.094 <sup>b</sup>
D9	3.64	11	3.64	6	4.04	4	3.50	17	4.00	7	3.71	0.911	9	0.00 <sup>a</sup>	0.115 <sup>b</sup>
D4	3.64	12	3.60	8	3.61	21	3.69	7	4.12	4	3.69	0.922	10	0.00 <sup>a</sup>	0.334 <sup>b</sup>
D14	3.63	13	3.60	10	3.91	8	3.42	23	4.18	2	3.69	0.916	11	0.00 <sup>a</sup>	0.071 <sup>b</sup>
D10	3.71	8	3.40	17	3.91	10	3.58	14	3.65	19	3.67	1.022	12	0.00 <sup>a</sup>	0.474 <sup>b</sup>
D7	3.79	3	3.28	22	3.65	19	3.62	11	3.35	24	3.64	1.043	13	0.00 <sup>a</sup>	0.162 <sup>b</sup>
D5	3.67	10	3.40	18	3.65	18	3.58	13	3.65	16	3.61	0.957	14	0.00 <sup>a</sup>	0.840 <sup>b</sup>
D2	3.63	14	3.36	20	3.74	15	3.46	22	3.94	11	3.61	0.885	15	0.00 <sup>a</sup>	0.307 <sup>b</sup>

Code	Contractors		Consultants		Developers		Client		Government officials		All respondent			Shapiro-Wilk Test	Kruskal-Wallis P-value
	Mean	RK	Mean	RK	Mean	RK	Mean	RK	Mean	RK	Mean	SD	RK		
D15	3.54	18	3.36	21	3.83	12	3.62	10	3.94	12	3.60	0.929	16	0.00 <sup>a</sup>	0.231 <sup>b</sup>
D18	3.49	20	3.56	12	3.74	16	3.69	8	3.88	13	3.60	0.982	17	0.00 <sup>a</sup>	0.560 <sup>b</sup>
D8	3.62	15	3.48	15	3.78	14	3.50	19	3.41	22	3.59	1.070	18	0.00 <sup>a</sup>	0.696 <sup>b</sup>
D20	3.48	21	3.40	19	3.83	13	3.58	12	3.94	10	3.57	0.932	19	0.00 <sup>a</sup>	0.167 <sup>b</sup>
D11	3.57	16	3.04	24	3.61	22	3.65	9	3.47	21	3.50	0.998	20	0.00 <sup>a</sup>	0.191 <sup>b</sup>
D13	3.46	22	3.24	23	3.83	11	3.54	16	3.53	20	3.49	1.036	21	0.00 <sup>a</sup>	0.475 <sup>b</sup>
D1	3.52	19	3.40	16	3.43	24	3.46	21	3.35	23	3.47	0.873	22	0.00 <sup>a</sup>	0.949 <sup>b</sup>
D19	3.37	23	3.52	13	3.61	20	3.50	18	3.65	17	3.46	0.952	23	0.00 <sup>a</sup>	0.740 <sup>b</sup>
D24	3.36	24	3.48	14	3.48	23	3.42	24	3.94	9	3.45	0.922	24	0.00 <sup>a</sup>	0.171 <sup>b</sup>

**Note:**

SD= Standard Deviation

RK = Rank

<sup>a</sup> The Shapiro-Wilks test result is significant at the significance level of 0.05 (p-value < 0.05),

<sup>b</sup> The Kruskal-Wallis H test is significant at the significance level of 0.05 (p-value < 0.05).

### Grouping of the driver into factors

The 24 key drivers (variables) found in this research were submitted to factor analysis to classify the drivers of the social acceptance of sandbag technology in housing construction. A Pearson correlation analysis was conducted on the 24 key drivers before submitting them to factor analysis. This was done to minimize any multiplier effects among the variables. As a consequence, the findings in Table 18 reveal that the 24 key drivers were significantly correlated.

A PCA was conducted on the 24 key drivers from 228 response samples, using the varimax rotation methodology (an orthogonal rotation method). Each component analysis explains the overall variation, as seen in Table 18. According to previous research, the sample size for component analysis should be in the 1:5 range (number of variables: sample size). Twenty-four key drivers multiplied by the five samples needed for each component equal at least 120. As a consequence, the study's requirements were satisfied with 228 samples.

**Table 18:** Varimax rotation factor structure on the key drivers

Code	Drivers for the social acceptance of sandbag technology	Factor loading	Eigen-value	Percent-age of variance explained	Cumulative Percentage of variance explained
<b>Driver 1-</b>	<b>Construction and health related driver (CHRB)</b>		10.921	45.504	45.504
CHRB1	Fast mode of construction	0.853			
CHRB2	Improved indoor environmental quality	0.846			
CHRB3	Better thermal comfort	0.810			
CHRB4	Reduced condensation and fungal growth	0.750			
CHRB5	Ease of construction	0.592			
CHRB6	A better alternative to adobe	0.571			
CHRB7	Improved occupant health	0.554			
<b>Driver 2-</b>	<b>Environmental related driver (ERD)</b>		3.222	13.427	58.931
ERD1	High energy efficiency	0.933			
ERD2	Reduce environmental impacts	0.901			
ERD3	Resist environmental hazard	0.780			
ERD4	Erosion and flood control	0.507			
ERD5	Wind resistant and bulletproof	0.633			
ERD6	Fireproof	0.420			

Code	Drivers for the social acceptance of sandbag technology	Factor loading	Eigen-value	Percentage of variance explained	Cumulative Percentage of variance explained
<b>Driver 3-</b>	<b>Economic related driver (ECD)</b>		1.957	8.154	67.085
ECRD1	Affordability	0.834			
ECRD2	Low maintenance cost	0.790			
ECRD3	Job creation opportunity	0.776			
ECRD4	Required little expertise	0.709			
ECRD5	Reusable and recyclable	0.609			
<b>Driver 4-</b>	<b>Material and cost related driver (MCRD)</b>		1.522	6.341	73.425
MCRD1	Material availability	0.791			
MCRD2	Waste reduction	0.568			
MCRD3	Less transportation cost	0.518			
<b>Driver 5-</b>	<b>Aesthetics and acoustic related driver (AARD)</b>		1.345	5.604	79.030
AARD1	Aesthetics	0.828			
AARD2	Diversity of forms and styles	0.787			
AARD3	Good acoustic insulation	0.742			

The KMO score for this research is 0.948 (Table 19), which is larger than the permissible threshold of 0.50 and also indicates an "excellent degree" of common variation. Variables with KMO values close to one indicate a pattern of close correlation. It suggests that the PCA is likely to generate clusters with a higher degree of reliability. Bartlett's test of sphericity produces a statistical test result (chi-square = 3242.008) and a minor significant value ( $p = 0.000$ ,  $df = 276$ ), showing that the correlation matrix is not an identity matrix. Thus, the prerequisite for continuing with the factor analysis has been met.

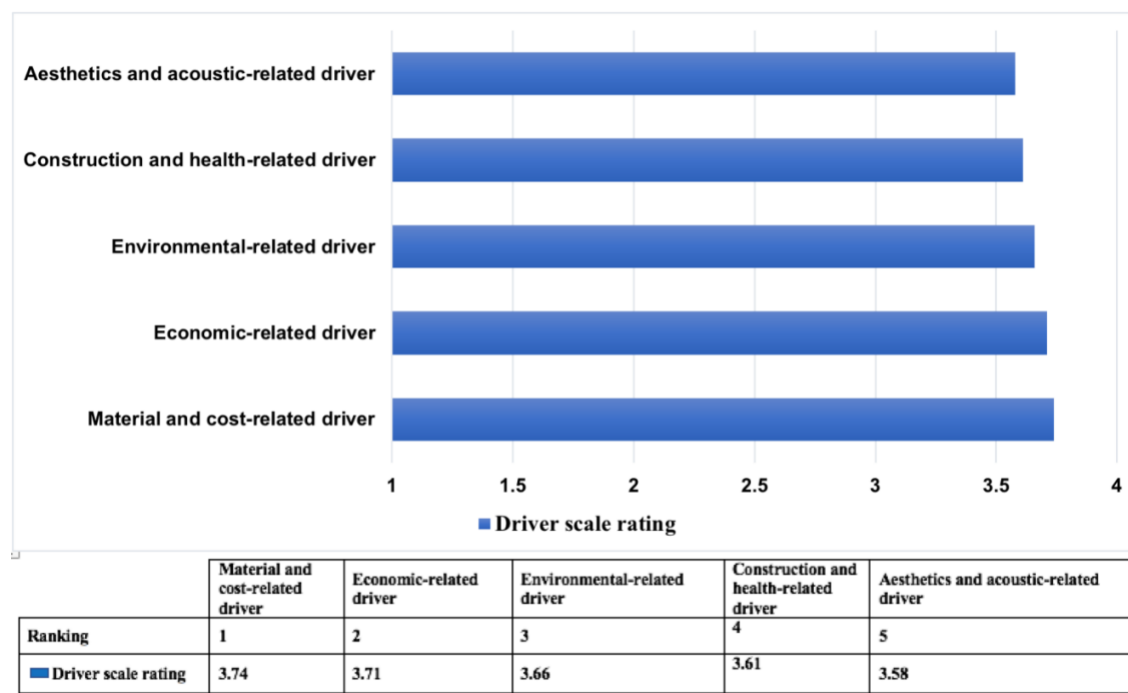
The research used principal component analysis to determine the underlying grouping drivers for factor extraction. PCA was used to discover five underlying groups (components) with eigenvalues larger than one, which account for 79.03 percent of the total variance in responses after varimax rotation (see Table 19), which exceeds the minimal criterion of 60 percent. Each of the twenty-four key drivers is represented by one of the five underlying driver groups (component)—Construction and health, Environmental, Economic, Material and cost, and Aesthetics and acoustics-related drivers; the factor loading for each group is greater than 0.4, indicating the consistency and reliability of the study's findings and interpretation of the extracted individual component. Variables having factor loadings greater than or equal to 0.40,

as revealed by the literature, will substantially contribute to the interpretation of the group factor.

**Table 19:** KMO and Bartlett’s Test for SBT drivers

KMO and Bartlett’s Test	Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.948
Bartlett's Test of Sphericity, Approx. Chi-Square	3242.008
df	276
Sig.	0.000

Furthermore, the driver groups were ranked to determine which was more important. The discussion of grouped drivers in the next chapter will focus on all five ranking driver groups (component).



**Figure 18:** Ranking result of the driver scale rating for the key drivers

### 5.3.2.3 Test of difference in the respondent's perception of the strategies and grouping of the strategies into factors: intergroup comparison

Objective four sought to determine the expert perception on the key strategies to the social acceptance of SBT in South Africa. However, towards establishing the key strategies, the study sought to check the intergroup comparison and test whether there were perception differences across the group. Table 20 summarises the data gathered from respondents based on

organizational affiliation. Table 20 suggest that contractors, consultants, and clients regarded "S5—availability of sandbag demonstration projects across all provinces" ( $M = 4.3$   $SD = 0.836$ ) as the most significant strategy for social acceptance of SBT in housing construction. But according to those who work for the government, "S13— Educational training for investors, experts, and end-users" ( $M = 4.21$   $SD = 0.977$ ) was selected as the most crucial strategy. Meanwhile, the contractor perceived S11—reformed bidding procedure — as the least important obstacle ( $M = 4.04$   $SD = 0.933$ ). The societal acceptability of sandbag construction technologies in South Africa would consequently not be significantly affected by these strategies, which were generally evaluated as the least important strategies.

Further, the 13 selected strategies were studied using the Kruskal-Wallis H test to see whether perception differences existed across diverse respondents from various organisational backgrounds (consultants, contractors, developers, government officials, and clients). According to the Kruskal-Wallis H test results, the significance values of 13 strategies exceeded 0.05. (Table 20). There are no statistically significant differences in the relevance of these strategies as seen by consultants, contractors, developers, government officials, and clients.

**Table 20:** Strategies for the social acceptance of sandbag technology uptake in housing construction: Intergroup comparisons

Code	Contractors		Consultants		Developers		Client		Government officials		All respondent			Shapiro-Wilks P-value	Kruskal-Wallis P-value
	Mean	RK	Mean	RK	Mean	RK	Mean	RK	Mean	RK	Mean	SD	RK		
S5	4.38	1	4.32	1	4.54	3	4.25	1	3.89	10	4.30	0.836	1	0.00 <sup>a</sup>	0.285 <sup>b</sup>
S3	4.35	2	4.09	5	4.62	2	4.10	3	4.39	2	4.30	0.878	2	0.00 <sup>a</sup>	0.136 <sup>b</sup>
S6	4.26	4	4.18	2	4.46	4	4.25	2	4.17	5	4.26	0.849	3	0.00 <sup>a</sup>	0.896 <sup>b</sup>
S2	4.26	5	4.14	4	4.46	5	4.00	8	4.22	4	4.22	0.854	4	0.00 <sup>a</sup>	0.391 <sup>b</sup>
S13	4.21	9	4.05	9	4.62	1	4.00	11	4.39	1	4.21	0.977	5	0.00 <sup>a</sup>	0.451 <sup>b</sup>
S10	4.16	10	4.09	7	4.46	7	4.05	6	4.33	3	4.18	0.930	6	0.00 <sup>a</sup>	0.664 <sup>b</sup>
S9	4.31	3	4.09	6	4.46	8	3.90	12	3.89	11	4.18	0.936	7	0.00 <sup>a</sup>	0.081 <sup>b</sup>
S4	4.25	6	4.14	3	4.38	9	4.10	4	3.83	13	4.17	0.878	8	0.00 <sup>a</sup>	0.347 <sup>b</sup>
S7	4.22	8	3.82	13	4.38	10	4.00	10	4.06	8	4.12	0.960	9	0.00 <sup>a</sup>	0.287 <sup>b</sup>
S12	4.12	12	4.05	8	4.38	11	4.00	9	4.11	6	4.11	0.863	10	0.00 <sup>a</sup>	0.706 <sup>b</sup>
S8	4.25	7	3.91	10	4.08	13	4.05	7	3.89	12	4.11	0.961	11	0.00 <sup>a</sup>	0.450 <sup>b</sup>
S1	4.13	11	3.86	11	4.46	6	3.85	13	4.11	7	4.08	0.903	12	0.00 <sup>a</sup>	0.196 <sup>b</sup>
S11	4.06	13	3.82	12	4.38	12	4.05	5	4.00	9	4.04	0.933	13	0.00 <sup>a</sup>	0.506 <sup>b</sup>

Note:

SD= Standard Deviation

<sup>a</sup> The Shapiro-Wilks test result is significant at the significance level of 0.05 (p-value < 0.05).

<sup>b</sup> The Kruskal -Wallis H test is significant at the significance level of 0.05 (p-value < 0.05)

### Grouping of the strategies into factors

FA was used to investigate the key strategies for social acceptance of SBT in South Africa. Before component analysis, a Pearson correlation analysis was done to avoid multiplier effects. Consequently, all thirteen strategies were highly correlated.

PCA was done on the 13 key strategies from 228 samples using the varimax rotation technique (an orthogonal rotation method), as shown in Table 21. A previous study stated that the sample size should be in the 1:5 (number of variables: sample size) range before it could be considered appropriate for component analysis. As a consequence, our research fulfilled these conditions. The KMO score for this research is 0.939 (Table 22), which is higher than the permissible threshold of 0.50 and indicates an "excellent degree" of common variation. Bartlett's sphericity analysis test yields a statistical result (chi-square = 1668.554) and a marginally significant value ( $p = 0.000$ ,  $df = 78$ ), indicating that the correlation matrix is not an identity matrix. As a result, the criterion for factor analysis has been satisfied.

**Table 21:** Varimax rotation factor structure on the key strategies

Code	Strategies	Factor loading	Eigen value	Percentage of variance explained	Cumulative Percentage of variance explained
<b>Factor 1-</b>	<b>Stakeholders integration and policy formation (SIPF)</b>		5.873	45.174	45.174
SIPF1	Support from executive management	0.919			
SIPF2	Approved sandbag technology building code	0.801			
SIPF3	Standardisation of the material and components	0.701			
SIPF4	Standard design methods for sandbags	0.692			
SIPF5	Availability of sandbag technology research centre	0.630			
SIPF6	Formulation of sandbag technology policies and regulations	0.513			
<b>Factor 2-</b>	<b>Effective education and knowledge sharing (EEKS)</b>		2.122	16.326	61.500

Code	Strategies	Factor loading	Eigen value	Percentage of variance explained	Cumulative Percentage of variance explained
EEKS1	Sandbag technology demonstration projects across all provinces	0.863			
EEKS2	Inclusion of sandbags in the curriculum of technical training colleges	0.585			
EEKS3	Educational training for investors, professionals and end-users	0.525			
EEKS4	Reformed tendering process	0.459			
<b>Factor 3-</b>	<b>Grassroots advocacy and incentives (GAI)</b>		1.721	13.237	74.736
GAI1	Competent promotion teams and grassroots supporters	0.807			
GAI2	Financial incentive for sandbag uptake	0.630			
GAI3	Public sandbag technology awareness creation through workshops, seminars, and conferences	0.517			

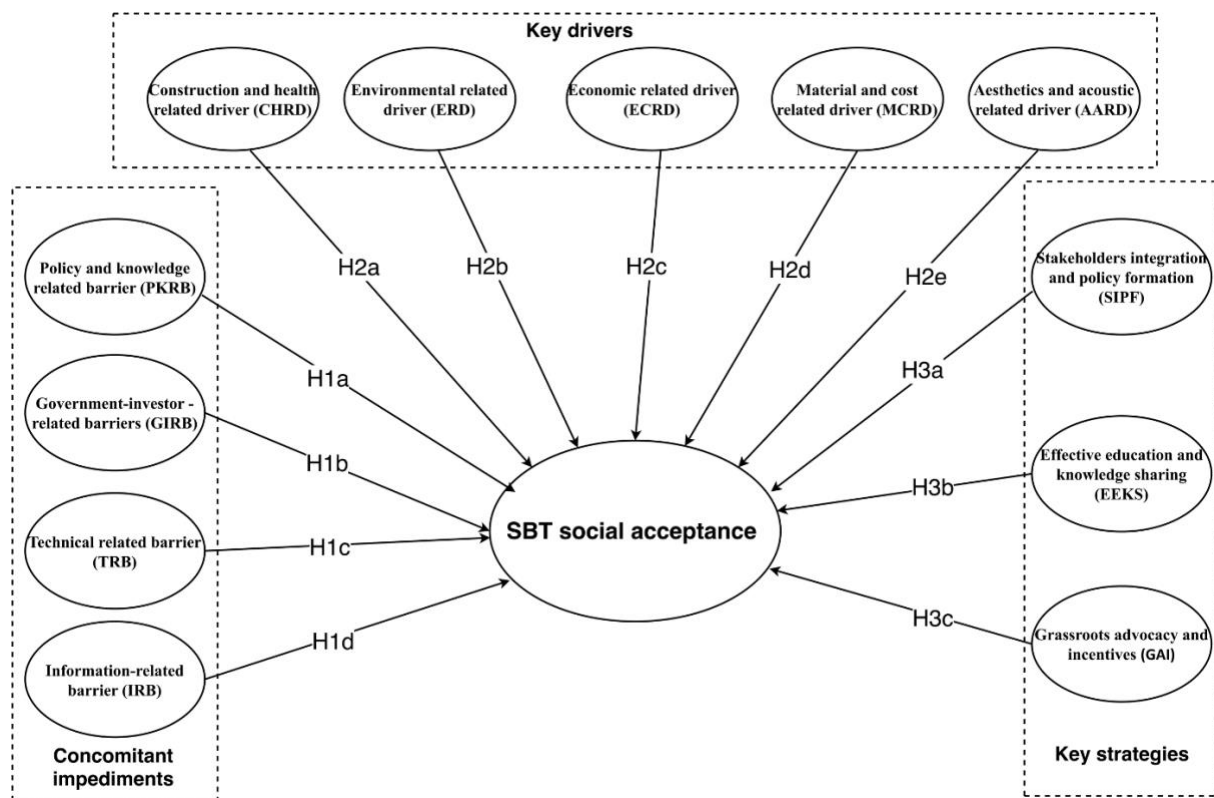
Following the varimax rotation, PCA discovered three underlying groups (components) with eigenvalues greater than one, accounting for 74.74 percent of the total variance (see table 21). Each strategy is represented by one of the three underlying strategy categories (components). Consequently, the study's findings and interpretation of the extracted component are consistent and credible.

**Table 22:** KMO and Bartlett's Test for SBT strategies

KMO and Bartlett's Test	Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.939
Bartlett's Test of Sphericity, approximate Chi-Square	1668.554
df	78

## 5.4 Testing of the research hypothesis

Objective Five sought to develop a framework to promote the social acceptance of SBT. In an effort to develop the framework, the study sought to test the hypothesis developed in chapter three. More so, based on the result of factor analysis, further subordinate hypothesis was developed, to examine the significance of the factor analysis results (barrier groups, driver groups, and strategies group) to the social acceptance of SBT (Figure 19). As previously stated, this research assessed the social acceptance of sandbag technology using four components. Upham et al. (2015) employed three key components to measure the societal acceptability of new technology; these four component are adapted from Upham et al. (2015) with minor adjustments to fit the current research.



**Figure 19:** Hypothetical model

This hypothetical model will be tested, and the outcome is critical for increasing knowledge of the roles of many variables in impeding or promoting societal acceptance of SBT and to develop a framework to promote the social acceptance of sandbag building technology.

**Main hypothesis 1:** The restraining forces (barriers) have a significant impact on the social acceptance of SBT

**H1a-H1d:** The policy and knowledge related barrier, government-investor -related barriers, technical related barrier and information-related barrier are significant barriers to the social acceptance of SBT.

**Main hypothesis 2:** The driving forces (drivers) have a significant impact on the social acceptance of SBT

**H2a- H2e:** the construction and health related driver, environmental related driver, economic related driver, material and cost related driver and aesthetics and acoustic related driver are significant drivers to the social acceptance of SBT.

**Main hypothesis 3:** The acceptance strategies have a significant impact on the social acceptance of SBT

**H3a- H3c:** The stakeholder integration and policy formation, effective education and knowledge-sharing, and grassroots advocacy and incentives are significant strategies to the social acceptance of SBT.

#### **5.4.1 Main hypothesis 1: The restraining forces (barriers) have a significant impact on the social acceptance of SBT**

##### **5.4.1.1 Model evaluation**

Tables 23, 24 and 25 shows the result of the hypothesis testing for the impact of the concomitant impediment on the SBT social acceptance. This research solely uses reflecting measurement items because the indicators are a representative group of items that all reflect the latent variable being measured (Janadari et al., 2016). Reflective models are based on the assumption that indicators may be used interchangeably and that removing one indicator may not affect the meaning of the construct (Hair, 2010; Hair et al., 2019; Hair Jr et al., 2020). As a result, any measuring item with a critical factor loading of less than 0.5 was eliminated from the lists of measurement items. The analysis was redone after the deletion; this procedure was repeated until a valid measurement model was achieved.

**Table 23:** Model evaluation (for barriers model)

Constructs	Measurement item code	Factor loading	Cronbach's Alpha	Composite reliability	AVE
TRB	TRB3	0.876	0.865	0.917	0.787
	TRB1	0.864	-	-	-
	TRB2	0.921	-	-	-
PKRB	PKRB4	0.868	0.871	0.906	0.665
	PKRB2	0.533	-	-	-
	PKRB1	0.842	-	-	-
	PKRB3	0.892	-	-	-
	PKRB5	0.883	-	-	-
GIRB	GIRB1	0.779	0.851	0.898	0.687
	GIRB4	0.882	-	-	-
	GIRB3	0.876	-	-	-
	GIRB2	0.773	-	-	-
IRB	IRB1	0.816	0.724	0.828	0.707
	IRB2	0.865	-	-	-
SA	C1	0.631	0.761	0.787	0.650
	C2	0.649	-	-	-
	C3	0.823	-	-	-
	C4	0.661	-	-	-

Note: TRB = Technical-related barrier, PKRB = Policy-knowledge-related barrier, GIRB = Government-investor-related barrier, IRB = Information-related barrier, AVE = Average variance extracted, SA = SBT Social acceptance

All Cronbach's Alpha values and composite reliability scores were more than 0.70, suggesting that the measuring items' internal consistency reliability was adequate. Furthermore, all factor loadings and measures of average variance extracted were greater than 0.50, showing the constructs' convergent validity. An average variance extracted (AVE) greater than 0.50 suggests that the concept accounts for more than half of the variation in its measurement items.

Furthermore, as indicated in Table 24, no correlation between any two constructs surpassed the square roots of their AVEs, indicating discriminant validity of the constructs. Examining the cross-loadings of the measuring items gives further evidence of discriminant validity. The Appendix 2 demonstrates that no cross-loading issues exist, since each measurement item had the maximum loading on its particular construct. These results suggest that the structural route modelling measurement models were accurate and valid.

#### 5.4.1.2 Model validation (Barriers)

**Table 24:** Discriminant validity of constructs (for barriers model).

	GIRB	IRB	PKRB	TRB	SSA
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GIRB	<b>0.829</b>	-			
IRB	0.737	<b>0.841</b>			
PKRB	0.801	0.777	<b>0.815</b>		
TRB	0.661	0.603	0.621	<b>0.885</b>	
SA	0.603	0.687	0.602	0.470	<b>0.807</b>

Note: The bold diagonal numbers represent the square root of the average variance taken from each construct, whereas the other values are the correlations between constructs. TRB = Technical-related barrier, PKRB = Policy-knowledge-related barrier, GIRB = Government-investor-related barrier, IRB = Information-related barrier; SA = SBT Social acceptance

**Table 25:** Bootstrapping result of the barrier model

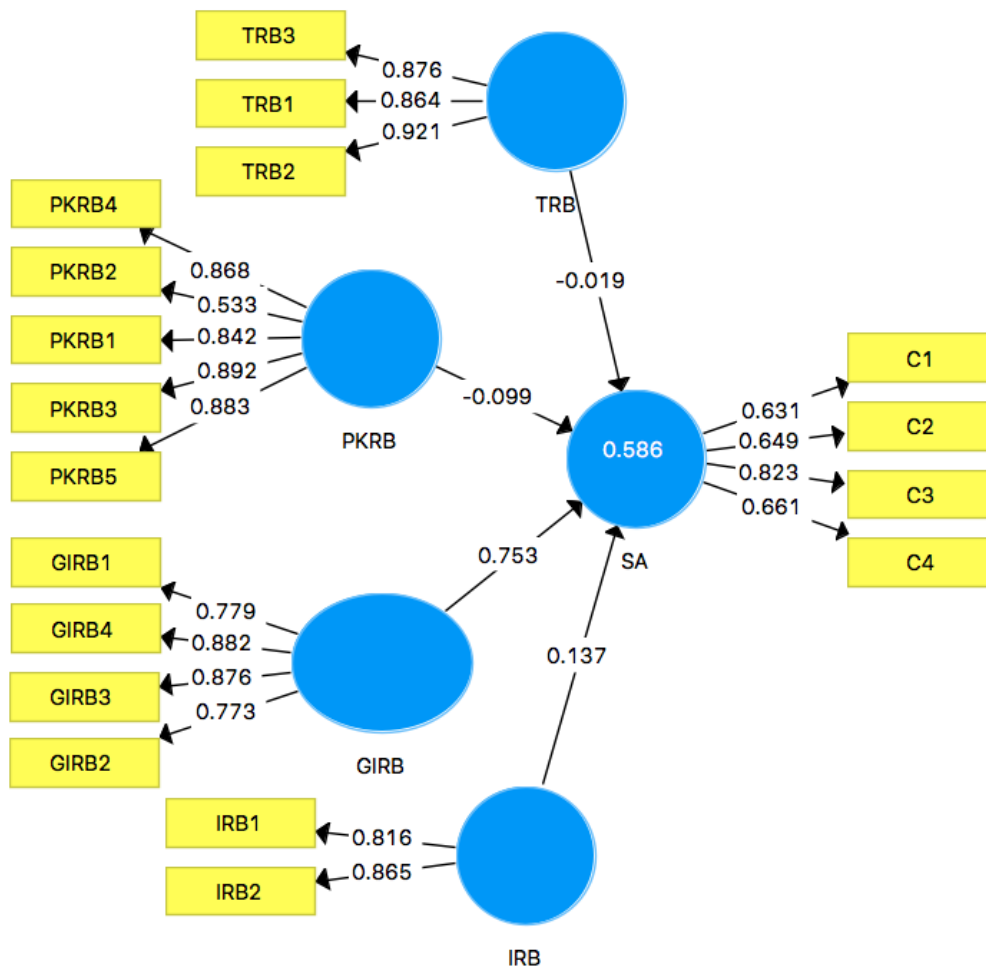
Hypothetical path	Path coefficient	Sample Mean	Standard Deviation	t-value	p-value	Interpretation
GIRB → SA	0.753	0.759	0.134	5.633	0.000	Supported
IRB → SA	0.137	0.126	0.124	1.102	0.271	Not supported
PKRB → SA	-0.099	-0.072	0.130	0.762	0.457	Not supported
TRB → SA	-0.019	-0.020	0.093	0.204	0.839	Not supported

Note: \* at  $p < 0.05$ , the path coefficient is significant; TRB = Technical-related barrier, PKRB = Policy-knowledge-related barrier, GIRB = Government-investor-related barrier, IRB = Information-related barrier, SA = SBT Social acceptance

Table 25 shows the result of the bootstrapping at one percent confidence interval which indicated that the path linking the Government-investor related barrier to SBT social acceptance, had a t-value greater than 2.58, implying that it was statistically significant at 1 percent confidence interval, hence the hypothesis H1b was supported. Furthermore, hypothesis H1b exhibited a path coefficient of 0.753, showing that the SBT social acceptability is strongly influenced. A path coefficient ranging from 0.1 to 0.3 suggests a minor effect, 0.3 to 0.5 shows a moderate influence, and 0.5 to 1.0 indicates a significant influence.

Hypotheses H1a, H1c, and H1d, on the other hand, were not supported since they are not statistically significant at a 1 percent confidence interval. Furthermore, the path coefficient was low, showing that the influence of investor-related hurdles, policy and knowledge-related barriers, and technical-related barriers on the societal acceptance of SBT was insignificant. Finally, the coefficient of determination ( $R^2$ ) of the dependent variable, SBT social acceptance, was 0.587, suggesting that the model had a reasonable degree of predictive accuracy.

Therefore, Figure 20 presents the final model of the impact of barriers on the SBT societal acceptability.



**Figure 20: Barriers model**

#### 5.4.2 Main hypothesis 2: The driving forces (drivers) have a significant impact on the social acceptance of sandbag building technology

##### 5.4.2.1 Model evaluation (Drivers)

As shown in Tables 26, 27 and 28, the measuring items ERD1 and C2 with less than 0.5 critical factor loading were deleted. After each elimination, the analysis was rerun until a good measurement model was found. More so, all Cronbach's Alpha values and composite reliability scores were above 0.70, indicating good internal consistency dependability. All factor loadings and average variance were over 0.50, indicating convergent validity. The result also indicated that no correlation between the two constructs exceeded the square roots of their AVEs, demonstrating discriminant validity. Examining item cross-loadings shows discriminant validity, as the appendix 3 shows no cross-loading difficulties, since each measurement item

had maximum loading on its unique construct. These findings show structural route modelling measurement models were reliable and valid.

**Table 26:** Model evaluation (driver model)

Constructs	Measurement item code	Factor loading	Cronbach's Alpha	Composite reliability	AVE
AARD	AARD3	0.785	0.759	0.860	0.672
	AARD1	0.815	-	-	-
	AARD2	0.858	-	-	-
CHRD	CHRD5	0.832	0.902	0.923	0.681
	CHRD1	0.844	-	-	-
	CHRD2	0.859	-	-	-
	CHRD7	0.802	-	-	-
	CHRD4	0.785	-	-	-
	CHRD3	0.718	-	-	-
	CHRD6	0.708	-	-	-
ECRD	ECRD4	0.660	0.834	0.883	0.704
	ECRD3	0.788	-	-	-
	ECRD5	0.627	-	-	-
	ECRD1	0.908	-	-	-
	ECRD2	0.869	-	-	-
ERD	ERD4	0.852	0.859	0.898	0.639
	ERD3	0.816	-	-	-
	ERD5	0.799	-	-	-
	ERD2	0.730	-	-	-
	ERD6	0.795	-	-	-
	MCRID	MCRD1	0.892	0.846	0.907
	MCRD2	0.878	-	-	-
	MCRD3	0.852	-	-	-
SA	C1	0.910	0.877	0.924	0.802
	C2	0.898	-	-	-
	C4	0.879	-	-	-

Note: AARD = Aesthetics and acoustic related drivers, CHRD = construction and health related driver, ECRD = Economic related drivers, ERD = Environment related barrier, MCRID = Material and cost related driver, AVE = Average variance extracted, SA = SBT Social acceptance

#### 5.4.2.2 Model validation (Drivers)

**Table 27:** Discriminant validity of barrier constructs

	AARD	CHRD	ECRD	ERD	MCRID	SA
AARD	<b>0.868</b>					
CHRD	0.754	<b>0.825</b>				
ECRD	0.776	0.794	<b>0.839</b>			
ERD	0.768	0.798	0.775	<b>0.800</b>		

	AARD	CHRD	ECRD	ERD	MCRID	SA
MCRID	0.693	0.786	0.789	0.772	<b>0.874</b>	
SA	0.753	0.810	0.778	0.744	0.724	<b>0.896</b>

Note: AARD = Aesthetics and acoustic related drivers, CHRD = construction and health related driver, ECRD = Economic related drivers, ERD = Environment related barrier, MCRID = Material and cost related driver, SA = SBT Social acceptance

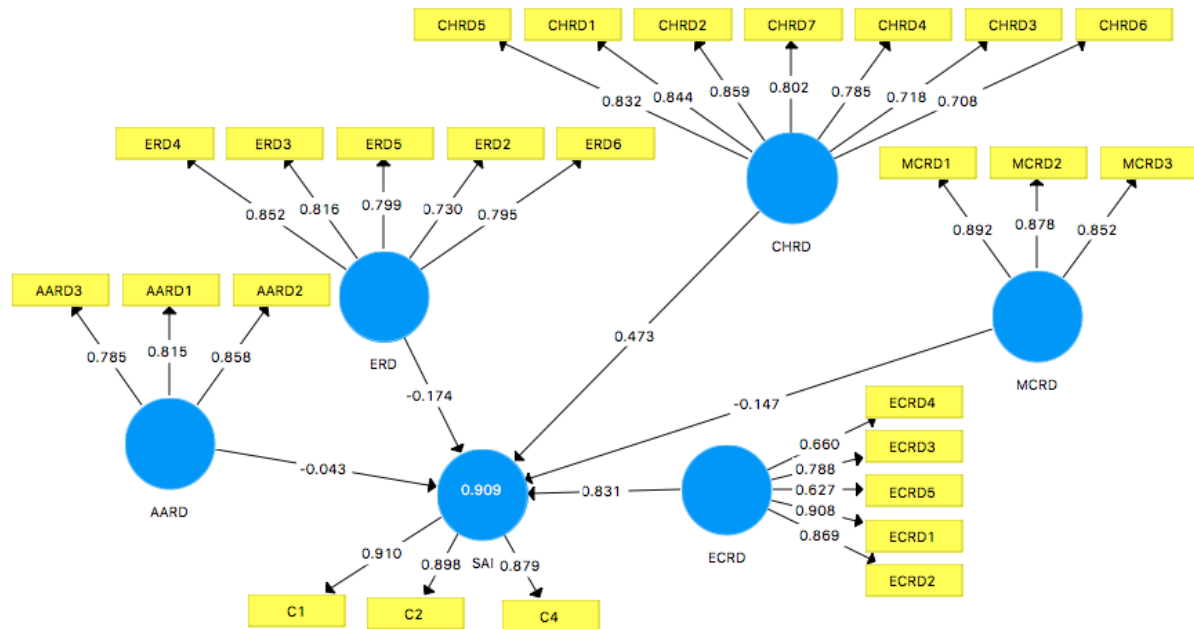
**Table 28:** Bootstrapping result of the driver model

Hypothetical path	Path coefficient	Sample Mean	Standard Deviation	t-value	p-value	Interpretation
AARD → SA	-0.040	-0.043	0.087	0.459	0.646	Not supported
CHRD → SA	0.454	0.451	0.082	5.543	0.000	Supported
ECRD → SA	0.850	0.844	0.066	6.852	0.000	Supported
ERD → SA	-0.170	-0.162	0.077	1.205	0.128	Not supported
MCRD → SA	-0.155	-0.148	0.062	1.482	0.213	Not supported

Note: \* at  $p < 0.05$ , the path coefficient is significant; AARD = Aesthetics and acoustic related drivers, CHRD = construction and health related driver, ECRD = Economic related drivers, ERD = Environment related barrier, MCRID = Material and cost related driver, SA = SBT Social acceptance

Table 28 shows the result of the bootstrapping at one percent confidence interval which indicated that the path linking construction and health related driver and Economic related drivers to SBT social acceptance had a t-value greater than 2.58 implying that it was statistically significant at 1 percent confidence interval, hence the hypothesis H2a and H2c was supported. Furthermore, hypothesis H1b exhibited a path coefficient of 0.853, showing that the SBT social acceptability is strongly influenced, while the H2c exhibited a path coefficient of 0.454, showing that the SBT social acceptability is moderately influenced. Hypotheses H2b, H2c, and H2e, on the other hand, were not supported since they are not statistically significant at a 1 percent confidence interval. Furthermore, the path coefficient was low, implying that the impact of the barriers group on the societal acceptance of SBT was insignificant. Finally, the coefficient of determination ( $R^2$ ) of the dependent variable, SBT social acceptance, was 0.909,

suggesting that the model had a reasonable degree of predictive accuracy. Therefore, Figure 21 presents the final model of the impact of drivers on the SBT societal acceptability.



**Figure 21: driver model**

### 5.4.3 Main hypothesis 3: The acceptance strategies have significant impact on the social acceptance of SBT

#### 5.4.3.1 Model evaluation (strategies)

Tables 29, 30 and 31 demonstrate that C3, SIPF2, SIPF5 and SIPF6 items with less than 0.5 critical factor loading were eliminated. The study was repeated after each exclusion until a satisfactory measurement model was established. All Cronbach's Alpha values and composite reliability scores were over 0.70, suggest high consistency. All factor loadings were > 0.50, showing convergent validity. No association between the two constructs surpassed their AVEs, suggesting discriminant validity. Examining item cross-loadings reveals discriminant validity, as the appendix 4 indicates no cross-loading problems because each measuring item loaded maximally on its unique concept. These results suggest structural path modelling measurement models are viable.

**Table 29:** Measurement model evaluation (for strategies model)

Constructs	Measurement item code	Factor loading	Cronbach's Alpha	Composite reliability	AVE
EEKS	EEKS2	0.671	0.778	0.826	0.602
	EEKS4	0.767	-	-	-
	EEKS3	0.673	-	-	-
	EEKS1	0.829			
GAI	GAI2	0.801	0.707	0.777	0.542
	GAI3	0.603	-	-	-
	GAI1	0.788	-	-	-
SIPF	SIPF3	0.613	0.740	0.849	0.658
	SIPF4	0.880	-	-	-
	SIPF1	0.908	-	-	-
SA	C1	0.907	0.877	0.924	0.802
	C2	0.899	-	-	-
	C4	0.881	-	-	-

Note: EEKS = Effective education and knowledge sharing, GAI = Grassroots advocacy and incentives, SIPF= Stakeholder integration and policy formation, AVE = Average variance extracted, SA = SBT Social acceptance

#### 5.4.3.2 Model validation (strategies)

**Table 30:** Discriminant validity of strategy constructs

	EDKS	GAI	SIPF	SA
EEKS	<b>0.775</b>			
GAI	0.585	<b>0.736</b>		
SIPF	0.738	0.630	<b>0.811</b>	
SA	0.729	0.587	0.656	<b>0.896</b>

Note: EEKS = Effective education and knowledge sharing, GAI = Grassroot advocacy and incentives, SIPF= Stakeholder integration and policy formation, SA = SBT Social acceptance

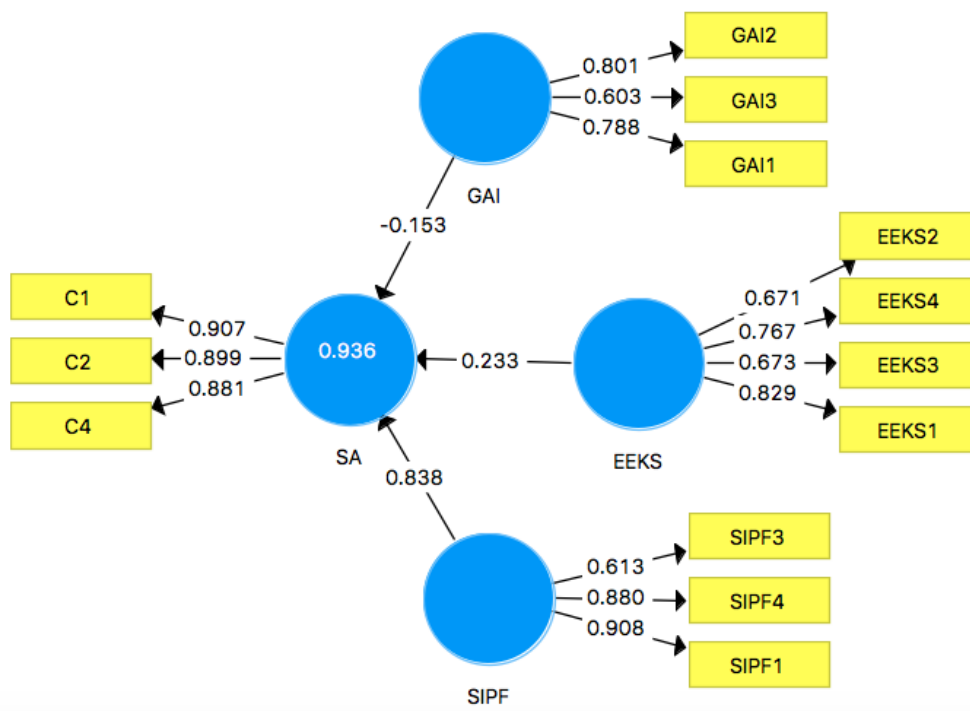
**Table 31:** Bootstrapping result of the strategy model

Hypothetical path	Path coefficient	Sample Mean	Standard Deviation	t-value	p-value	Interpretation
EEKS→ SA	0.214	0.212	0.077	2.791	0.005	Supported
GAI → SA	-0.148	-0.128	0.044	0.375	0.101	Not supported
SIPF → SA	0.853	0.850	0.066	2.934	0.000	Supported

Note: \* at  $p < 0.05$ , the path coefficient is significant EEKS = Effective education and knowledge sharing, GAI = Grassroots advocacy and incentives, SIPF= Stakeholder integration and policy formation, SA = SBT Social acceptance

Table 31 above shows the result of the bootstrapping at one percent confidence interval which indicated that the path linking Effective education and knowledge sharing and Stakeholder

integration and policy formation to SBT social acceptance had a t-value greater than 2.58. This implies that it was statically significant at a 1 percent confidence interval, hence the hypothesis H3a and H3b was supported. Furthermore, hypothesis H3a exhibited a path coefficient of 0.838, showing that the SBT social acceptability is strongly influenced, while the H3b exhibited a path coefficient of 0.23, showing that the SBT social acceptability is minimally influenced. Hypotheses H3c on the other hand, were not supported since they are not statistically significant at a 1 percent confidence interval. Furthermore, the path coefficient was low, implying that the impact of the barriers group on the societal acceptance of SBT was insignificant. Finally, the coefficient of determination ( $R^2$ ) of the dependent variable, SBT social acceptance, was 0.936, suggesting that the model had a reasonable degree of predictive accuracy. Therefore, Figure 22 presents the final model of the impact of drivers on the SBT societal acceptability.



**Figure 22:** Strategies model

### 5.5 Chapter summary

This chapter presented the qualitative and quantitative analysis of data gathered from a survey of nine provinces of South African housing stakeholders and end-users. And the subordinate hypotheses were developed, evaluated and tested, based on the outcome of the quantitative and qualitative analysis. The next chapter describes the result of the analysis and hypothesis testing.

## CHAPTER SIX

### DISCUSSION OF FINDINGS

#### 6.1 Introduction

This chapter discusses the qualitative and quantitative data acquired from the research, using the study objectives as the foundation. It emphasises the similarities and contrasts between the study's variables and then relates the results to current literature. It is organised in five sections as follows: The actor's perception of the use of Sandbag Technology as a SAH solution in South Africa; key drivers to the social acceptance of SBT in South Africa; the concomitant impediments to the social acceptance of SBT in South Africa and the key strategies to the social acceptance of SBT in South Africa; and, a presentation of the implication of the findings which the hypothesis developed for the study.

#### 6.2 The actor's perception of the use of Sandbag Technology as a SAH solution in South Africa

This NVivo analysis, carried out to achieve this objective, produced fourteen themes, grouped into three primary groups, as discussed below.

##### 6.2.1 Group 1: Perception of the use of Sandbag Technology in South Africa

This section primarily investigates the expert's and the occupant's perceptions of the sandbag house in South Africa. Four perspectives on using SBT as a sustainable, affordable housing solution emerged in the South African context: sustainability, affordability, fire resistance, job creation potential, and earthquake resistance. These are described in the following subsections.

The respondents perceived sustainability as an essential factor in the use of sandbag technology in South Africa, with 22 references (Figure 16). There was an emphasis on sustainable attributes of sandbag building technology. One of the experts' presentations of the life cycle assessment of an SBT revealed that it is a great alternative to traditional building techniques in terms of sustainability.

*"They are a fantastic alternative to traditional building techniques. The concrete used in a sandbag house (columns and lintels) accounts for around 50% of its carbon footprint, and low-carbon concretes or alternative materials may greatly lower the carbon footprint of sandbag construction"* (Participant D2)

Given that the vast majority of building in South Africa comprises of bricks and concrete with mortar of a high cement content (Dlamini, 2020; Schmidt & Msinjili, 2014), experts stated that this releases a considerable amount of carbon dioxide into the environment, and they saw SBT as a better alternative in South Africa.

*"Over time, the manufacture of cement has a considerable carbon impact. According to research, every tonne of cement produced emits an equal amount of carbon dioxide into the environment. So, when it comes to sandbag housing, the sandbag is a sustainable building technique that utilises less cement, and I believe that everyone should embrace it"* (Participant D1).

The literature supports this finding (Cataldo-Born et al., 2016; Hunter & Kiffmeyer, 2004).

Affordability was discussed extensively by the expert forum respondents. This was seen as a significant factor in the use of sandbag technology in South Africa, with 14 references. There was a consensus that sandbag technologies are one of the alternative solutions to resolving the ever-increasing housing problem in South Africa, because of their affordability (cheap and affordable).

*"Sandbag technology is the most extensively utilised unknown local building material in South Africa. It is less expensive than traditional materials and is one of the potential solutions to affordable housing"* (Participant C1).

This study finding is supported by the literature (Barnes et al., 2006; Sharma, 2015). However, several respondents contended that the cost of a sandbag home is determined by many factors, including location, market structure, and specifications.

*"Sandbag construction should be less expensive than traditional construction, but this relies on how you operate the site, the building specification, the type of sand and availability of sand, the geography of the land, and the market structure. For example, houses developed in Val de Vie will be more costly than those erected in Durbanville or Mossel Bay"* (Participant D4).

On the other hand, the argument demonstrated that sandbag technologies are critical to alleviating South Africa's affordable housing crisis, particularly in informal settlements.

*"It is typically a good and inexpensive method, especially in remote development, and it might be one of the answers to the question of human settlements"* (Participant C5).

These findings are supported by research from the National Home Builder's Registration Council (2020) and Ncube (2017). They established that the employment of alternative construction technologies, such as sandbag technology, is essential to reducing South Africa's ever-increasing housing shortfall. This is due to its affordability and capacity to provide houses that are cheaper, quicker, and of a higher quality.

In the light of South Africa's high young unemployment rate, experts emphasised that any suggested housing solution must address South Africa's unemployment problem. As seen in Figure 16, eight references deemed the provision of jobs for unskilled labour an essential factor in the use of sandbag technology in South Africa.

*"Sandbag [technology] is labour-intensive and can generate employment"* (Participant C3).

This is consistent with Ben-Alon et al. (2020) and Shaker et al. (2017), who confirmed that sandbag construction provides local job possibilities and boosts local economies.

Experts established that SBT is simple to learn since it needs less professional knowledge.

*"I've trained many people over the years how to construct a sandbag house since it's simple to understand; they're still doing it and generating money from it"* (Participant C2).

This is congruent with Geiger and Zemsikova (2015)'s research. They discovered that sandbag technology enables unskilled workers to be taught while building houses. The sandbag technology is easy to build and requires no specialised machinery or knowledge.

As seen in Figure 16, fire and earthquake resistance were viewed as the least relevant factors for the usage of sandbag technology. According to experts, most structures in South Africa's informal settlements are comprised of shacks, which are easily destroyed by fire. As a result, many people have perished in fire mishaps in South Africa.

*"We know that around 2,000 people each year are killed by fire because, in these shacks, when a fire breaks out, it quickly spreads over the whole town, but a sandbag home cannot burn up"* (Participant D5).

This result is consistent with existing research (Cataldo-Born et al., 2016).

Furthermore, experts established that SBT is earthquake resistant.

*"In 2014, we erected a sandbag school in Nepal. Six days later, a major earthquake struck Nepal, destroying all of the buildings in the town. The only structure that remained intact after the earthquake was the sandbag school we had just completed. And the Nepalese government initiated an inquiry on why this structure is still intact when everything else has crumbled, as broadcast on BBC TV and CNN. Consequently, sandbag construction is now an officially recognised building method in Nepal"* (Participant D4).

This finding is consistent with the findings of Shaker et al. (2017).

### **6.2.2 Group 2: Perception of the challenges to the use of sandbag technology**

This section highlights and examines the perspectives of experts and end-users on the key challenges to deploying sandbag technology in South Africa. As indicated in Figure 16, they were categorised into six subcategories, totalling 48 references.

The expert noted that the lack of social acceptance of building with sandbags is a key impediment in South Africa, despite their benefits and potential to fix housing issues (17 references as shown in Figure 16). Bricks and concrete are the preferred building materials for most South Africans.

*"Social acceptance is a significant difficulty. People associate living in a sandbag house with poverty and prefer to reside in a masonry building"* (Participant D6).

This is supported by the findings of Kulshreshtha et al. (2020) and Rincón et al. (2019), who discovered that the populace connected sandbag homes with poverty and felt embarrassed to live in one. Further, the experts stated that the informal settlement residents burnt down most houses constructed using alternative construction technologies since the community does not accept or approve of them.

*"In Vrede, we erected 600 houses out of polystyrene, and when the contractors finished, people have set fire to buildings because the community does not recognise and approve of alternative building technologies"* (Participant C2).

Experts indicated that they were subjected to a life-threatening assault from the community. Because of the lack of acceptance and clearance for this technology, the project team was stoned and forced to leave the townships.

*"We attempted to construct SBT houses in townships like Khayelitsha, but we were stoned and forced to leave. If I had remained there for another five minutes, I would have been murdered"* (Participant D4).

This conclusion is consistent with previous research that has connected limited adoption of earth technology to stakeholders' lack of social acceptability (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Kulshreshtha et al., 2020). Social acceptability surfaced as a significant element that must be addressed in adopting sandbag material technology in South African affordable housing; when people do not accept a notion, adopting it may be challenging.

More so, from the expert discussion, community members' choice of traditional materials significantly influenced the rejection of ABTs (7 references as shown in Figure 16). South Africans have a long-standing preference for brick and concrete structures.

*"One of the problems is that South Africans have a natural preference for brick-and-concrete dwellings, and many fear alternative building technology would label them as impoverished"* - (Participant D3).

According to experts, most people feel that homes built using alternative construction technologies are of inferior quality and have a short lifespan. The expert acknowledged that SBT might never be deployed if the community does not embrace this technology.

*"People assume that since a house is made of sand, it is of inferior quality and has a short lifespan. When the community does not accept a notion, it will not be implemented"* (Participant C3).

This is consistent with the results of Reddy (2022). They established that the increasing adoption of energy-intensive conventional buildings has dramatically decreased sandbag construction use.

According to the experts' discussion, South Africa has no government backing in the form of defined building regulation codes and policies for the use of alternative construction technologies such as sandbags.

*"We've never been able to implement SBT in South Africa, despite our efforts since the impression is negative and the government is unwilling to accept it"* (Participant C2).

As illustrated in Figure 16, government support was seen as a significant barrier, with 11 references, compared with professional expertise (9 references), preference for brick and block (7 references) and access to finance (4 references). Further, the experts ascribed this to the absence of published studies on the performance of alternative building technologies, such as sandbags.

*"Only until the performance of sandbag housing is made public can the government have faith in its effectiveness"* (Participant D1).

This is congruent with the results of Rincón et al. (2019), who noted the lack of broad government recommendations and construction codes for sandbag technology.

As seen in Figure 16, professional expertise was mostly cited as a barrier with nine references. From the expert discussion, it became apparent that the attitude of building professionals towards sandbag technology had a key impact in implementing sandbag technologies in South Africa. According to experts, building professionals lack a comprehensive grasp of the sandbag construction process. Consequently, a practical grasp of the sandbag building requirements is required to use this construction technique effectively.

*"Construction experts should understand the process of building with sandbags and what must be done to avoid difficulties such as cracking"* (Participant C5)." This is similar to the findings of Grady et al. (2019) and Ugochukwu and Chioma (2015), which found that most experts prefer to employ traditional construction materials and technology since they are better acquainted with them.

Figure 16 shows that access to financing was the least ranked impediment, with four references. According to the experts, banks refused to give bonds/mortgages for sandbag houses, and without this sort of financing, it isn't easy to own a sandbag house or receive enough funds to construct one.

*"The major concern is that banks will not fund it"* (Participant C1).

According to Grady et al. (2019), many investors are unaware of the technology and efficiency of ABTs. As a result, obtaining house finance and insurance from financial organisations is almost impossible (Zami & Lee, 2011). Some experts, however, contended that the financial institution's backing is contingent on significant government consent.

*"Banks have no trouble lending money to construct a sandbag home as long as the government has authorised SBT"* (Participant C5).

### **6.2.3 Group 3: Perception of measures to promotes the social acceptance of Sandbag Technology**

This section investigates experts' perspectives on measures to promote social acceptance of sandbag technology in South Africa. Table 13 shows how the perception was categorised into four subcategories with 36 references.

A substantial number of specialists believe that the government's and professionals' lack of adoption of sandbag technologies is due to a lack of published findings on the performance of sandbag technologies. There was consensus that there is a need for significant study into the performance of sandbag technologies, as indicated in Figure 16. With 17 references, an extensive study on sandbag technology performance was recognised as a successful strategy to enhance SBT social acceptance, compared to awareness (13 references), building sandbag prototypes throughout cities (6 references), and training (5 references).

*"There is a need to conduct more tests and publish more results to educate people on the performance integrity of sandbag technology to assure its widespread adoption"* (Participant D6).

The expert discussion revealed that developing sandbag technology prototype houses throughout towns and provinces would considerably improve its social acceptance in South Africa. As demonstrated in Figure 16, this was mostly seen as a strategy with six references. *"One approach to get it accepted is to bring that technology into our cities, so people can witness it from start to finish, rather than just building it in rural areas"* (Participant D1). Experts agreed that establishing prototypes is an important technique for promoting this technology, stating...

*"... one essential strategy to sell out this technology is to create prototype buildings in cities"* (Participant D4).

Existing research indicates that individuals become more receptive to alternative construction technologies after physically seeing a home constructed using an alternative technology (Grady et al., 2019).

As indicated in Figure 16, awareness was an effective strategy for increasing social acceptance of ABTs, such as SBT in South Africa. With 12 references, awareness is viewed as the most important approach, followed by training (5 references) and establishing sandbag prototypes throughout cities (6 references).

*"I believe raising awareness is one of the most important techniques for promoting the widespread adoption of alternative technology"* (Participant C3).

There was consensus among the experts that people's awareness of sandbag technologies' environmental and economic benefits, profoundly influenced its adoption.

The experts' discussion revealed that training is critical to the social acceptance of sandbag technology. "Training is one strategy to promote the ABT system" (Participant C2). Experts further revealed that professionals and residents of alternative technology housing often claim that they do not comprehend the building process of ABT and hence despise the system. Therefore, training individuals is necessary for SBT acceptance.

### **6.3. Concomitant impediment to the social acceptance of SBT**

All four barrier scale groupings are thus discussed in descending sequence.

#### **6.3.1 Component 1– Policy and knowledge related barrier**

Group (component) 1 consists of five barrier-related components and has the highest barrier scale rating of  $M = 3.872$ . The group is related to a lack of sandbag technology 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 technology courses and training. The lack of sandbag technology policy and regulations is one of the major hurdles to its general use in South Africa.

The absence of sandbag technology policies and regulations has hindered its broad application and societal acceptance. In contrast to conventional building techniques, alternative construction techniques, such as sandbags, are not governed by a specific policy or rule (Cataldo-Born et al., 2016; Sharma, 2015). Government policies are excellent tools that can ultimately increase sandbag utilisation in construction. However, establishing national and international sandbag building regulations and standards is crucial for adopting and socially accepting the technology (Dlamini, 2020; Zami & Lee, 2011). This is also corroborated by Gou, Lau, and Prasad (2013), who discovered that government laws and regulations play an

important role in supporting new technology in the construction industry. This finding suggests that stakeholders and the general public will comply if expectations about the use of sandbag technology are set as legal obligations. Mpakati-Gama et al. (2012) and Hadjri et al. (2007) found similar results in research conducted in sub-Saharan Africa (SSA). The results imply that the South African government should play a more active role in the construction industry's pursuit of sustainability, by introducing laws and regulations to promote societal acceptance and adoption of ABTs such as 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 sandbag and superadobe construction techniques, general guidelines and building rules are still lacking, with no mention in building codes (Sharma, 2015; Zami & Lee, 2011). Meanwhile, according to Cataldo-Born et al. (2016), earthbag technology has been included in the building standards of California, USA, after it was established that these earthbag constructions surpassed these standards..

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. Ugochukwu and Chioma (2015) and MacDougall (2008), in their work, established that many experts in the conventional building sector are reluctant 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 (Grady et al., 2019). As a result, low-income housing development in the country has become homogeneous. This corresponds to a lack of professional knowledge and abilities, and is a major impediment to the social acceptance and adoption of sandbag technology. Previous research indicates that most construction stakeholders lack appropriate knowledge, competence, and understanding of the ABTs (Grady et al., 2019; Santos & Beirão, 2016). A lack of knowledge, ability, and understanding among experts, the government, donors, and consumers of alternative construction technologies constitute a significant impediment to their societal acceptance and uptake. Santos and Beirão (2016) and Zami and Lee (2011) 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 (2011). These findings show that the number of construction professionals and stakeholders who understand the building process of sandbag technologies is low. On the other side, 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 as barriers to sandbag social acceptance than is professional reluctance to shift from the employment of traditional technologies.

Lack of training and courses on sandbag technology is another major impediment to the social acceptability and adoption of sandbag technologies (Ugochukwu & Chioma, 2015). According to Succar, Sher, and Williams (2013), 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 about alternative construction is all and how to construct a sandbag building effectively, might negatively influence the successful adoption of sandbag technology.

### **6.3.2 Component 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. (2019). Therefore, it is difficult to obtain a house loan or insurance from financial organisations (Mbambo et al., 2021; Olojede et al., 2019; Ugochukwu & Chioma, 2015). 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 (Olojede et al., 2019; Sameh, 2014). It is also imperative that the Government of South Africa learn from developed countries like Australia, Hong Kong and the United States. According to Gou et al. (2013), it is easier to obtain financial support through grants and bank loans for innovative technologies and sustainable projects in developed countries.

According to Ben-Alon et al. (2020) and Santos and Beirão (2016), developing-country leaders and governments resist using earthen materials such as sandbag technology because they are

hesitant to build dwellings with ordinary soil. Zami and Lee (2011) note that most new innovative building technology promotion is done by foreign organisations, but the developing country governments are uninterested in ABTs. The lack of attention of the government, according to this report, is a significant impediment to the societal acceptance of sandbag technology in housing construction. The study's findings correspond with those of Potbhare, Syal, and Korkmaz (2009), who 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 South African government's failure to promote sandbag technology.

The lack of existing sandbag machines and technologies is also a significant barrier to its acceptance. According to Potbhare et al. (2009), the lack of established technologies or demonstration projects might stymie the application of new technologies. Existing technologies will provide people with 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 and Windapo (2022a) 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

### **6.3.3 Component 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. This Group is related to a lack of sandbag databases and information and technologies and a lack of awareness of sandbags and their benefits.

This lack is the most significant impediment to the social acceptance of SBTs in housing construction. According to Grady et al. (2019), 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 (Department of Housing, 1994; Grady et al., 2019).

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. (2020), more information and technical data is required for sandbag adoption, which is aligned with the findings of this study, that the lack of sandbag databases and information is impeding sandbag technology uptake in South Africa. This demonstrates how difficult it is for South Africa's present building sector practitioners to get information on the technical properties of sandbags.

#### **6.3.4 Component 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 findings of previous research by Cataldo-Born et al. (2016), who uncovered a defect in sandbag building procedures that impacts the bonding of sand and cement. Their investigation is consistent with the studies by Adetooto and Windapo (2022a) and Adetooto et al. (2022b). Sharma (2015) agrees, adding that it is difficult to grasp the sandbag building style when looking at how it is built. The study by Sharma (2015) revealed that a lack of standard design methods and sandbag building procedures is the cause of insufficiency, deficiency, and inconsistency in sandbag construction techniques and recommends that the government and interested construction stakeholders should 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 SBT is a lack of standard design methods for sandbag technology. This aligned with previous findings by Adetooto and Windapo (2022a), Windapo et al. (2022d) and Adetooto et al. (2022b). Canadell et al. (2016) discovered a lack of a standard design techniques 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 (Adetooto and Windapo (2022a); yet, in other countries such as India and Egypt, long continuous bags are used without eco beams (Sharma, 2015).

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 SBT. 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 (Cataldo-Born et al., 2016; Santos & Beirão, 2016). In their studies, Barros and Imhoff (2010) and Gutiérrez Aliaga and Manco Rivera (2006) 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.

## **6.4 Key drivers to the social acceptance of SBT**

The grouped drivers are analysed in decreasing order of significance in Figure 18 to evaluate the individual driver.

### **6.4.1 Component 1 — Material and cost related driver**

Group (component) 4 comprises three driver-related components and has the highest driver scale rating of  $M = 3.740$ . The group is related to Material availability, Waste reduction, and Lower transportation cost. The material availability is one of the key drivers to the social acceptance of sandbag technology.

Material availability seems to be a driving factor in the widespread adoption of SBT. According to Daigle et al. (2011), the primary building material for SBT is sand or stones, which are locally accessible in the vast majority of the world's locations. This is reinforced by Rincón et al. (2019), who argued that the SBT was an excellent option since it permits the utilization of local resources, such as stones and soil. In the light of the high cost and shortage of traditional construction materials in South Africa and other regions (Alabi & Fapohunda, 2021), SBT is a viable option because of its material availability. In contrast, Torres et al. (2021), assert that sand extraction rates surpass sand replenishment rates, a matter of global relevance. This showed that despite the availability of materials being a crucial factor in SBT's adoption, sand should be sustainably exploited, and future research should investigate the use of sand waste from building sites for SBT construction.

Another significant driver of SBT acceptance is waste reduction. This is analogous to the preceding discussion on "Material availability." Conventional construction techniques consume a lot of raw materials for building purposes, including up to 40% of stones, sand, and

gravel; 25% of timber; and 16% of all water worldwide (Dimoudi & Tompa, 2008). As a result, considerable volumes of construction waste are generated yearly (Lachimpadi, Pereira, Taha, & Mokhtar, 2012). However, existing research has demonstrated that SBT generates a small amount of waste (Sharma, 2015), which is a crucial driver of its implementation. This research is compatible with the findings of Sharma (2015) and Daigle et al. (2011).

As revealed by this research, fewer transportation costs appeared as a key driver of the social acceptance and implementation of sandbag technology in the South African construction industry. This result is congruent with Geiger and Zemskova (2015). They proved that since SBT depends mostly on locally obtained materials, there is less need for transportation, and a reduction in fuel expenditure. This research is consistent with the investigations of Shaker et al. (2017) and Sharma (2015)

#### **6.4.2 Component 2 — Economic related driver**

Group (component) 2 comprises five driver-related factors and has the second-highest driver scale rating,  $M = 3.720$ . The group consists of Affordability, Low Maintenance Cost, Job Creation Opportunity, Minimal Skill Requirement, and Reusability and Recyclability.

Affordability is one of the key factors influencing the social acceptance of SBT. According to Kennedy (2002), SBT is one of the most cost-effective construction techniques in the world due to its use of locally sourced, naturally existing materials. According to Adegun and Adedeji (2017), SBT is four times less expensive than traditional technologies. Moreover, Shaker et al. (2017) proved that the price of a sandbag dwelling is 30 to 60 percent cheaper than that of a conventional brick dwelling. Consequently, this study revealed that the cost-effectiveness of SBT is a key factor in its social acceptance. This study suggests that South African housing stakeholders should pay greater attention to SBT as one of the most cost-effective solutions to the housing need in South Africa. This result is consistent with previous research (Rincón et al., 2019; Santos & Beirão, 2016).

Low maintenance cost also emerged as one of the key drivers to the social acceptance of SBT in South Africa. Previous research has shown that most ABT constructions in South Africa had structural flaws, roof leaks, unstable roofs, and water penetration (Mbambo et al., 2021; Olojede et al., 2019). In contrast, Ben-Alon et al. (2020) noted that SBT does not need much maintenance if effectively constructed. This suggested that the low maintenance cost of SBT

is important to its widespread adoption as a sustainable and affordable housing solution in South Africa. This finding is consistent with Santos and Beirão (2016) and (Sharma, 2015)

According to this research, the creation of job creation opportunities is the most important driver influencing the social acceptance of SBT. According to Ben-Alon et al. (2020), SBT is often considered a self-sufficient construction form. It is frequently used as a community-engaging activity, offering local job possibilities and enhancing local economies. It also allows for female participation since males and females may readily create it (Shaker et al., 2017). This research conclusion suggests that, given South Africa's high rate of youth unemployment (Booyens, 2020), the job creation attribute of SBT is a key driving force for its social acceptance in South Africa. This study agrees with the results of (Adetooto et al., 2022c).

According to the research findings, one of the key drivers of social acceptance of SBT is the need for minimal skill. According to Daigle et al. (2011), SBT does not need highly skilled labour or costly materials; the amount of competence necessary to erect an earthbag home is reachable by almost anybody, regardless of prior construction experience. Furthermore, Cataldo-Born et al. (2016) said that no advanced technology is necessary for SBT construction since hand tools are employed. As a result, the findings revealed that SBT might be carried out by anybody with no previous education or building experience, allowing for the engagement of any interested person in the community. As a result, if a minimum skill requirement is identified, it may serve as a major driver of SBT's broad acceptance.

According to the research findings, reusability and recycling are significant drivers of social acceptance of SBT. Once no longer in use, the SBT structure may be recycled (Kennedy, 2002). According to previous research (Adetooto & Windapo, 2022a; Khalili & Outram, 2008; Shaker et al., 2017), the SBT bag is constructed of recyclable polypropylene material, and the plastering material is similarly environmentally beneficial. Given the present worldwide need for environmentally friendly and waste reducing building materials, this suggests that reusability and recyclability are important drivers of the widespread usage of SBT for sustainable and inexpensive housing solutions.

### **6.4.3 Component 3 — Environmental related driver**

Group (component) 3 has the third-highest driver scale rating,  $M = 3.660$ , and comprises six driver-related elements. The group includes the elements of high energy efficiency, reduced

environmental impacts, resistance to environmental hazards, erosion and flood control, wind resistance and being bulletproof and fireproof.

In South Africa, high energy efficiency emerged as one of the primary drivers of social acceptance of SBT. This is not unexpected, given that energy efficiency is a top priority for national development in both wealthy and developing nations (Pacheco, Ordóñez, & Martínez, 2012). Given the vast quantity of energy used by buildings, developing energy-efficient buildings might be crucial to national growth. Utilizing SBT in building construction might improve a country's energy efficiency position. Using SBT in building construction, for instance, reduces energy consumption during construction and operation (Cataldo-Born et al., 2016). In addition, SBT construction does not need electricity, and the quantity of water required is small (Geiger & Zemsikova, 2015). This outcome is consistent with Manoliadis, Tsolas, and Nakou (2006) and Darko (2019), in which energy efficiency was emphasized as the significant driver for implementing sustainable construction measures. The conclusion was further supported by Vardy et al. (2006), who discovered that "SBT's great energy efficiency enables it to lessen the environmental impact of new construction."

Reduced environmental impacts appeared as one of the leading drivers of SBT's social acceptance. This is not surprising because construction activities are not environmentally friendly by nature (Li, Zhu, & Zhang, 2010). Traditional construction and operations have a significant direct and indirect detrimental impact on the environment (Levin, 1997). In many countries, mitigating the environmental impacts of building operations has thus been a major objective for national development. Utilizing sustainable construction practices such as SBT is essential to reducing the environmental impacts of building construction. For instance, buildings using SBT have been shown to emit fewer greenhouse gases (GHG) during their life cycle and to require less energy than other comparable construction techniques (Christoforou et al., 2016; Freney, 2014). Moreover, according to (Shaker et al., 2017), the sandbag's CO<sub>2</sub> emission per 1m<sup>2</sup> is 95% less than that of a traditional brick wall. This result is similar to previous research (Darko, 2019; Darko et al., 2017), who stressed environmental impact reduction as the major driving force for employing sustainable building practices. Further support for the finding was provided by Sharma (2015), who observed that SBT is both economical and environmentally benign, due to its minimal energy input and environmental contamination.

The ability of SBT to efficiently withstand environmental hazards emerged as a key driver in its broad acceptance. Cañizio (2006) asserts that SBT has the structural potential to withstand recurrent natural catastrophes such as hurricanes, earthquakes, floods, and fires by ensuring its weight, rigidity, and water-resistant materials. This conclusion is comparable to that of Sharma (2015), who cited environmental hazard resistance as the major driving force for using SBT in Nepal. According to Shaker et al. (2017), SBT is resistant to earthquakes and not only does the plastering of a sandbag house give it fire resistance, but it also provides it with a high impermeability.

The ability of SBT to endure erosion and floods, as well as fire, wind, and bullets, emerged as important factors in its widespread adoption. This is hardly unexpected, given that fires have been a continual concern among inhabitants of low-income residential areas in South Africa (Denoon-Stevens, 2018). According to Cataldo-Born et al. (2016), SBT walls are fireproof, do not spread fire, and produce no toxic gases. Furthermore, because of their weight, SBT walls are wind resistant and bulletproof, since the sand composition can absorb such impacts. Shaker et al. (2017), have shown that SBTs are employed for flood control, erosion management, and retaining walls. The research findings revealed that the SBT erosion and flood management, resistance to fire hazards, wind, and bullet proofing might be important factors in its adoption for sustainable and economical housing delivery in South Africa.

#### **6.4.4 Component 4 — Construction and health related driver**

Group (component) 4 has the fourth-highest driver scale rating,  $M = 3.610$ , and consists of seven driver-related components. The group consists of fast building techniques, better indoor environmental quality, better thermal comfort, reduced condensation and fungus growth, ease of construction, improved occupant health and a superior alternative to adobe.

The fast construction mode emerged as one of the key factors of social acceptance of SBT in South Africa. Barnes et al. (2006) found that SBT construction requires much less time than conventional building techniques. According to Cañizio (2006), SBT could construct a simple house in less than a week using between 5 and 10 employees. This is supported by Shaker et al. (2017), who stated that SBT is one of the fastest techniques owing to the wide availability of materials and the ease of mastering the technique. The outcomes of this study suggest that the speed of SBT construction might be a significant factor in its acceptance for the delivery of sustainable and cost-effective housing in South Africa. This study is consistent with the results of Sharma (2015) and Rincón et al. (2019)

Another important component in the social acceptance of SBT in South Africa was the ease of its construction. This is comparable to prior drivers in "fast building mode." Barnes et al. (2006) discovered that SBT construction is relatively simple to make since it takes low expertise, and SBT homes are often constructed by their owners. According to Daigle et al. (2011), SBTs are often low- or intermediate-technology solutions that do not need specialized equipment or skills for construction. This is reinforced by Geiger and Zemskova (2015), who noted that SBT may be constructed by a group of untrained labourers under the direction of a construction manager and can be simply taught to rural villages. Sharma (2015) also observed that the whole family might construct an SBT home together, from the grandmother to the youngest child, and that anybody could master this construction technique, including the entire community, from young to old. The findings of this research imply that the simplicity of SBT construction might be a major element in its acceptability for delivering sustainable and cost-effective housing in South Africa. The findings of this research are congruent with those of Sharma (2015) and Geiger and Zemskova (2015).

In South Africa, better thermal comfort emerged as one of the key factors in the societal acceptability of SBT. Reddy (2022) discovered that SBT offers cool interior habitats in hot areas and warm internal environments during the winter in hilly regions. According to Daigle et al. (2011), SBT is especially appealing because of its substantial thermal mass, which may operate to control interior temperature changes by collecting excess heat during the day and releasing it at night. This is corroborated by Shaker et al. (2017), who noted that SBT provides excellent thermal mass material: optimal heat storage capacity, temperature and humidity management, resulting in a pleasant interior microclimate. Taking into account the harsh cold and heat of South Africa, SBT's better thermal comfort may be a crucial element in its acceptability for the creation of sustainable and cost-effective housing in South Africa. This investigation confirms the findings of Rincón et al. (2019)

In South Africa, improved indoor air quality appeared as one of the most important factors influencing social acceptance of SBT. This is equivalent to the previous driver regarding "thermal comfort." Ben-Alon et al. (2020) found that SBT enables a continual circulation of air between the interior and outside, filters pollutants generated by manufactured items, and functions as a natural deodorizer. According to Cataldo-Born et al. (2016), SBT's large thermal mass buffers both indoor temperatures and relative humidity and helps regulate indoor humidity. Considering the increasing demand for health and safety in South Africa, the

improved indoor air quality of SBT might be a major factor in its acceptance for developing sustainable and cost-effective housing in South Africa. This research verifies Ben-Alon et al. (2020)'s conclusions.

Improved occupant health appeared to be one of the most influential factors on the societal acceptability of SBT in South Africa. This is the same as the preceding driver for "thermal comfort" and "better indoor air quality." Ben-Alon et al. (2020) discovered that SBT is a non-allergenic material that offers a safe, healthy, and pleasant interior atmosphere for the residents of non-toxic gas-emitting SBT dwellings. Due to the thermal comfort feature and the capacity of SBT to enhance indoor air quality, it will considerably improve occupant health, which may be a key element in its acceptability for developing sustainable and cost-effective housing in South Africa. This research confirms the findings of Cataldo-Born et al. (2016) and Sharma (2015).

Some of the most influential factors on the social acceptance of SBT in South Africa include reduced condensation and fungal development, as well as a preferable alternative to adobe. Daigle et al. (2011) observed that SBT is mostly utilized in restrooms, where it may prevent moisture and fungal development. Moreover, Little and Morton (2001) said that SBT is more resistant to fungus, insects, and rodents than other types of earthen buildings such as adobe. Therefore, according to prior studies, SBT is a preferable alternative to adobe since it solves some of adobe's drawbacks, such as structural performance and durability (Cataldo-Born et al., 2016; Rincón et al., 2019). This study corroborates the results of Cataldo-Born et al. (2016) and Rincón et al. (2019)

#### **6.4.5 Component 5— Aesthetics and acoustic related driver**

Group (component) 5 has the lowest rating on the driver scale,  $M = 3.58$ , comprised of three driver-related components. The category includes aesthetics, diversity of forms and styles, and good acoustic insulation.

In South Africa, the aesthetics, variety of forms, and styles emerged as a significant factor in SBT's societal acceptability. Sharma (2015) discovered that SBT is utilized to build dome-shaped dwellings as well as more typical rectilinear structures, allowing diverse architectural styles to be interpreted based on the cultural setting to produce an aesthetically pleasing appearance. The outcomes of this study suggest that the aesthetics, variety of forms, and styles

may play a significant role in its acceptance for creating sustainable and affordable housing in South Africa. This research corroborates the findings of Rincón et al. (2019)

Furthermore, the societal acceptability of SBT was shown to be significantly influenced by the quality of the acoustic insulation. Shaker et al. (2017) found that SBT is an effective sound absorber owing to its high density, which affords places with limited space a feeling of privacy. The outcomes of this study suggest that good acoustic insulation may be a significant factor in its acceptance for creating sustainable and affordable homes in South Africa. This investigation supports the findings of previous research (Cataldo-Born et al., 2016; Little & Morton, 2001; Sharma, 2015).

## **6.5. Strategies for the social acceptance of sandbag building technology**

### **6.5.1 Factor 1— Stakeholders' integration and policy formation**

Stakeholders' integration and policy formation comprises of six significant strategies, and explains about 45.17% of the total variance in the strategies to SBT's social acceptance. The six significant strategies are: (1) Support from executive management; (2) Approved sandbag technology building code; (3) Standardisation of the material and components; (4) Standard design methods for earthbags (5) Availability of a Sandbag Technology Research Centre; and (6) formulation of sandbag technology policies and regulations.

It is crucial to get the backing of the executive management to increase the social acceptance of SBT for the development of affordable and sustainable housing in South Africa. These results are congruent with Belofsky and Zemskova (2018), and Adetooto and Windapo (2022a). They found that integration amongst stakeholders (developers, government officials, and experts) is necessary to facilitate the adoption of SBTs and ABTs. An institutional framework outlining each stakeholder's role and responsibility can be developed through the inclusion and support of stakeholders (Darko, 2019; Darko et al., 2018). This can lay the groundwork for South African communities' acceptance and implementation of SBTs more widely and sustainably.

Furthermore, according to this research, a recognised sandbag technology building code is one of the most important measures for enhancing social acceptance of SBT. Ben-Alon et al. (2020) argue that the acceptance of earth construction is dependent on the development of universal and user-friendly standards and codes. This result is consistent with the previous research by (Adetooto & Windapo, 2022a; Adetooto et al., 2022b). Moreover, SBT material and

components standardisation are critical to its social acceptability. Due to a lack of national regulations, earthen buildings are deemed unapproved and unregulated, according to Burnet (2007). This study's findings are compatible with those of Adegun and Adedeji (2017), who noted that it is essential to get material and component standardisation following global trends, as well as to establish national standards and other local institutional regulatory apparatus.

According to the findings, the availability of standard design methods for earthbags is also vital to their general acceptability. Rincón et al. (2019) proposed that researchers focus their study on establishing design methodologies for earthbag and superadobe structures in order to increase their widespread acceptance. This result is consistent with prior South African investigations on alternative building methods (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c; Windapo et al., 2022c). The study also highlighted that establishing a construction research centre, where earthbag materials and methods can be investigated and assessed before being widely deployed, is crucial to their social acceptance. According to Hadjri et al. (2007), research may enhance the wider acceptance of sandbag building techniques by fostering ground-breaking research, funding, collaboration, innovation, and integration among stakeholders. This agrees with Ben-Alon et al. (2020)'s earlier research. The findings also emphasised that enacting policies that encourage the use of SBTs is critical to their social acceptance. These results agree with those obtained by (Hadjri et al., 2007)

### **6.5.2 Factor 2 — Effective education and knowledge sharing**

Effective education and information sharing comprise four significant strategies and explain about 16.33% of the total variance in the strategies to SBT's social acceptance. The four significant strategies are (1) sandbag demonstration projects across all provinces; (2) Inclusion of sandbag technology in the curriculum of technical training colleges; (3) Educational training for investors, professionals and end-users; (4) A reformed tendering process.

The availability of sandbag demonstration projects in all provinces is one of the most important strategies for the social acceptance of sandbag technology in South African housing construction. Grady et al. (2019) claim that after seeing a house built using alternative methods, people become more accepting of ABTs. Furthermore, Hadjri et al. (2007) advocated that community members be included in the construction of such demonstration buildings since it would teach them about the sandbag material and its special construction procedure. As a result, the finding implies that building a sandbag model house for the community to view throughout all provinces will allow community members to observe how the house is made, be involved

in the construction process, and, eventually, improve the social acceptance of sandbag technology. This result is consistent with the research of Grady et al. (2019) and Adetooto and Windapo (2022a). The study also highlighted that the inclusion of sandbags in technical training colleges' curricula is crucial to their social acceptance. This finding is consistent with the research of Lyamuya and Alam (2013). They also advised that earth construction technologies should be included in the curriculum of technical training colleges, polytechnics and universities of technology, to enhance its wide adoption.

Another significant strategy for the social acceptance and adoption of sandbag technologies is educational training for investors, professionals and end-users. Providing SBT-related educational and training programs for developers, professionals, and policymakers in fostering SBT social acceptance cannot be overstated. Succar et al. (2013) agreed, believing that stakeholder training is essential for effectively adopting new technologies and applications. This finding is consistent with the research of Belofsky and Zemskova (2018), which listed educational training for investors, experts, and end-users as one of the primary ways to catalyse SBT social acceptance and implementation in India's underdeveloped nations. Also, according to the study, the reformed tendering process is critical to SBT's social acceptance. Grady et al. (2019) said that the bidding procedure in South Africa should be modified so that innovative construction technologies may be more competitive in the tendering process and used more often.

### **6.5.3 Factor 3— Grassroots advocacy and incentives**

Grassroots advocacy and incentives comprise three significant strategies and explain about 13.24% of the total variance in the strategies to SBT's social acceptance. The three significant strategies are (1) Competent promotion teams and grassroots supporters; (2) Financial incentives for sandbag uptake; (3) Public sandbag awareness creation through workshops, seminars, and conferences.

One of the most important strategies for social acceptance of sandbag technology in South African housing construction is competent promotion teams and grassroots supporters. According to Ben-Alon et al. (2020) and Grady et al. (2019), the formation of teams to educate professionals and beneficiaries on the usage and benefits of SBT is critical to its widespread acceptability. Furthermore, establishing grassroots and indigenous demand for earthbag technology in developing nations is critical to its acceptance, according to Belofsky and Zemskova (2018), since most earthbag initiatives in emerging nations have been restricted to

foreign-run assistance initiatives. This finding is consistent with Grady et al. (2019)'s study. The research also stated that providing financial incentives for sandbag technology adoption is critical to their social acceptance. This outcome is similar to Dosumu and Aigbavboa (2019) findings, who also recommended a reward system for innovation toward ensuring the adoption of sandbag technology. According to the research, boosting public awareness of sandbag technology via workshops, seminars, and conferences is a major technique for increasing the societal acceptability of sandbag technology. Ben-Alon et al. (2020) and Grady et al. (2019) have shown that recurrent and regular outreach actions in low-income neighbourhoods will improve communities' perceptions of ABTs. This will help raise people's awareness and understanding of earthbags. This is supported by Adegun and Adedeji (2017), Bobbo, Ali, Garba, and Salisu (2015) and Sameh (2014), who argue that utilising public media to create awareness about the advantages of earthen construction is a potent method for its universal adoption. The report also indicated that researchers do further research to demonstrate the advantages of sandbag technology or improve existing studies and information sheets. This outcome is consistent with earlier studies on alternative building techniques in South Africa (Adetooto & Windapo, 2022a; Grady et al., 2019)

## **6.6. Hypothesis developed for the study**

### **6.6.1 The restraining forces have significant impact on SBT social acceptance.**

The government-investor-related barrier strongly impacts the social acceptance of sandbag building technology, out of all the barrier groups determined from the factor analysis based on the PLS-SEM results. Therefore, the government-investor-related barrier, which includes the government's lack of promotion of sandbags, their lack of interest, and the lack of finance schemes (bank loans, grants), are significant barriers to social acceptance of SBT. There is a need for strategies to be developed to counterbalance the strong effect of the barriers. However, unless the government-investor-related barriers are removed, South African stakeholders may find it difficult to accept SBT. This finding is consistent with previous research that established that government plays a major role in the widespread implementation and acceptance of new technology in most nations (Upham et al., 2015).

### **6.6.2 The driving forces (key drivers) have significant impact on SBT social acceptance**

The economic-related driver strongly impacts the social acceptance of sandbag building technology. In contrast, the construction and health-related drivers have a moderate impact on SBT social acceptance out of all the driver groups, determined from the factor analysis based

on the PLS-SEM results. Therefore, the significant drivers of the SBT social acceptance are the economic-related driver, which includes affordability, low maintenance cost, job creation opportunities, requiring little expertise, and reusable and recyclable materials. The construction and health-related drivers are also significant drivers of SBT social acceptance. This set of significant drivers must be presented to the South African housing market to enhance the societal acceptance of SBT. This finding is confirmed by the critique of Santos and Beirão (2016) and (Sharma, 2015).

The driving forces (drivers) have a significant impact on the social acceptance of sandbag building technology.

### **6.6.3 The key strategies have a significant impact on SBT social acceptance**

The stakeholder integration and policy formation strongly impact the social acceptance of sandbag building technology. In contrast, effective education and knowledge sharing have minimal influence, out of all the strategy groups, determined from the factor analysis based on the PLS-SEM results. This group of strategies is significant to SBT social acceptance and may be used to address the major impediment to the social acceptability of SBT. This conclusion is supported by Grady et al. (2019) and Hadjri et al. (2007).

## **6.7 Chapter summary**

This chapter presented the discussion of findings on the quantitative analysis of data gathered from a survey of nine provinces of South African housing stakeholders and end-users. The results of factor analysis of the objectives 2, 3, and 4 were discussed. The next chapter presents the SBT social acceptance framework developed from the study.

## **CHAPTER SEVEN**

### **DEVELOPMENT OF A FRAMEWORK FOR SBT SOCIAL ACCEPTANCE**

#### **7.1 Chapter overview**

This chapter discusses the development and validation of the framework to the social acceptance of SBT.

#### **7.2 Proposed SBT social acceptance framework**

This study's conceptual framework is grounded on change theory, social acceptance theory, and Field theory. Several activities, including PLS-SEM analysis, contributed to developing the SBT Social Acceptance and Adoption Framework to achieve SAH delivery in South Africa (Figure 23). The constructs underpinning the barriers, drivers, and strategies were identified using PLS-SEM analysis (see Chapter Five) also see; (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c). In prior research on construction management, a framework was also built to generate new knowledge in the studied field (Darko, 2019; Olawumi & Chan, 2021).

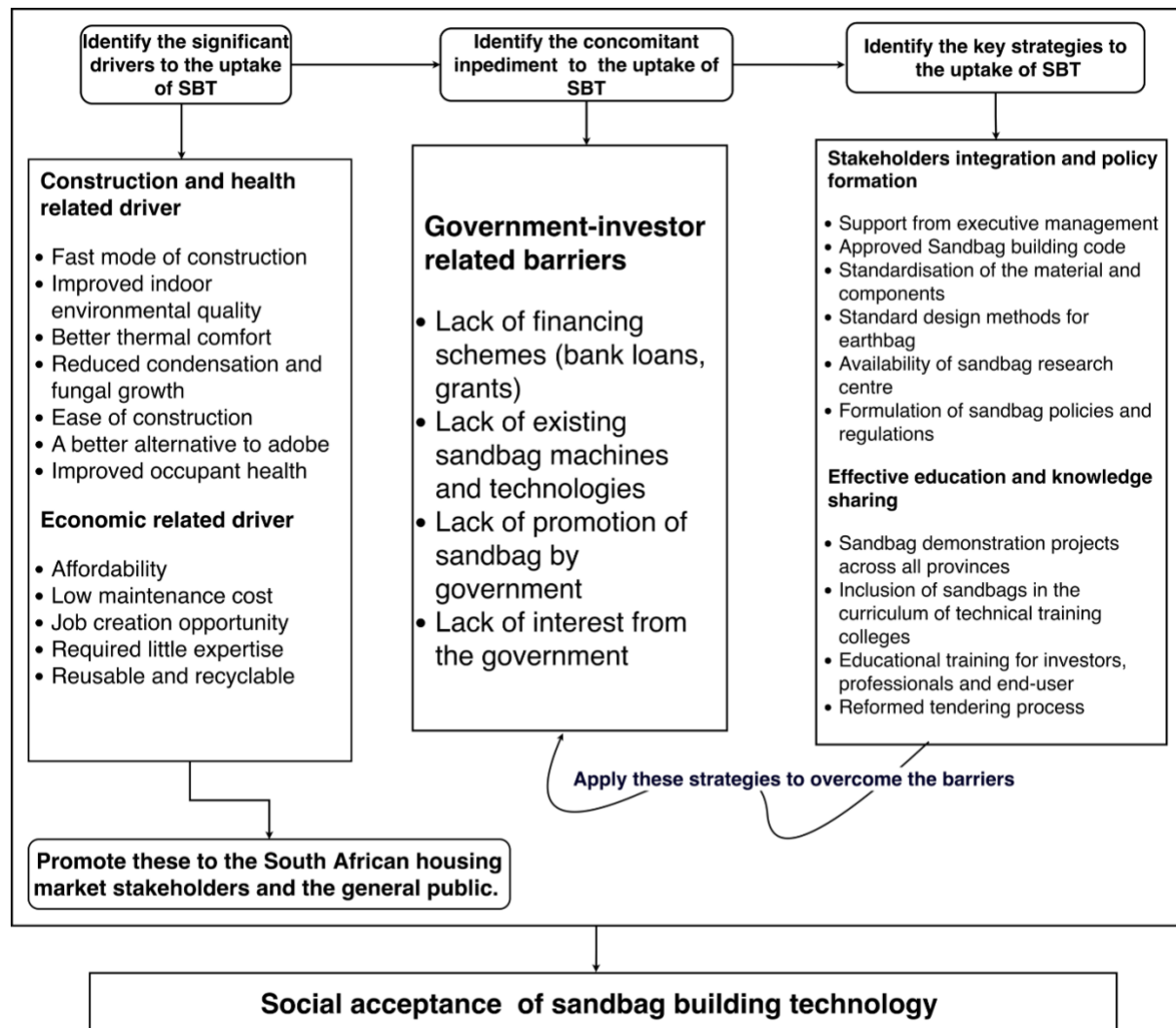
Building on the theoretical foundation of this research (change theory, social acceptance theory, and field theory), and PLS-SEM result, the framework development for SBT social acceptability consists of three important steps:

1. Identify the key driver group that has a significant impact on the SBT social acceptance
2. Identify the concomitant impediment group that has a significant impact on the SBT social acceptance
3. Identify the key strategies group that has a significant impact on the SBT social acceptance

The first phase of the implementation strategy is to identify the key driver group that has a significant impact on the SBT social acceptance. As the knowledge of the key drivers may encourage South African housing stakeholders and the general public to embrace and use SBT (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c), hence, promoting them in the South African housing market and among the general public is vital.

In addition, the second phase of the implementation plan identifies the concomitant impediment group that has a significant n impact on the SBT social acceptance. As knowledge of the concomitant impediment is necessary for developing and implementing substantial promotion

strategies to overcome the key barriers, it is essential to have this information (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c). Therefore, the framework for SBT social acceptance and adoption is shown in Figure 23.



**Figure 23:** SBT social acceptance framework

### 7.3 Validation of the Framework for the social acceptance of SBT

Validation is essential to all research studies and is considered the most important step in the last phase of a research cycle (Darko, 2019; Olawumi & Chan, 2021). The primary objective of validation is to evaluate the cogency and efficacy of the study findings or framework. (Darko, 2019). One of the difficulties with the framework validation process is the lack of a standardized method for selecting which validation techniques and statistical tests to use (Osei-Kyei, 2017). The research project's objective largely determines the validation method (Darko, 2019). Validity relates to "doing the correct things" (Lucko & Rojas, 2010). In other words,

the objective of validation is to ensure that the different steps of the study technique conform to the highest quality standards to provide credible and acceptable findings to practitioners/users. There are six types of construction management validation processes (construct, content, criteria, face, internal, and external validity), according to Lucko and Rojas (2010), resulting in statistics for construct validity, content validity, criteria validity, external validity, internal validity, and face validity. External validity relates to the applicability of the research's findings and procedures (Hu, Chan, Le, Xu, & Shan, 2016). This research evaluates the external validity of the SBT social acceptability paradigm proposed for delivering affordable and sustainable housing in South Africa.

Quantitative and qualitative procedures may be categorised as research validation processes (Ameyaw, 2014). The quantitative method is exhibited through the use of paired t-tests for validation, whilst the qualitative approach is demonstrated through the analysis of research findings and framework based on the following validity (construct, content, external, and internal validity) (Lucko & Rojas, 2010). In this study, a qualitative method for the validation of research was used. This method was used since the suggested SBT social acceptability framework is related to difficult-to-quantitatively-evaluate abstract notions (Osei-Kyei, 2017). Therefore, gathering data based on opinions against predetermined evaluation criteria was more acceptable.

### **7.3.1 Validation survey of the framework for the social acceptance of SBT**

A validation questionnaire survey was conducted to assess the cogency, validity, application, and quality of the proposed SBT social acceptability framework for cheap and sustainable housing delivery in South Africa. In prior construction management research, Darko (2019), Olawumi and Chan (2021) and Osei-Kyei (2017) also cited this.

The use of an e-message (email) was used for the questionnaire survey because it is inexpensive and enables researchers to contact and engage with target respondents easily (Wuni & Shen, 2020). Six statements from Darko (2019) and Osei-Kyei (2017) were amended and included on the validation questionnaire. Ten respondents with over ten years of expertise in alternative building technologies and sustainable construction in South Africa were requested to participate in the validation questionnaire survey as part of the study. Eight out of ten respondents eventually answered the validation survey. This sample size was judged suitable and appropriate for the framework validation since there were more than the six respondents in the validation questionnaire surveys conducted by Darko (2019) and Osei-Kyei (2017)

### **7.3.2 Validation result of the framework for the social acceptance of SBT**

Respondents were asked to indicate their degree of agreement with each of the six validation statements on a five-point scale, (1 = strongly disagree, 2 = disagree, 3 = natural, 4 = agree, and 5 = strongly agree). The validation questionnaire survey results are shown in Table 32. Notably, the mean scores for all six Framework validity assertions on the social acceptability of SBT exceeded 4.00. This indicates that respondents regarded all four validation components of the Framework for the Social Acceptance of SBT as effective and satisfactory (external, internal, construct, and content).

**Table 32:** Validation result of the Framework to the social acceptance of SBT

No	Validation statement Framework to the social acceptance of SBT	Responses								Mean
		R1	R2	R3	R4	R5	R6	R7	R8	
1	The significant SBT social acceptance and adoption drivers, barriers, and acceptance strategies identified are reasonable and correctly reflect the current situation in South Africa	5.0	5.0	4.0	4.0	4.0	4.0	5.0	5.0	4.50
2	The SBT social acceptance and adoption framework is easily understandable and could be used in the industry	5.0	5.0	5.0	3.0	4.0	3.0	5.0	5.0	4.38
3	The steps within the SBT social acceptance and adoption framework are appropriate	5.0	5.0	5.0	4.0	4.0	4.0	5.0	5.0	4.63
4	The SBT social acceptance and adoption framework is inclusive	5.0	5.0	4.0	3.0	4.0	4.0	4.0	4.0	4.13
5	The appropriate use of the SBT social acceptance and adoption framework would definitely help to promote the SBT acceptance and adoption in the industry	5.0	5.0	5.0	5.0	4.0	4.0	5.0	5.0	4.75
6	Overall, the SBT social acceptance and adoption framework is suitable for helping to promote SBT social acceptance and adoption in South Africa	5.0	5.0	5.0	3.0	4.0	4.0	5.0	5.0	4.50

The average score for the first statement is 4.50, indicating that the identified important SBT social acceptance and adoption drivers, impediments, and strategies are plausible and accurately represent the existing reality in South Africa. In addition, the average score for the sixth statement is 4.50, indicating that the SBT social acceptance and adoption framework is adequate for promoting SBT social acceptance and adoption in South Africa.

External validity was connected with both the first and sixth statements of the SBT social acceptability framework. Internal validity is represented by statement 2 with an average score of 4.38 which demonstrates that the SBT social acceptance and adoption framework is clearly understood and applicable to the industry. Statements 3 (mean score = 4.63) and 4 (mean score = 4.13) are representative of the concept validity. The finding suggests that the SBT social acceptability and adoption paradigm processes are adequate. It also indicates that the social acceptance and adoption framework of the SBT is inclusively high.

In addition, statement 5 (mean score = 4.75) is used to measure the content validity of the SBT social acceptance and adoption framework. This suggests that if market stakeholders and the general public in South Africa apply the SBT framework effectively, the possibility of sustainable housing construction is expected to be high. Overall, the high average scores obtained for the four validation characteristics imply that the SBT social acceptance and adoption framework is trustworthy, credible, inclusive, and suitable for promoting SAH delivery in South Africa. Several actions have been or must be done to assist the adoption and societal acceptability of SBT and the use of the framework. The SBT framework has been made accessible to users by reporting and publication (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c; Windapo, Jarratt, Adetooto, Pomponi, & Emuze, 2022a; Windapo et al., 2022d). In addition, the framework will be made accessible to the National Home Builders Registration Council (NHBRC), the South African housing industry, and the general public.

In addition, the SBT framework for social acceptability and adoption will be disseminated through workshops, seminars, and conferences. Furthermore, an in-depth and comprehensive explanation of the value of and how to use the SBT social acceptance and adoption framework to local stakeholders can play a pivotal role in facilitating their adoption and use within the industry.

This study provides a comprehensive framework for the social acceptance and adoption of sandbag technology in housing projects by drawing on the diverse opinions and practical experience of ABT experts and housing industry stakeholders in South Africa. In addition, this is the first and only effort to establish a framework for effectively adopting sandbag technology in South Africa to provide inexpensive and sustainable housing. If completely implemented and approved, the framework may contribute to resolving South Africa's housing shortfall problem.

#### **7.4 Chapter summary**

This chapter included the development and validation of the framework for the societal acceptability of SBT. This study's framework was based on change theory, field theory and theory of social acceptability. Several initiatives, including factor analysis, aided in developing the SBT social acceptance and adoption framework for sustainable and affordable housing delivery in South Africa. The framework was validated using a survey, and the results indicate that the SBT social acceptance and adoption framework is reliable, credible, inclusive, and adequate for encouraging sustainable and affordable housing delivery in South Africa.

## **CHAPTER EIGHT**

### **CONCLUSION AND RECOMMENDATIONS**

#### **8.1 Introduction**

Chapters 1-7 discuss many facets of this research topic area. The current chapter closes this research project. It presents an overview of the results, evaluates the research objectives, and provides the primary conclusions. In addition, the chapter presents recommendations for theory and practice, and suggested areas of future research.

#### **8.2 Summary of key findings**

The research aimed to develop a framework to promote the social acceptability of Sandbag Building Technology (SBT) in housing delivery in South Africa. To achieve the research aim, the study used a mixed research method. The research began with two focus group sessions with thirteen (13) randomly selected South African housing market participants and end-users. Also, a questionnaire survey was conducted across South Africa's nine provinces and yielded 228 valid responses. The data were analysed using various methods such as inductive content analysis with NVivo, the Shapiro-Wilks test and Cronbach's Alpha, mean score rating, the Kruskal-Wallis H Test, the Kaiser-Meyer-Olkin (KMO) sample adequacy measure, Bartlett's test for sphericity, and factor analysis. The hypotheses developed for the study were tested using the PLS-SEM analysis technique.

#### **Objective 1: To determine the actor's perception of the use of Sandbag Building Technology as a Sustainable Affordable Housing Solution in South Africa**

The objective was achieved through qualitative analysis with NVivo. The result indicated that SBT was perceived as a better alternative to delivering sustainable and affordable housing in South Africa. On the drivers of the use of SBT in South Africa, job creation opportunity, material availability, waste reduction, reduced environmental effects and affordability were the top five drivers. Social acceptance and lack of support from the government were perceived as top barriers to using SBT in South Africa. Also, based on expert perception, adequate research on the performance of sandbag technology, and social awareness emerged as the top strategies to the use of SBT in South Africa.

#### **Objective 2: To identify and establish the critical drivers of the social acceptance of SBT in South Africa**

The objective was reached through a literature study and quantitative research analysis, which included the Shapiro-Wilks test and Cronbach's Alpha, Mean score rating, the Kruskal- Wallis H test, the Kaiser-Meyer-Olkin (KMO) sample adequacy measure, Bartlett's sphericity, and factor analysis. The top five SBT social acceptance drivers in South Africa were job creation potential, material availability, waste reduction, decreased environmental consequences, and affordability. Factor analysis revealed that the underlying drivers for the twenty-two significant drivers were construction and health-related, environment-related, economic-related, material and cost-related and aesthetics and acoustic-related.

**Objective 3: To identify and establish the concomitant impediment to the social acceptance of SBT in South Africa**

The objective was achieved through literature review and quantitative research analysis, using a five-level analysis framework including the Shapiro-Wilks test and Cronbach's Alpha, Mean score rating, the Kruskal- Wallis H test, the Kaiser-Meyer-Olkin (KMO) sample adequacy measure, Bartlett's sphericity, and factor analysis. Eighteen impediments were identified, based on the analysis of concomitant impediments to the social acceptance of SBT in South Africa. The top five most critical impediments were lack of awareness of sandbag technology and its benefits, absence of SBT courses and training, lack of professional knowledge and expertise, lack of SBT promotion by the government and the absence of SBT policies and regulations. Factor analysis showed that the underlying impediments of the eighteen critical impediments were policy and knowledge-related, government-investor-related, technical related and information-related.

**Objective 4: To identify and establish key strategies to the social acceptance of SBTs in South Africa**

The objective was achieved through literature review and quantitative research analysis, using a five-level analysis framework including the Shapiro-Wilks test and Cronbach's Alpha, Mean score rating, the Kruskal-Wallis H test, the Kaiser-Meyer-Olkin (KMO) sample adequacy measure, Bartlett's sphericity, and factor analysis. On the strategies to promote the social acceptance of SBT in South Africa, availability of sandbag demonstration projects across all provinces, approved sandbag building code, availability of standard design methods for sandbags, public sandbag awareness creation, and educational training for investors, experts, and end-users were the top five strategies. Factor analysis showed that the underlying strategies

of the thirteen important strategies were stakeholder integration and policy formation, effective education and knowledge sharing, and grassroots advocacy and incentives.

**Objective 5: To develop a framework for the uptake and social acceptance of SBT in South Africa.**

The research findings were integrated into the constructed framework, using the PLS-SEM result and the established theoretical underpinning of this study. The framework was validated using a survey approach. The validation survey indicated that the framework for the uptake and social acceptance of SBTs in South Africa was reliable, credible, inclusive, and adequate for encouraging sustainable and affordable housing delivery in South Africa.

**Hypotheses developed for the study**

Three main hypotheses were formulated to address Research objective 5 and to answer the main research question.

Three main hypotheses were formulated to address research objective 5. Hypothesis 1 stated that: *the restraining forces (concomitant impediments) have significant impact on SBT social acceptance*. Hypothesis 2 stated that *the driving forces (key drivers) have significant impact on SBT social acceptance* and hypothesis 3 stated that *key strategies have a significant impact on SBT social acceptance*. The main hypothesis was validated with PLS-SEM, and all the sub-hypotheses tested to address hypotheses 1, 2 and 3, were also validated. Hence based on the result, it is inferred that the government-investor-related barrier is a significant barrier that influences the social acceptance of sandbag building technology in South Africa. Also, economic, construction and health-related drivers are significant drivers and impact the social acceptance of sandbag building technology. Meanwhile, stakeholder integration, policy formation, and effective education and knowledge sharing are significant strategies that impact the social acceptance of sandbag building technology. The research inferred that the significant drivers and strategies identified in this study could be used to counterbalance the effect of the barriers and enhance the social acceptance of SBT in South Africa.

Four sub-hypotheses to hypothesis 1 were formulated to answer the main research question, that is: **What constraints impede the social acceptance and use of sandbag building technology in South African housing construction?**

The sub-hypotheses 1 (H1a-H1d) stated that: *the policy and knowledge related barrier, government-investor-related barriers, the technical related barrier and information-related barrier are significant barriers to the social acceptance of SBT*. Based on the result, it is inferred that the government-investor-related barrier, which includes: the government's lack of promotion of sandbags, the government's lack of interest and the lack of finance schemes (bank loans, grants), are significant barriers that impede the social acceptance and use of SBT in South Africa.

### **8.3 Conclusion**

The following conclusion was drawn, based on the empirical result obtained from this study.

The sandbag construction technology is a superior choice for providing sustainable and affordable homes in South Africa. Still, the level of social acceptance of sandbag technology is very low in South Africa. Government and investors are the major players that impede the use and social acceptance of sandbag technology in South Africa due to their lack of support for it. To promote the social acceptance of SBT in South Africa, there is a need for stakeholder integration; the government and the other South African housing market players need to support the adoption of SBT through the formation of strategic policy. More so, there is a need for effective education, training availability of sandbag demonstration projects in all provinces and knowledge sharing with housing stakeholders and end-users. The major benefits of SBT, which include its economic, construction and health-related benefits, should be communicated to South African housing stakeholders and the general public to promote its acceptance.

### **8.4 Recommendation for practice and policy**

Based on the findings, the study recommends that:

1. Interested stakeholders and the South Africa housing market should leverage on the research framework and communicate the drivers of the social acceptance of SBT to South African housing stakeholders and the general public.
2. The government of South Africa should offer assistance and adopt laws and regulations to encourage the societal acceptability and the usage of sandbag building technology.
3. Sufficient resources should be available, to support training and educate stakeholders and the general public about sandbags, and other alternative technologies.

4. Access to financial incentives and assistance, such as bank loans and grants, should encourage the use of sandbag technology comparable to that provided in Australia, Hong Kong, and the United States.

### **8.5 Recommendations for further studies**

Future studies examining use of alternative building technology in South Africa should consider the following recommendations:

1. All the alternative building technology should be considered. The emphasis of this study was only on the social acceptability and adoption of SBT in South Africa; hence, generalisations about ABT may be limited.
2. Consideration should be given to a comparative empirical study of ABT and conventional procedures in terms of cost, time, and quality. Due to the extensive scope of the research and time constraints, no empirical comparison analysis was conducted; instead, information on cost, quality, and length was derived through a literature review.
3. Consideration should be given to the empirical lifecycle assessment of SBT in South Africa. Due to the extensive scope of the research and time constraints, lifecycle assessment of SBT was not conducted, instead, information on lifecycle assessment of SBT was derived through a literature review.

### **8.6 Contribution to knowledge**

The findings of this study have practical implications for implementing and adopting alternative construction technologies in South Africa. Further, the findings of this research have important implications for the social acceptance and implementation of sandbag construction technologies in South Africa. The study is the first and only attempt to assess the drivers, barriers, and strategies for social acceptance and adoption of SBT to provide sustainable and affordable housing within developing countries, particularly South Africa. Therefore, it greatly adds to the limited understanding of the social acceptability of the sandbag construction technique.

The framework developed from this research will aid South African housing stakeholders in clearly understanding how to promote the adoption and social acceptance of SBT to address the country's housing crisis. In addition, the framework can contribute to resolving South Africa's housing shortfall problem if completely implemented and approved. Further, this finding may apply to many other nations that are dealing with a large housing shortfall and

nations with comparable environmental conditions to South Africa. Finally, 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 sandbag technology in South Africa, to achieve more sustainable and affordable housing delivery.

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## APPENDIX

### Appendix 1: measurement constructs

Constructs	Code	Measurement items
Policy and knowledge related barrier (PKRB)	PKRB1	Lack of sandbag technology policy and regulations
	PKRB2	Professionals resistant to change from the use of conventional technologies
	PKRB3	Lack of building code
	PKRB4	Lack of professional's knowledge and expertise
	PKRB5	Lack of courses and training on sandbag technology
Government-investor -related barriers (GIRB)	GIRB1	Lack of financing schemes (bank loans, grants)
	GIRB2	Lack of existing sandbag machines and technologies
	GIRB3	Lack of promotion of sandbag technology by Government
	GIRB4	Lack of interest from the Government
Technical related barrier (TRB)	TRB1	Technical limitations
	TRB2	Lack of standard design method for sandbag technology
	TRB3	Deficiency in sandbag construction techniques
Information-related barrier (IRB)	IRB1	Lack of sandbag technology databases and information
	IRB2	Lack of awareness of sandbag technology and its benefits
Construction and health related driver (CHRD)	CHRD1	Fast mode of construction
	CHRD2	Improved indoor environmental quality
	CHRD3	Better thermal comfort
	CHRD4	Reduced condensation and fungal growth
	CHRD5	Ease of construction
	CHRD6	A better alternative to adobe
	CHRD7	Improved occupant health
Environmental related driver (ERD)	ERD1	High energy efficiency
	ERD2	Reduce environmental impacts
	ERD3	Resist environmental hazard
	ERD4	Erosion and flood control
	ERD5	Wind resistant and bulletproof
	ERD6	Fireproof
Economic related driver (ECDR)	ECDR1	Affordability
	ECDR2	Low maintenance cost
	ECDR3	Job creation opportunity
	ECDR4	Required little expertise
	ECDR5	Reusable and recyclable

<b>Constructs</b>	<b>Code</b>	<b>Measurement items</b>
Material and cost related driver (MCRD)	MCRD1	Material availability
	MCRD2	Waste reduction
	MCRD3	Less transportation cost
Aesthetics and acoustic related driver (AARD)	AARD1	Aesthetics
	AARD2	Diversity of forms and styles
	AARD3	Good acoustic insulation
Stakeholders' integration and policy formation (SIPF)	SIPF1	Support from executive management
	SIPF2	Approved sandbag building code
	SIPF3	Standardisation of the material and components
	SIPF4	Standard design methods for sandbag construction
	SIPF5	Availability of sandbag technology research centre
	SIPF6	Formulation of sandbag technology policies and regulations
Effective education and knowledge sharing (EEKS)	EEKS1	Sandbag technology demonstration projects across all provinces
	EEKS2	Inclusion of sandbag technology in the curriculum of technical training colleges
	EEKS3	Educational training for investors, professionals and end-users
	EEKS4	Reformed tendering process
Grassroots advocacy and incentives (GAI)	GAI1	Competent promotion teams and grassroots supporters
	GAI2	Financial incentive for sandbag uptake
	GAI3	Public sandbag awareness creation through workshops, seminars, and conferences
SBT Social acceptance (SA)	C1	Members of the community construct their houses using sandbag construction technique.
	C2	Government officials promote the use of sandbag technology in construction.
	C3	Investors and financial institutions encourage the usage of sandbag technology.
	C4	Professionals in construction endorse the usage of sandbag technology.

**Appendix 2:** Cross loading (barriers model discriminant validity)

Constructs	GIRB	IRB	PKRB	SSA	TRB
C1	0.202	0.200	0.192	0.631	0.185
C2	0.220	0.204	0.162	0.649	0.163
C3	0.773	0.655	0.710	0.823	0.457
C4	0.269	0.242	0.198	0.661	0.313
GIRB1	<b>0.779</b>	0.508	0.536	0.557	0.456
GIRB2	<b>0.865</b>	0.582	0.682	0.411	0.486
GIRB3	<b>0.876</b>	0.674	0.533	0.622	0.611
GIRB4	<b>0.882</b>	0.668	0.729	0.519	0.499
IRB1	0.541	<b>0.816</b>	0.564	0.470	0.550
IRB2	0.691	<b>0.865</b>	0.732	0.541	0.604
PKRB1	0.638	0.607	<b>0.842</b>	0.485	0.503
PKRB2	0.336	0.463	<b>0.799</b>	0.174	0.377
PKRB3	0.742	0.648	<b>0.892</b>	0.601	0.502
PKRB4	0.765	0.795	<b>0.868</b>	0.542	0.562
PKRB5	0.769	0.645	<b>0.883</b>	0.575	0.516
TRB1	0.491	0.591	0.507	0.349	<b>0.864</b>
TRB2	0.569	0.584	0.555	0.455	<b>0.921</b>
TRB3	0.539	0.655	0.536	0.435	<b>0.876</b>

Note: Bold values indicate those items with the greatest loading on their respective constructs; TRB = Technical-related barrier, PKRB = Policy-knowledge-related barrier, GIRB = Government-investor-related barrier, IRB = Information-related barrier, SSA = SBT Social acceptance

**Appendix 3:** Cross loading (driver model discriminant validity)

Constructs	AARD	CHRD	ECRD	ERD	MCRD	SSA
AARD1	<b>0.815</b>	0.707	0.571	0.703	0.506	0.556
AARD2	<b>0.858</b>	0.728	0.756	0.677	0.643	0.733
AARD3	<b>0.785</b>	0.667	0.548	0.730	0.538	0.531
C1	0.739	0.730	0.627	0.679	0.686	<b>0.910</b>
C2	0.637	0.702	0.660	0.620	0.567	<b>0.898</b>
C4	0.643	0.708	0.754	0.696	0.686	<b>0.879</b>
CHRD1	0.643	<b>0.844</b>	0.754	0.696	0.686	0.819
CHRD2	0.777	<b>0.859</b>	0.687	0.719	0.651	0.672
CHRD3	0.694	<b>0.823</b>	0.590	0.733	0.504	0.558
CHRD4	0.691	<b>0.785</b>	0.582	0.721	0.571	0.582
CHRD5	0.650	<b>0.832</b>	0.710	0.726	0.718	0.768
CHRD6	0.655	<b>0.844</b>	0.558	0.599	0.505	0.546
CHRD7	0.688	<b>0.802</b>	0.642	0.754	0.689	0.598
ECRD1	0.747	0.735	<b>0.908</b>	0.685	0.691	0.912

Constructs	AARD	CHRD	ECRD	ERD	MCRD	SSA
ECRD2	0.635	0.705	<b>0.869</b>	0.629	0.584	0.829
ECRD3	0.598	0.652	<b>0.856</b>	0.638	0.736	0.678
ECRD4	0.499	0.547	<b>0.900</b>	0.525	0.542	0.508
ECRD5	0.512	0.544	<b>0.788</b>	0.545	0.597	0.504
ERD2	0.582	0.632	0.551	<b>0.778</b>	0.605	0.544
ERD3	0.763	0.718	0.689	<b>0.816</b>	0.734	0.634
ERD4	0.782	0.763	0.670	<b>0.852</b>	0.583	0.685
ERD5	0.668	0.657	0.550	<b>0.799</b>	0.581	0.512
ERD6	0.651	0.660	0.617	<b>0.795</b>	0.581	0.572
MCRD1	0.592	0.665	0.742	0.629	<b>0.892</b>	0.662
MCRD2	0.603	0.684	0.682	0.703	<b>0.878</b>	0.590
MCRD3	0.621	0.713	0.667	0.696	<b>0.852</b>	0.642

Note: Bold values indicate those items with the greatest loading on their respective constructs; AARD = Aesthetics and acoustic related drivers, CHRD = construction and health related driver, ECRD = Economic related drivers, ERD = Environment related barrier, MCRID = Material and cost related driver, SA = SBT Social acceptance

#### Appendix 4: Cross loading (strategies model discriminant validity)

Constructs	EEKS	GAI	SSA	SIPF
C1	0.671	0.287	<b>0.907</b>	0.781
C2	0.619	0.285	<b>0.899</b>	0.820
C4	0.687	0.314	<b>0.881</b>	0.808
EEKS1	<b>0.829</b>	0.287	0.807	0.781
EEKS2	<b>0.829</b>	0.582	0.292	0.397
EEKS3	<b>0.693</b>	0.610	0.300	0.400
EEKS4	<b>0.767</b>	0.595	0.407	0.476
<b>GAI1</b>	0.555	<b>0.788</b>	0.259	0.327
<b>GAI2</b>	0.418	<b>0.801</b>	0.297	0.358
<b>GAI3</b>	0.273	<b>0.630</b>	0.116	0.177
SIPF1	0.687	0.314	0.861	<b>0.908</b>
SIPF3	0.652	0.537	0.443	<b>0.913</b>
SIPF4	0.619	0.285	0.799	<b>0.880</b>

Note: Bold values indicate those items with the greatest loading on their respective constructs; EEKS = Effective education and knowledge sharing, GAI = Grassroot advocacy and incentives, SIPF= Stakeholder integration and policy formation, SA = SBT Social acceptance

## Appendix 5: General Questionnaire Survey

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### **CONSENT FORM**

Title of the research project:

*Investigation of the Utilization and Barriers to the Social Acceptance of Alternative Building Technologies in Housing Construction.*

Dear participant,

You are invited to participate in a research study on *the Investigation of the Utilization and Barriers to the Social Acceptance of Alternative Building Technologies in Housing Construction*. This research is conducted by Johnson Adetooto, an MPhil Candidate at the University of Cape Town. The enquiry is supervised by Professor Abimbola Windapo of the University of Cape Town. The study results will be presented to the Department of Construction Economics and Management, to fulfil the requirements for the degree of Master of Philosophy in Construction Economics and Management.

The questionnaire can be completed in approximately 15-20 minutes at a time convenient to you. Please be aware that information provided by you will be treated in the strictest confidence, and your company will be kept anonymous. Further, the key findings of the research can be communicated with you if you request. In case you have any concerns or question(s) relating to the research, please do not hesitate to contact me, Johnson Adetooto or the research supervisor, Professor Abimbola Windapo, on:

Johnson Adetooto	adtjoh001@myuct.ac.za	+27 (073) 558 6412
Abimbola Windapo	Abimbola.Windapo@uct.ac.za	+27 (021) 650 2049

Purpose of the Study:

The research's primary aim is to investigate whether there are factors inhibiting the use and social acceptance of sandbag building technology in housing construction in South Africa. The study will also determine the actors' level of use and perceptions on the use of sandbag technologies in South Africa. It will also identify the significant drivers of the social acceptance of sandbag technologies in the South and develop a framework to promote the social acceptability of sandbag building technologies in South Africa.

Rights of Participation:

Participation in this study is voluntary. Hence, your consent may be withdrawn, and at any time, your participation discontinued without any repercussions.

Signature of Research Participant:

I have read the information provided for this study on

*“Investigation of the Utilization and Barriers to the Social Acceptance of Alternative Building Technologies in Housing Construction”*

I have been provided with a copy of this form as a point of reference. My questions have been answered to my satisfaction, and I consent to participate in this study.

Full Name of Participant: \_\_\_\_\_ Signature: \_\_\_\_\_ Date \_\_\_\_\_

Principal Researcher: Adetooto Johnson D Signature:  Date: 21/09/2022

## **SECTION A: BACKGROUND INFORMATION OF RESPONDENT**

This section of the questionnaire refers to background or biographical information. Although we are aware of the sensitivity of the questions in this section, the information provided will allow the comparison of groups of respondents.

1. Which of the following categories best describes you? Consultant ; Developer ; Contactor ; Government ; End user ; Other (please specify): \_\_\_\_\_
2. Kindly indicate the province where your company head is located/ where you are based? Eastern Cape ; Western Cape ; Free State ; Gauteng ; Limpopo ; Mpumalanga ; Northern Cape ; North West ; KwaZulu Natal
3. How many years of working experience do you have in the South African construction industry? 0-5 years ; 6-10 years ; 11-15 years ; 16-20 years ; Over 20 years
4. Do you have an understanding of alternative building technology or have you been exposed to any product? Yes ; No
5. Which of the following best describes your academic qualifications? Doctoral degree ; Master's degree ; Bachelor's degree ; Matric
6. Could you live in a sandbag technology house? Yes ; No

Note: You may refer to the definition of Alternative Building Technologies and Sandbag Technology if necessary, in section F (last page)

Section B: Drivers to the social acceptance of Sandbag building technology in housing construction

This section of the questionnaire identifies the drivers of the social acceptance of sandbag building technology in housing construction in South Africa

Please indicate your level of agreement on each of the following drivers using the following five-point Likert scale where: 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree.

S/N	Drivers of sandbag building technology uptake in housing construction	Level of agreement	
		Low	High
1.	Adobe alternative	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
2	High energy efficiency	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
3	Reduce environmental impacts	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
4	Better thermal comfort	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
5	diversity of forms and styles	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
6	Affordability	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
7	Low maintenance cost	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
8	Less transportation cost	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
9	Fireproof	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
10	Ease of construction	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
11	Required little expertise	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
12	Fast mode of construction	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
13	Erosion and flood control	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
14	good acoustic insulation	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
15	improved indoor environmental quality	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
16	Job creation opportunity	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
17	Material availability	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
18	Improved occupant health	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
19	Reduced condensation and fungal growth	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
20	Resist environmental hazard	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
21	Reusable and recyclable	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
22	Waste reduction	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
23	wind resistant and bulletproof	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
If this questionnaire omits any drivers, please list and rate them here			
1		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
2		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
3		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
4		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
5		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	

**Section C: Barriers to social acceptance of Sandbag building technology in housing construction**

This section of the questionnaire identifies the barriers to the social acceptance of Sandbag building technology in housing construction in South Africa.

Please indicate how critical each of the following barriers is to the social acceptance of Sandbag Building Technology in Housing Construction in South Africa. Use the following scale: 1 = not critical; 2 = less critical; 3 = neutral; 4 = critical; 5 = very critical.

S/N	Barriers to sandbag building technology uptake in housing construction	Level of agreement	
		Low	High
1.	lack of sandbag databases and information	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
2	Lack of interest from Government	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
3	lack of Sandbag policy and regulations	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
4	Lack of building code	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
5	Lack of promotion of sandbag technology by Government	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
6	Lack of courses and training on sandbag technology	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
7	Lack of sufficient research on earthbag material	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
8	lack of sandbag databases and information	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
9	Negative effect on human health	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
10	Lack of interest from clients	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
11	Lack of existing sandbag machines and technologies	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
12	lack of professional knowledge and expertise	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
13	Professionals resistant to change from the use of conventional technologies	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
14	Lack of awareness of sandbag technology and its benefits	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
15	Deficiency in sandbag construction techniques	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
16	Durability issue	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
17	Technical limitations	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
18	Lack of standard design method for sandbag tech	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
19	Inexperienced labor	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
20	Lack of financing schemes (bank loans, grants)	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
If this questionnaire omits any barriers, please list and rate them			
1		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
2		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
3		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
4		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	
5		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,	

**Section D: Strategies to the social acceptance of Sandbag Building Technology in housing construction**

This section of the questionnaire identifies the strategies to the Social acceptance of Sandbag building technology in housing construction in South Africa.

Please indicate the level of importance of each of the following strategies to promote acceptance sandbag building technology in the housing construction. Use the following scale: 1 = not important; 2 = less important; 3 = neutral; 4 = important; 5 = very important.

S/N	Strategies to Sandbag Building Technology uptake in housing construction	Level of agreement
		Low ↔ High
1.	A financial incentive for sandbag uptake	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
2	More publicity through media (internet; television, and radio)	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
3	Public sandbag awareness creation through workshops, seminars, and conferences	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
4	Approved sandbag technology building code	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
5	Availability of the competent promotion teams and grassroots supporters	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
6	Availability of sandbag demonstration projects across all provinces	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
7	Availability of standard design methods for earthbag	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
8	Availability of sandbag research center	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
9	Support form executive management	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
10	formulation of sandbag policies and regulations	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
11	Inclusion sandbag in the curriculum of technical training colleges	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
12	reformed tendering process	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
13	Standardization of the material and components,	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
14	Educational training for investors professionals and end-user	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
If this questionnaire omits any barriers, please list and rate them		
1		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
2		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
3		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
4		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
5		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,

**Section E: Indicators of the social acceptance of Sandbag Building Technology in housing construction**

This section of the questionnaire identifies the indicators to the social acceptance of sandbag building technology in housing construction in South Africa.

Please indicate the level of importance of each of the following components of the social acceptance of sandbag building technology in housing construction. Use the following scale: 1 = not important; 2 = less important; 3 = neutral; 4 = important; 5 = very important.

S/N	Indicators to Sandbag building technology social acceptance in housing construction	Level of agreement
		Low $\longleftrightarrow$ High
1.	Members of the community construct their houses using sandbag construction technique.	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
2	Government officials promote the use of sandbag technology in construction.	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
3	Investors and financial institutions encourage the usage of sandbag technology.	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
4	Professionals in construction endorse the usage of sandbag technology.	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
If this questionnaire omits any barriers, please list and rate them		
1		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
2		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
3		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
4		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
5		<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,

**Appendix 5: Questionnaire for Validating the Framework to the Social Acceptance of Sandbag Technology**

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**CONSENT FORM**

Questionnaire for Validating the Framework to the Social Acceptance of Sandbag Technology

Dear participant,

You are invited to participate in validating the framework for the social acceptance of sandbag building technology to promote the adoption and acceptance of SBT for sustainable and affordable housing delivery.

The SBT social acceptance framework was developed as part of the deliverables of an MPhil research study carried out at the University of Cape Town by Mr Johnson Adetooto, under Professor Abimbola Windapo's supervision. In general, the study aimed to promote SBT social acceptance and adoption for sustainable and affordable housing delivery. The SBT social acceptance framework was developed as a result of a general questionnaire survey with south African housing market stakeholders, which was analysed using factor analysis and Partial least square structural equation modelling (PLS-SEM). The survey was conducted from August 2021 to Feb 2022

This document has four pages (1 page of background and instructions and three pages that describe the SBT social acceptance framework). At the end of this document, you are kindly asked to indicate your level of agreement with statements aimed at validating the SBT social acceptance formwork and implementation strategy.

All of your contributions towards this MPhil research study, from the general survey until now, are highly appreciated. Thank you very much in advance for your kind contribution.

Kind regards,

Johnson Adetooto (MPhil Candidate)  
Email: adtjoh001@myuct.ac.za

### **About the SBT Social Acceptance Framework.**

This study's conceptual framework is grounded on change theory, social acceptance theory, and Field theory. Several activities, including PLS-SEM analysis, contributed to developing the SBT Social Acceptance and Adoption Framework to achieve Sustainable and Affordable Housing Delivery in South Africa (Figure 21). The constructs underpinning the barriers, drivers, and strategies were identified using PLS-SEM analysis (see Chapter five) also see; (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c). In prior research on construction management, a framework was also built to generate new knowledge in the studied field (Darko, 2019; Olawumi & Chan, 2021).

Building on the theoretical foundation of this research (change theory, social acceptance theory, and field theory), and PLS-SEM result, the framework development for SBT social acceptability consists of three important steps: 1. Identify the key driver group that has a significant impact on the SBT social acceptance, 2. Identify the concomitant impediment group that has a significant impact on the SBT social acceptance and 3. Identify the key strategies group that has a significant impact on the SBT social acceptance

The first phase of the implementation strategy is to key driver group that has a significant impact on the SBT social acceptance. As the knowledge of the key drivers may encourage South African housing stakeholders and the general public to embrace and use SBT (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c), hence, promoting them in the South African housing market and among the general public is vital.

In addition, the second phase of the implementation plan identifies the concomitant impediment group that has a significant impact on the SBT social acceptance. As knowledge of the concomitant impediment is necessary for developing and implementing substantial promotion strategies to overcome the key barriers, it is essential to have this information (Adetooto & Windapo, 2022a; Adetooto et al., 2022b; Adetooto et al., 2022c). Therefore, the framework for SBT social acceptance and adoption is shown in the figure below. Please click on the attached link to access the tables and the figures and then indicate your level of agreement with the statement at the end this document to validate the framework

<https://drive.google.com/file/d/1yW6ZaQuIDpC9mBjGRgTSqDiPe3vHd77J/view?usp=sharing>

### Section B: Sandbag building technology social acceptance framework

Please indicate your level of agreement about the framework to the social acceptance of sandbag technology for sustainable and affordable housing delivery in south Africa using the following five-point Likert scale where: 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree.

S/N	Sandbag building technology social acceptance framework	Level of agreement
		Low $\longleftrightarrow$ High
1.	The significant SBT social acceptance and adoption drivers, barriers, and promotion strategies identified are reasonable and correctly reflect the current situations in South Africa	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
2	The SBT social acceptance and adoption framework is easily understandable and could be used in the industry	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
3	The steps within the SBT social acceptance and adoption framework are appropriate	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
4	The SBT social acceptance and adoption framework is inclusive	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
5	The appropriate use of the SBT social acceptance and adoption framework would definitely help to promote the SBT acceptance and adoption in the industry	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,
6	Overall, the SBT social acceptance and adoption framework is suitable for helping to promote SBT social acceptance and adoption in South Africa	<input type="checkbox"/> 1, <input type="checkbox"/> 2, <input type="checkbox"/> 3, <input type="checkbox"/> 4, <input type="checkbox"/> 5,