Appraising the Nexus between Influencers and Sustainability-Oriented Innovation Adoption in Affordable Housing Projects

Abstract

The emergence of a plethora of innovative construction methods, materials and technologies in the construction industry has been projected to enhance the effective delivery of sustainable affordable housing. However, a lack of empirical evidence buttressing an extensive analysis of the effect of internal and external influencers on adopting these innovations within the affordable housing context in developing countries persists. This study examines the nexus between company and project characteristics as internal influencers, and challenges as external influencers, on the extent of use of sustainability-oriented innovations (SOIs), on affordable housing projects. Variables emanating from an extensive literature review were presented in a causal model detailing sustainable, innovative, and affordable housing (SIAH). The model and the inherent causality between the constructs were validated through a survey administered on a population of registered South African home developers. The results of structural equation modelling posit a minimal positive impact of internal influencers and moderate negative effects of external challenges on the extent of use of SOIs by home developers. Also, results highlighted the negative mediating impact of challenges on the relationship between internal influences and the extent of use of SOI in affordable housing projects. The study concludes that the external challenges are the key drivers of adopting innovation in SIAH, and by addressing these challenges, the extent of use will significantly improve. The validated causal model can be used as a framework to enhance SOIs adoption in SIAH.

Keywords: Challenges, Company characteristics, Project Characteristics, Sustainability-oriented innovation, Sustainable innovative affordable housing, Sustainable development.

1. Introduction

Demands for improved sustainability performance, adoption of innovation and attainment project objectives have caused a positive paradigm shift in the construction industry through the emergence of innovative construction methods, materials and technologies (Moghayedi *et al.*, 2021; Adabre and Chan, 2019). Similarly, sustainability-oriented innovative practices within affordable housing projects have been identified as mechanisms that can engender cost reduction and improvement of housing quality whilst enhancing the environmental and social aspects of affordable housing deemed necessary for housing market continuity (Winston, 2021; Jamaludin et al., 2018).

However, awareness of a particular sustainability-oriented innovative practice does not necessarily ensure its adoption, as a series of interrelated events are required for successful adoption (Moghayedi et al., 2022), thus supporting the general perception that the construction industry is penurious in the uptake of innovation (Adafin et al., 2021). Certain organizational and project characteristics have also been identified as influencing the rate of adoption of innovation in the construction industry (Wei and Lam, 2021, Seng et al., 2020). Several scholars espouse the need for a deep understanding of the key drivers and challenges which prevent the use of sustainability-oriented innovations (SOI) on affordable housing projects (Moghayedi *et al.*, 2021). Patently, the ability to know how, why, and where home designers and developers adopt sustainability and innovation concepts is critical and empowers the industry players within the housing sector on how to expedite the adoption rate thereby enabling effective supply of SIAH.

In response to the foregoing, this study seeks to determine the key internal factors that influence the adoption of sustainability-oriented and innovation-related practices, materials, and technologies in affordable housing projects, both at company and project levels, and the external factors which might influence adoption levels. Furthermore, it seeks to determine the extant causality between these key drivers, challenges, and the extent of use of sustainable and innovative methods, materials, and technologies in affordable housing projects. Suffice to say that it seeks to establish how these factors and challenges impact on the extent of use of SOIs on affordable housing projects using a developing country exemplar. It is expected that such understanding and the emergent causal model will promote the use of these SOIs as catalysts for developing SIAH whilst providing valuable reference for affordable housing stakeholders and decision-makers on the adoption of various SOIs in similar contexts.

To achieve its aim, the following three research questions are answered by this study:

1. What are the internal drivers influencing the adoption of SOI on affordable housing projects at both company and project levels?

2. What are the challenges negating adoption of SOI during design and construction of affordable housing projects?

3. What is the impact of these internal drivers and challenges on the extent of use of SOI in affordable housing projects?

The rest of the paper is structured accordingly: Section 2 offers a literature review on SOI related to affordable housing projects and internal and external influences on adoption of SOIs, Section 3 puts forward the research hypothesis and the development of the causal model, Section 4 presents the methods used for data collection and analysis; Sections 5 and 6 offer the findings and the discussion; and the conclusion is provided in Section 7.

2. Literature review

2.1 Sustainability-oriented innovations in affordable housing

Knowledge concerning the importance of sustainability and innovation in housing development is globally gaining traction, albeit slowly, within the affordable housing sub-sector, hampered mainly by client ignorance and lack of associated regulations (Moghayedi et al., 2021). For many developers, using conventional methods and materials to minimise housing construction cost, regardless of their associated negative financial effects on operation/maintenance of such houses, remains the norm. Also, the lack of incentives for developers to take the operating cost of the dwelling into consideration has resulted in a tendency for them to ignore critical facets such as sustainability and innovation when developing affordable houses (Patel and Padhya, 2021).

Innovation is considered an important criterion in affordable housing development. Innovation is about changing paradigms, creating new ideas; it is a process which inspires change and creates value, or more practically defined as the implementation of a new or significantly changed product or process (Adams *et al.*, 2016). Within the affordable housing context, scholars admit to the potential of innovation to enhance the sustainability performance of the houses (Moghayedi *et al.*, 2021). There are many types of innovations, each finding some application in the affordable housing sector. For instance, technological innovation is has been described as capacitating construction firms with new technologies that can appropriately transform and complement current technologies to achieve and sustain better levels of performance (Osunsanmi et al., 2020).

To significantly reduce the negative environmental impacts whilst improving the social and economic sustainability performance of buildings, innovations pertaining to construction methods, materials and technologies for housing delivery have become imperative (Kornilov *et al*., 2020). Hence, there is a need to determine and deploy these innovative practices, materials, and technologies during the design and development of affordable housing projects.

Likewise, it is necessary to identify the factors influencing the adoption of innovation in such housing projects, particularly at company and project levels.

SOIs like passive design, renewable energy, prefabrication, water harvesting and recycling, building information modelling (BIM), green recycled materials and many more are commonplace in the construction industry. Globally, scholars are continuously exploring SOIs to provide solutions to issues associated with housing delivery. For instance, Panda et al., (2018) explored the contributions of 3D printing-enabled architecture and interior designs towards achieving sustainable residential houses.

Similarly, Modular Construction System (MCS) is gaining popularity in developed countries but remain nascent in developing countries. Eng and Zainal (2021) explored MCS awareness levels among home developers and the challenges faced in the adoption of robotics within such systems. Sertyesilisi *et al.,* (2021) posit that sustainability performance of houses can be enhanced using BIM where the integration of energy simulation software allows improved energy efficiency as well as reduced lifecycle costs across various phases of the building lifecycle (Sertyesilisi et al., 2021).

From the foregoing, the role of SOIs in enabling SIAH can be discerned. Unfortunately, rising levels of dissatisfaction of occupants within the affordable housing space, point to the contributions of innovative practices, materials, and technologies to improve sustainability performance of construction projects, as being poorly understood by relevant stakeholders. The limited use of SOIs within the affordable housing context has been attributed to the challenge negating the adoption of these innovative practices, methods and technologies (Jamaludin et al., 2018). Afanasyeva *et al.*, (2020) analysed the problems of socio-economic accessibility of innovative housing from the perspective of sustainable construction, using the lens of legislative norms and strategy implementation. The research showed that the lack of tools, legislation, and policies for efficient management of sustainable construction practices seeking to improve housing affordability, posed a salient challenge (Afanasyeva et al., 2020). Therefore, the idea of sustainable innovative housing can and should become a national idea, playing an important role in determining state priorities and prospects for further housing reform (Afanasyeva et al., 2020).

In developing countries like South Africa, there is no widely accepted definition of the sustainable affordable housing concept (Moghayedi et al., 2021). This lack of a widely accepted definition for SIAH is reflective of the assertions made by Afanasyeva et al., (2020) concerning the absence of governance and legislative frameworks and policies for adoption of innovation towards improving sustainability performance and affordability of such houses. The advocacy for SIAH remains largely business-driven by some large developers in the developing country context although the market remains lucrative for developers who are not keen on its implementation (Patel and Padhya, 2021).

2.2 Internal influences on adopting sustainability-oriented innovation in affordable housing

Internal innovation enablers refer to the competency, commitment and actions within an organisation which motivates for innovation adoption as an essential commitment to pursue sustainable projects (Martins and Saavedra Farias, 2019). These enablers can be split into (i) commitment and interest, (ii) management and policies, and (iii) capability and resources. The characteristics of construction organisations either impede or expedite the adoption of SOIs on construction projects, where Khurana *et al.,* (2019) and Banihashemi *et al.*, (2017) conclude that the awareness and familiarity of construction companies with sustainability and innovation concepts remained critical factors affecting the level of success in the adoption of appropriate SOIs in construction projects. Banihashemi *et al.*, (2017) argued for advancing sustainability and innovation whilst overcoming adoption-related challenges on construction projects through increased focus on the climate and structure of a construction company and project team, both of which were identified as impacting factors.

A well-established firm, with an open, receptive, and conducive organisational climate that highlights and supports efforts to explore and try new ideas as a core value and strategy, elicit greater efficiency and productivity from workers, thus benefitting from SOIs adoption (Rahdari et al., 2016). Drucker (2014) identified organizational climate and structure attributes such as establishment and size of company, experience of company with specific type of project, familiarity and awareness of company leadership and technical staff with sustainability and innovation as influencing the level of SOI adoption on projects. For example, large companies can adopt more sustainable and innovative practices because of their strong capital-base, wide-range of experience, full commitment from executive management, and expertise. Small companies tend to keep costs to the minimum and adopting innovation practices would invariably affect their profit margin (Zakaria *et al.*, 2018).

At the project-level, Ozorhon and Oral, (2017), Zakaria *et al.*, (2018) and Stanitsas *et al.*, (2021) identified project attributes such as size of project, type of project, procurement method and type of client as posing a strong influence on the extent of SOI adoption on construction projects. Within the housing sector, different types of housing would require different types of SOIs due to differences in building typology, budget and cost, complexity and target client (Olanrewaju et al., 2018). Companies are also becoming increasingly concerned with establishing closer connections with customers through ensuring improved end user satisfaction. Banihashemi *et al.*, (2017) opined that project owners/clients serve a pivotal role in the SOIs capacity of a construction project.

Based on the foregoing, it is evident that company characteristics and project attributes influence the adoption of SOIs within the affordable housing context. Hence, the following hypotheses:

H1: There is a positive correlation between the company characteristics and the extent of use of SOI in affordable housing.

H2: There is a positive correlation between the project characteristics and the extent of use SOI in affordable housing.

2.3 External challenges on adoption of sustainability-oriented innovation in affordable housing

There are several challenges, occurring at project, company and industry-wide levels, that negate the adoption of SOI on affordable housing projects in developing countries (Adabre et al., 2021). It is administrative and policy barriers, such as the absence of policy and regulation, and the lack of incentives at all stages of design and construction lifecycle, that negatively affect the adoption of SOI in housing projects (Kornilov et al., 2020). The lack of incentives impedes effective collaboration between institutional enablers, stifling their readiness and commitment to adopt new ideas (Martins and Saavedra Farias, 2019). According to Olanrewaju *et al.,* (2018), most developers in developing countries abide by the standard and minimum regulatory requirements with only a few showing any interest and capability to go beyond that due to the lack of incentives.

The adoption of SOIs in the housing sector is further constrained by the high cost of deployment, difficulty in obtaining local innovative materials and technologies, and lack of local technical skills to harness such innovations (Patel and Padhya, 2021). Most construction companies and home developers are comfortable with their business marketability and hence, reluctant to commit to something more sustainable and innovative since doing so requires higher capital investment upfront (Li and Liu, 2019). The deployment of SOIs like alternative production methods, new materials and technologies requires the development of new forms of competencies and knowledge. As such, the lack of technical knowledge and understanding constitute barriers to the successful deliver of sustainable and affordable housing (Adabre and Chan, 2020). Since most affordable housing projects in developing countries are constructed by small-to-medium sized enterprises (SMEs) with low internal knowledge and expertise about SOIs, housing developers tend to appoint external experts to assist thereby adding to overhead costs of projects and significantly impacting on the profitability of a development (Pablo and London, 2020). Innovation transfer endeavours within affordable housing projects are being severely hampered by a lack of proper understanding of innovation transfer issues and their interrelationships with company capabilities and processes, and the knowledge characteristics of the technologies being transferred (Khan *et al.*, 2019).

Moghayedi et al., (2022) stated that due to the paucity in development, manufacturing, and supply of local innovative construction materials in developing countries, most are imported at high cost compared to the conventional materials, thereby making it a challenge to be deployed in the affordable housing projects. Imported innovative products are often incompatible with local climatic conditions, necessitating some degree of customisation which may farther increase project costs.

From the foregoing, the challenges impeding the adoption of SOI in affordable housing projects can be discerned. This study will seek to examine the negatively mediating effect of these challenges on the correlation between the company and project characteristics and, the extent of use of SOIs (methods, materials, and technologies) in affordable housing. To achieve this, the following hypotheses have been articulated:

H3: There is a negative correlation between the challenges and the extent of use of SOI in affordable housing projects.

H4: Challenges are negatively mediating the correlation between the project characteristics and extend of use of SOI in affordable housing projects.

H5: Challenges are negatively mediating the correlation between the company characteristics and extend of use of SOI in affordable housing projects.

3. Modelling causality

Taking the literature review and formulated research hypotheses into consideration, a theoretical framework was developed detailing the causality between the company characteristics, project influential factors, challenges to adoption of SOI and extent of use of SOI (methods, materials, and technologies) in affordable housing projects, as shown in Figure 1.

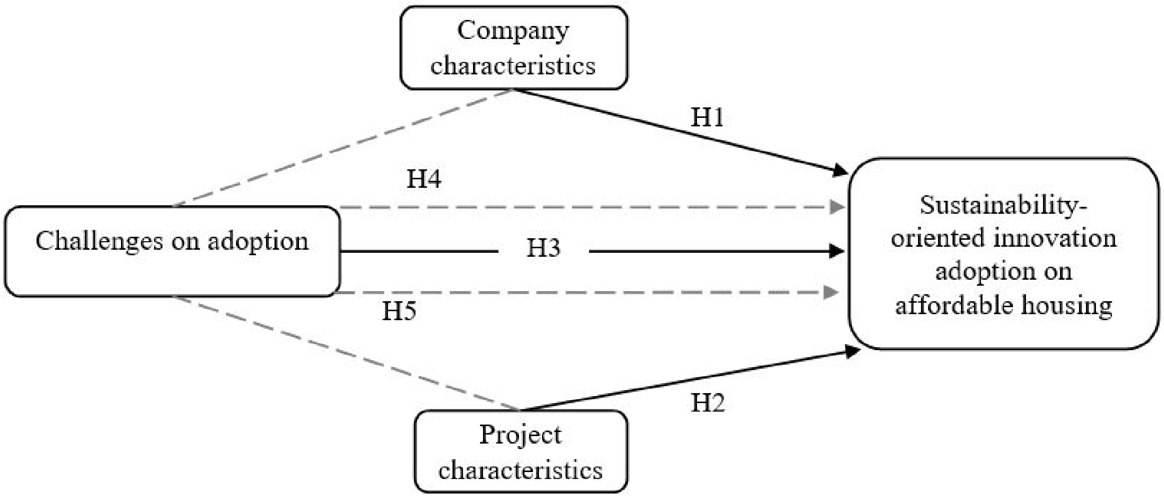

Figure 1: Causal model of SOI on SIAH

The five hypotheses formulate the company and project characteristics as internal variables, directly influence the extent of adoption of SOI in delivery of affordable housing projects (H1 & H2). The challenges have direct effect on the extent of use of SOI in affordable housing projects (H3). Moreover, the challenges mediate the effect of company and project characteristics on the extent of use of SOIs (H4 & H5).

The company-related influential factors were theorised as consisting of company size, experience with housing projects, familiarity with SOI in housing projects and, establishment of the company. The project-related influential factors include project size, owner of the project, project procurement, type of housing projects. Based on the reviewed literature, the challenges to the adoption of SOI in affordable housing projects were established as; high cost (initial/ maintenance/ operation), lack of guidelines and standards, incompatibility with other methods/ materials/ technology, tendency to use conventional methods/ materials/ technologies, lack of incentives, lack of technical knowledge and skill, lack of awareness, lack of policy and regulation, low social acceptance, low availability in local market. Moreover, the extent of use of SOI in affordable housing projects is evaluated through the usance of sustainable new methods in design, sustainable alternative methods in construction, new building materials and innovative technologies.

4. Research methods

A quantitative research design was adopted as the most appropriate approach to objectively model and verify the extant relationships among the variables. Quantitative models allow for deductive testing, thus offering protection against contradiction of bias and the generalisation and replication of findings. (Creswell and Creswell, 2017). Accordingly, an online questionnaire survey was undertaken to establish the impact of the company and project characteristics as internal factors and challenges, as external factors, influencing the extent of use of SOIs by housing developers on affordable housing projects in South Africa. The study's constructs, the variables used in measuring the study constructs and its corresponding measurement scale are shown in Table 1.

Table 1: Variables used in measuring the study constructs

Constructs	Sub Constructs	Variables	Source	Measurement Scale
Characteristics (CH)	Company (C)	Size of company (CHC1)	2, 3, 5, 6, 7, 8, 10	Respondents were asked to indicate the characteristics of their company and the latest completed affordable housing project by answering the semi-structured questions.
		Experience in affordable housing projects (CHC2)	2, 3, 4, 5, 6, 7, 8, 10, 11	
		Establishment of the company (CHC3)	2, 3, 5, 6, 7, 8, 10	
		Familiarity and awareness with innovative methods, technologies, and materials (CHC4)	2, 3, 4, 5, 6, 7, 8, 10, 11	
	Project (P)	Size of project (CHP1)	3, 5, 7, 8, 9, 10	
		Type of housing (CHP2)	5, 6, 7, 8, 10	
		Client of project (CHP3)	2, 3, 5, 6, 7, 8, 9, 10	
		Procurement (CHP4)	3, 5, 7, 9, 10	
Challenges on adoption (CH)		High cost (initial/ maintenance/ operation) (CH1)	8, 11, 13, 14, 16, 17	Developers were asked to indicate the degree of impact of the challenges on the use of innovative methods, technologies, and materials in their latest completed affordable housing projects on a four-point Likert scale:
		Lack of technical guidelines and standards (CH2)	8, 11, 13, 14, 16, 17	
		Incompatibility with other methods/materials/technology (CH3)	8, 11, 13, 14, 16, 17	
		Tendency to use conventional methods/materials/technologies (CH4)	8, 11, 13, 14, 17	
		Lack of public incentives (CH5)	8, 11, 13, 14, 16, 17	
		Lack of technical knowledge and skill (CH6)	8, 11, 13, 14, 16, 17	
		Lack of awareness of the availability (CH7)	8, 11, 13, 14, 16	
		Lack of policy and regulation (CH8)	8, 11, 13, 14, 16, 17	
		Low social acceptance (CH9)	8, 11, 13, 14, 16	
		Low availability in local market (CH10)	8, 11, 13, 14, 16	

The extent of use (EU)	Sustainable methods in design (D)	Passive design (EUD1)	1, 11, 12, 15, 16	Developers were asked to indicate the level of extent of innovative methods, technologies, and materials in their latest completed affordable housing projects on a four-point Likert scale: Not at all, Low, Average and High
		Inclusive design (EUD2)	1,11, 12, 15, 16	
		Cultural and heritage conservation design (EUD3)	1,11, 12, 15	
		Disaster resistance (EUD4)	1, 11, 12, 15, 16	
		Green building (EUD5)	1, 11, 12, 15, 16	
		Natural lighting (EUD6)	1, 11, 12, 16	
		Natural ventilation (EUD7)	1, 11, 12, 16	
		Passive thermal (EUD8)	1, 11, 12	
		Life-cycle cost (EUD9)	1, 11, 12, 16	
		Life-cycle energy (EUD10)	1, 11, 12, 16	
		Life-cycle carbon footprint (EUD11)	1, 11, 12	
		Water conservation (EUD12)	1, 11, 12, 15, 16	
		Renewable energy (EUD13)	1, 11, 12, 15, 16	
		Lean design (EUD14)	1, 11, 12, 15, 16	
	Sustainable methods in construction (C)	Water efficient methods (EUC1)	1, 11, 12, 15, 16	
		Energy efficient methods (EUC2)	1, 11, 12, 15, 16	
		Deconstruction/disassembly methods (EUC3)	1, 11, 12	
		Prefabrication (EUC4)	1, 11, 12, 16	
		Modular (EUC5)	1, 11, 12	
		Construction waste management (EUC6)	1, 11, 12, 15, 16	
		Lean construction (EUC7)	1, 11, 12, 15, 16	
		Safe methods (EUC8)	1, 11, 12	
		Less labour intensive (EUC9)	1, 11, 12, 16	
	New building materials (M)	Natural materials (EUM1)	1, 11, 15, 16	
		Local materials (EUM2)	1, 11, 15, 16	
		Recycled materials (EUM3)	1, 11, 15, 16	
		Green materials (EUM4)	1, 11, 15, 16	
		Light materials (EUM5)	1, 11, 16	
		Nano materials (EUM6)	1, 11	
	Innovative technologies (T)	Computer-Aided Design (CAD) (EUT1)	1, 16, 18, 20	
		Object-oriented Computer-aided design (EUT2)	1, 16, 18, 19, 20	
		Engineering design software (EUT3)	1, 16,	

		Artificial Intelligence in design (EUT4)	1, 16, 18, 19	
		Building Information modelling (EUT5)	1, 16, 18, 19, 20	
		Virtual Reality (EUT6)	1, 16, 18	
		Augmented Reality (EUT7)	1, 16, 18	
		Mixed Reality (EUT8)	1, 16, 18	
		Project portfolio management software (EUT9)	1, 16	
		Laser scanner (EUT10)	1, 16, 18, 20	
		Geographic Information System (EUT11)	1, 16, 20	
		Drone (EUT12)	1, 16, 19	
		Sensor (EUT13)	1, 16, 19	
		Wearable device (EUT14)	1, 16, 19	
		Tracking system (EUT15)	1, 16, 19, 20	
		Special equipment or machine (EUT16)	1, 16, 19	
		3D Printer (EUT17)	1, 16, 18	

1: (Moghayedi *et al.*, 2021), 2:(Banihashemi *et al.*, 2017), 3: (Khurana *et al.*, 2019), 4: (Rahdari *et al.*, 2016), 5: (Drucker, 2014), 6:(Ozorhon and Oral, 2017), 7:(Stanitsas *et al.*, 2021), 8: (Olanrewaju et al., 2018), 9: (Naoum and Egbu, 2016), 10: (Zakaria *et al.*, 2018), 11: (Darko *et al.*, 2018), 12: (Adabre and Chan, 2019a), 13: (Adabre and Chan, 2021), 14: (Adabre *et al.*, 2021), 15: (Adabre and Chan, 2019b), 16: (Kornilov *et al.*, 2020), 17: (Patel and Padhya, 2021), 18: (Sidani *et al.*, 2021), 19: (Li and Liu, 2019), 20:(Song *et al.*, 2017)

The study population consisted of 16,000 housing companies registered with the South African National Home Builders Registration Council (NHBRC). A total of 517 valid responses was collected across South Africa, representing a sufficient sample size (376) at a confidence level of 95% and confidence interval of 5.

The questionnaire comprised of three sections directed at the study objectives. The items in first section were focused on eliciting general background information of the home developer companies. The second section of the questionnaire comprised of four sub-sections and used the Likert scale to obtain information on the extent of use of SOIs in designing and developing of latest affordable housing project completed by participants. The third section of the questionnaire was collected the level of impact of challenges on adoption of sustainable methods, new materials and innovative technologies in design and construction of their recent affordable housing project using Likert Scale.

The data collected was analysed using descriptive and inferential statistical techniques to determine the frequency and Relative Important Index (RII) of the study variables. Path analysis and confirmatory factors analysis were conducted to quantify the relationships among multiple variables and estimate latent constructs, respectively. Structural equation modelling

(SEM) was used to test the five hypotheses of the study. SEM, as a multivariate technique that coheres networks of constructs to data with the capability to test and evaluate both direct and indirect effects of multivariate causal relationships, was used to validate the causal relationship between the constructs, using the maximum likelihood estimate and estimated latent variables based on the correlated variations of the dataset.

Five analytical steps were utilised in SEM: model specification, identification, parameter estimation, evaluation, and modification. Model specification defines the hypothesized relationships among the variables. Model identification checks overall model fitness based on the fit indices for the test of a single path coefficient. Model evaluation assesses model performance, with quantitative indices calculated for the overall appropriacy of fit. Modification adjusts the model to improve model fitness. Finally, validation is the process of improving the reliability and stability of the model.

5. Results

5.1 Company characteristics

Table 2 presents the company characteristics analysis of the 517 home developers participated in the study. Table 2 indicates that majority of the developers (33.7%) established more than 5 years and 27.9% of companies established within 5 years. The results show 50% of companies have low experience with affordable housing projects (1 completed project). The findings on the size of companies show that most of the companies are small (38.5%) and micro (30.8%) size in regarding of employees/workers. About 65% of the housing developers are moderately or highly familiar with sustainable methods, new materials, and innovative technologies, while 10.6% of companies are unfamiliar with sustainability and innovation in design and construction. This suggests that the majority of the home developers belong to micro and small size categories with low experience in design and construction of affordable housing.

Table 2: Company characteristics of housing developers

Establishment	Frequency
Less than 5 years	27.9%
6 to 10 years	33.7%
11 to 20 Years	26.0%
More than 20 years	12.5%
Experience with affordable housing projects	
No experience (1st project)	3.8%
Low	50.0%
Moderate	28.8%
High	17.3%
Size of company by employees/workers	
Micro	30.8%
Small	38.5%
Medium	18.3%
Large	12.5%
Familiarity with innovative methods, technologies, and materials	
Not at all	10.6%
Low	24.0%
Moderate	40.4%
High	25.0%

5.2 Project characteristics

A summary of the affordable housing project characteristics is shown in Table 3. Most of the housing projects sizes range from small (33.7%) to medium (26.9%). Results indicate that 65.4% of projects are owned by private clients whilst 34.6% of projects had government as client, clearly illustrating the strong role of private developers and investors in middle-income affordable housing projects in South Africa.

Table 3: Project characteristics

Size of project	%
Very small (less than 5 units)	25.0%
Small (5-10 units)	33.7%
Medium (11-20 units)	26.9%
Large (more than 20units)	14.4%
Client of project	
Private	65.4%
Local government	20.2%
National government	14.4%
Type of housing	
Detached	26.9%
Semi-detached	32.7%
Apartment	14.4%
Mixed	26.0%
Procurement	
Design–Bid–Build	41.3%
Design & Build	26.9%
Management contracting	24.0%
Others	7.7%

Semi-detached and detached housing types were most prevalent among affordable housing projects being delivered in South Africa. The results on the project procurement reveal the Design–Bid–Build (conventional procurement) is the predominant type of procurement used in developing affordable housing projects in South Africa.

5.3 Extent of use of sustainability-oriented innovations (methods, materials, and technologies)

The Relative Importance Index (RII) was used to quantify the extent of SOIs (sustainable methods, building materials and innovative technologies) adoption in affordable housing projects, as illustrated in Figures 2 to 5.

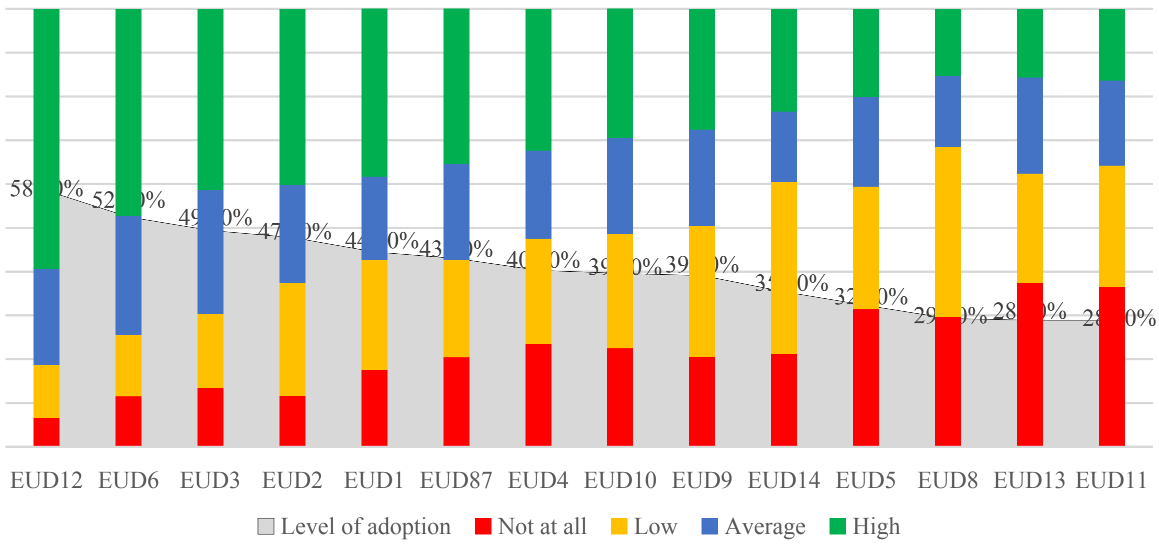

Figure 2: Extent of use of sustainable methods in design of affordable housing projects

As shown in Figure 2, water conservation (EUD12), natural lighting (EUD6), cultural and heritage conservation design (EUD3), inclusive design (EUD2) and passive design (EUD1) are the most common five sustainable methods used in design of affordable housing. On the other hand, life-cycle carbon footprint (EUD11), renewable energy (EUD13) and passive thermal (EUD8) are the least sustainable methods considered by South African designers during the design of affordable housing. This proved that most developers ignored sustainable design methods which impact on the operation of houses to minimise the development cost of units. Therefore, innovative methods which require initial investment are not considered by most South African designers.

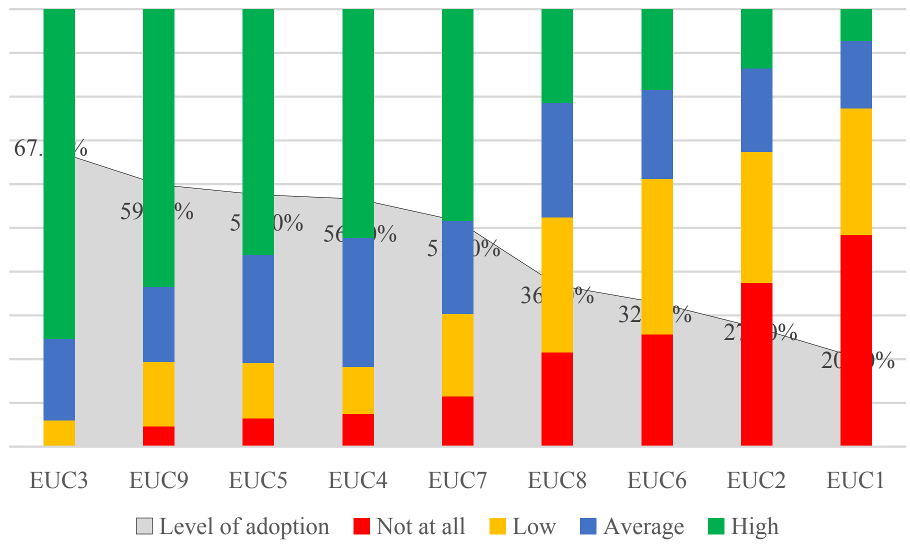

Figure 3: Extent of use of sustainable methods in construction of affordable housing projects

The results concerning sustainable methods used in construction projects reveal the water efficient methods (EUC3), energy efficient methods (EUC9) and construction waste management (EUC5) were the most common construction methods adopted by home developers during construction of the affordable housing projects as shown in Figure 3. Moreover, deconstruction/disassembly methods (EUC1), and less labour-intensive methods (EUC2) were not adopted by most developers.

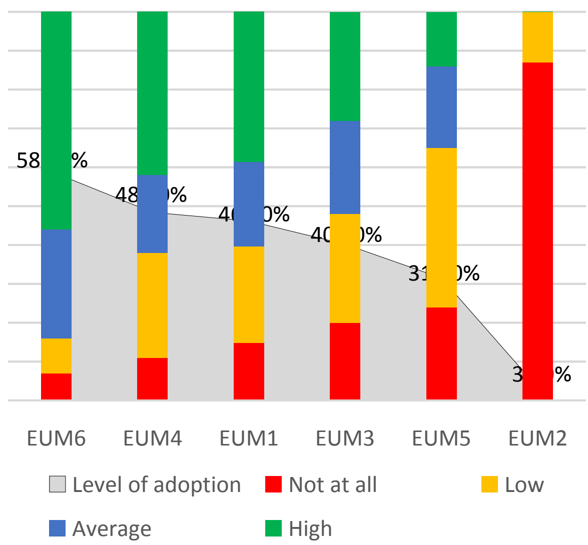

Figure 4: Extent of use of new building materials in construction of affordable housing projects

The analysis of the extent of use of new materials highlights that local materials (EUM6), light materials (EUM4) and recycled materials (EUM1) were used more in the construction of affordable housing, which can be linked to availability of materials in local market and lower transportation cost. Also, nano materials (EUM2) were the least used materials in affordable housing projects, due to high cost and lack of availability within South Africa.

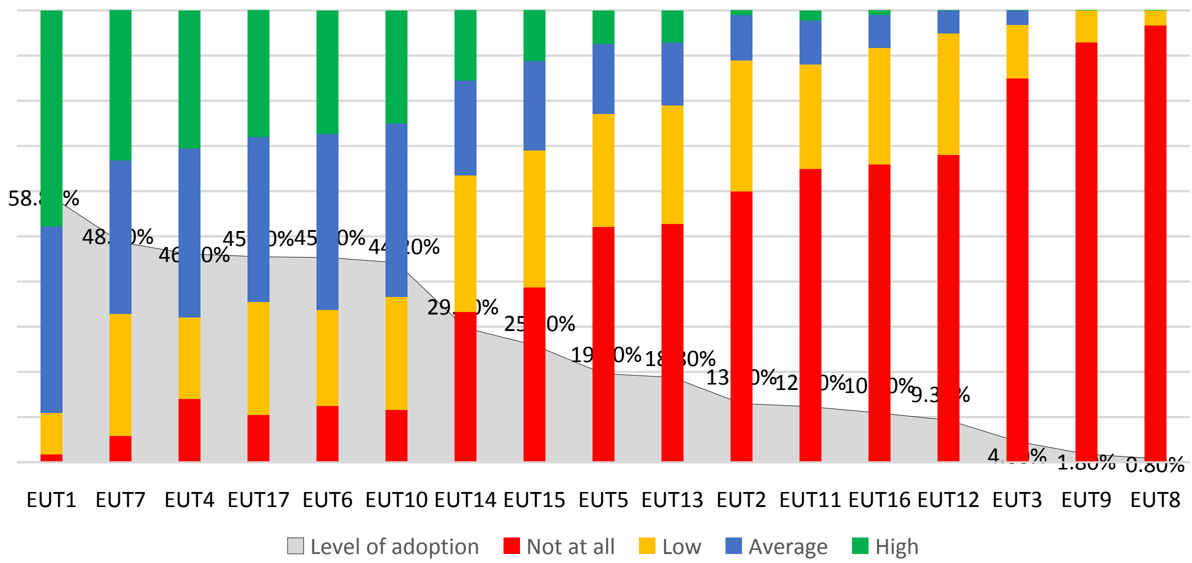

Figure 5: Extent of use of technologies in design and construction of affordable housing projects

As shown in Figure 5, Computer Aided Design (EUT1), Project portfolio management software (EUT7), engineering design software (EUT4) were the most common technologies used in the design or construction of South African affordable housing projects. Still, the level of adoption of innovative technologies in design and construction of affordable housing projects in South Africa are relatively low. For instance, only less than 10% of South African home developers admitted to using mixed reality and augmented reality in design or construction of affordable housing. Despite these findings, most respondents indicated that drones have been used on majority (70%) of the sampled size housing projects.

5.4 Challenges negating adoption of sustainability-oriented innovation

The respondents were asked to rate the level of difficulty caused by 10 most critical challenges to adopt sustainable design and construction methods, new materials and innovative technologies in design and construction of their latest affordable housing project. These 10 critical challenges were identified from literature and validated by the NHBRC experts panel and small groups of developers through pre-testing of the questionnaire. RII is used to compare the level of difficulty of challenges made for adopting each sustainable methods, new materials, and innovative technologies.

Table 4: Challenges negating adoption of SOI in affordable housing projects

Sustainable methods in design		Sustainable methods in construction		New building materials		Innovative technologies	
Challenge	RII	Challenge	RII	Challenge	RII	Challenge	RII
CH1	63.09%	CH1	56.50%	CH1	55.87%	CH1	55.61%
CH5	52.46%	CH4	44.40%	CH5	49.87%	CH6	53.71%
CH2	50.32%	CH2	43.90%	CH4	48.92%	CH4	44.82%
CH6	45.61%	CH8	41.60%	CH8	47.63%	CH2	42.94%
CH8	44.71%	CH5	40.70%	CH10	45.73%	CH7	39.89%
CH4	43.29%	CH10	37.90%	CH6	44.68%	CH5	37.16%
CH7	33.09%	CH3	33.30%	CH2	43.67%	CH8	36.88%
CH3	31.81%	CH6	32.30%	CH7	40.38%	CH3	35.52%
CH10	24.09%	CH7	31.20%	CH9	38.42%	CH9	29.39%
CH9	9.00%	CH9	30.40%	CH3	37.07%	CH10	29.21%

The results of RII concerning adoption challenges impeding the use of sustainable methods in design of affordable housing reveals that high cost (CH1), lack of incentives (CH5), lack of technical guidance and standards (CH2) and lack of technical knowledge and skill (CH6) are the most predominant barriers to adoption of sustainable methods in designing affordable housing over all 14 sustainable design methods (EUDs) studied as listed in Table 4.

The results show high cost (CH1), tendency to use conventional methods (CH4), lack of technical guidelines and standards (CH2) and lack of policy and regulation (CH8) as the main barriers preventing the adoption of sustainable methods during the construction of affordable housing. Like challenges on adoption of sustainable methods in design and construction, high cost (CH1) of new materials, lack of public incentives (CH5), tendency to use conventional materials (CH4) and lack of policy and regulation (CH8) in using new materials are the key challenges on using new materials in South African affordable housing projects. Furthermore, high cost (CH1), lack of technical knowledge and skill (CH6), reluctance to use innovative technologies (CH4) and lack of technical guidelines and standards (CH2) are the most predominant challenges on adopting innovative technologies in design and construction of affordable housing in South Africa.

5.5 Causal Model

To validate the developed SIAH causal model and association between the constructs, all identified variables (see Table 2) were included to the initial mode in SmartPLS, and the hypothesised model was tested using collected data.

5.5.1 Analysis of the measurement model

The measured variables were assessed for consistency, reliability and validity using confirmatory factor analysis. The results of the internal consistency, composite reliability, convergent validity tests and discriminant validity are summarised in Table 5.

Table 5: Consistency, reliability and validity of the constructs and variables

Construct	**variables**	**NO of variables**	Characteristics		Challenges	Extend of use			
			CHC	CHP	CH	EUD	EUC	EUM	EUT
Characteristics	CHC	4	**0.892**						
	CHP	4	0.828	**0.855**					
Challenges (CH)		10	-0.855	-0.837	**0.853**				
Extend of use	EUD	14	0.886	0.827	-0.827	**0.852**			
	EUC	9	0.855	0.822	-0.836	0.851	**0.841**		
	EUM	6	0.880	0.835	-0.816	0.844	0.840	**0.868**	
	EUT	17	0.829	0.816	-0.828	0.839	0.838	0.837	**0.848**
Internal consistency	**Cronbach's Alpha**		0.814	0.877	0.873	0.873	0.848	0.835	0.875
	rho_A		0.818	0.886	0.874	0.873	0.849	0.835	0.876
Composite Reliability			0.839	0.889	0.876	0.875	0.856	0.849	0.877
Convergent validity (AVE)			0.795	0.731	0.728	0.726	0.708	0.754	0.719

The results of Cronbach's Alpha are between 0.7 and 0.95, which indicate a reliable internal consistency between the variables under the same constructs and that the variables are not highly inter-correlated. Furthermore, the coefficient rho-A test results between Cronbach's Alpha and Composite Reliability also prove the acceptable internal consistency between the variables of the study's sub-constructs. The composite reliability test results and Average Variance Extracted (AVE) tests are above 0.7 and 0.5 respectively, which prove the reliability and convergent validity between variables of sub-constructs and indicating that the reliability of the developed model is acceptable. Furthermore, the square root of the AVE value of each measured variable is greater than the correlation coefficient between the variables as shown in Table 6, which indicates that measures of variables that theoretically should not be highly related to each other are, indeed, not found to be highly correlated to each other.

Following the reliability and validity checks, the fitness-for-purpose of the casual model of SIAH was evaluated. As shown in Figure 6, the R-squared values for the constructs are above 0.7 which indicate the strength relationship between developed model and the dependent variable, moreover the results from the analysis of the model show that all fit indices of model are above the recommended values ($x^2 = 163.351$; $x^2/DF = 1.677$; $p = 0.000$, CFI = 0.934; GFI = 0.917; RMSEA = 0.031).

Finally, the path analysis for the causal model of SIAH was developed. As illustrated in Figure 6, all loading factors of variables are greater than 0.8, indicating highly satisfactory relationships of variables in the reflective measurement of constructs and the model. Since all the variables are above the acceptable level, they were used to discuss the importance of each variable for the defined constructs in the model. This was to identify which variables should be focused on to yield higher extent of use of sustainable methods, new materials, and innovative technologies in affordable housing projects. Overall, the results of these tests prove that the collected data have high satisfactory validity, reliability, and internal consistency.

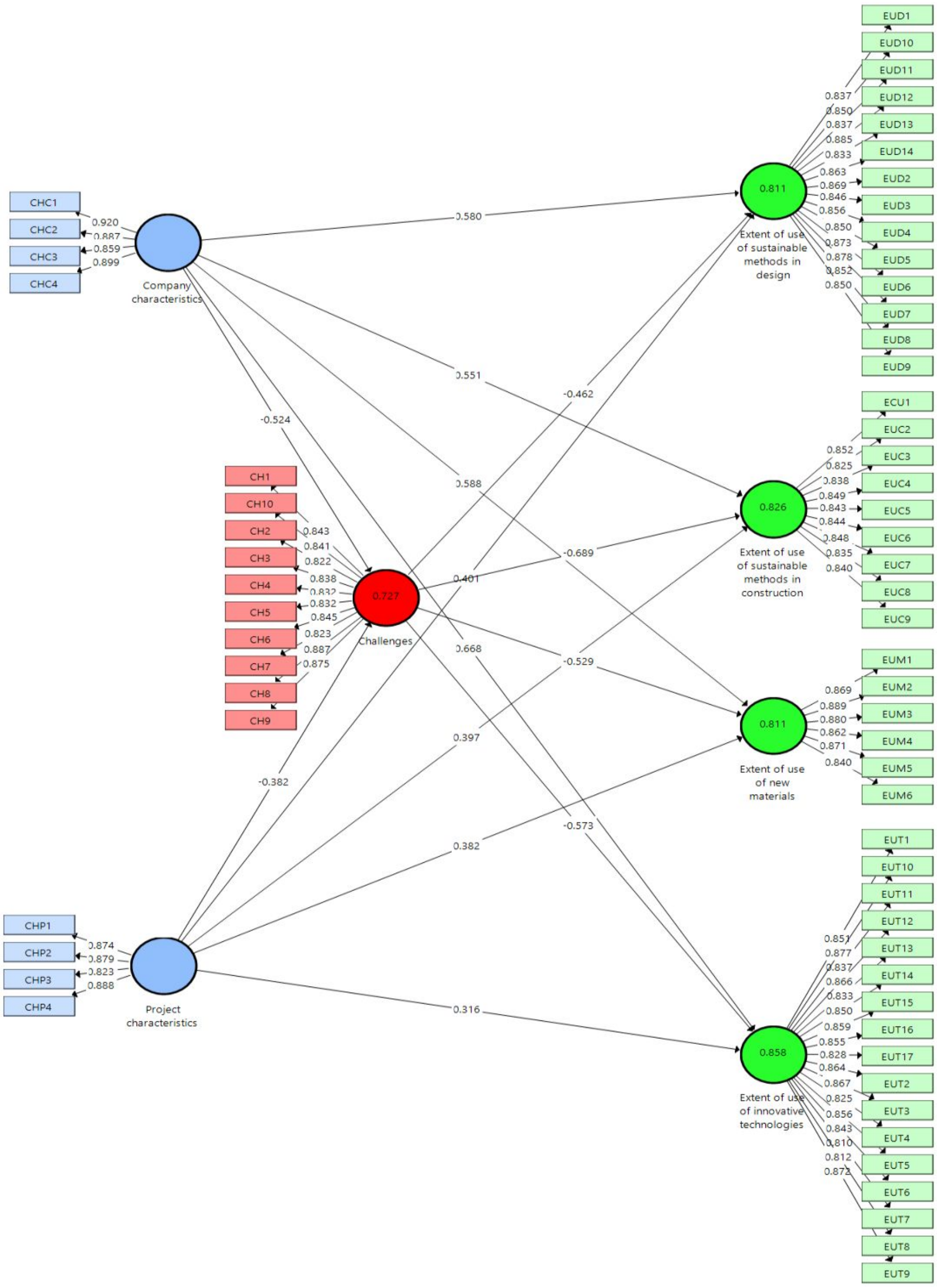

Figure 6: Initial SIAH causal model (path analysis)

5.5.2 Analysis of the structural model

After the analysis of the measurement model, the research hypotheses were tested using T-Statistics. The resultant P-Values of all hypotheses (paths) test are less than 0.05, which indicate, all research hypotheses and their sub-hypotheses are statistically significant, as presented in Table 6.

Table 6: Hypotheses testing results

Hypothesis	T Statistics	P Values	Decision
Hypothesis 1: Company characteristics (CHC)-> Extent of use (EU)			
SH1.1: Company characteristics (CHC)-> Extent of use of sustainable methods in design (EUD)	6.167	0.000	Significant
SH1.2: Company characteristics (CHC)-> Extent of use of sustainable methods in construction (EUC)	3.692	0.000	Significant
SH1.3: Company characteristics (CHC)-> Extent of use of new materials (EUM)	5.119	0.000	Significant
SH1.4: Company characteristics (CHC)-> Extent of use of innovative technologies (EUT)	8.248	0.000	Significant
Hypothesis 2: Project characteristics (CHP)-> Extent of use (EU)			
SH2.1: Project characteristics (CHP)-> Extent of use of sustainable methods in design (EUD)	4.449	0.000	Significant
SH2.2: Project characteristics (CHP)-> Extent of use of sustainable methods in construction (EUC)	2.752	0.006	Significant
SH2.3: Project characteristics (CHP)-> Extent of use of new materials (EUM)	3.247	0.001	Significant
SH2.4: Project characteristics (CHP)-> Extent of use of innovative technologies (EUT)	3.576	0.000	Significant
Hypothesis 3: Challenges (CH)-> Extent of use (EU)			
SH3.1: Challenges (CH)-> Extent of use of sustainable methods in design (EUD)	9.773	0.000	Significant
SH3.2: Challenges (CH)-> Extent of use of sustainable methods in construction (EUC)	14.647	0.000	Significant
SH3.3: Challenges (CH)-> Extent of use of new materials (EUM)	9.353	0.000	Significant
SH3.4: Challenges (CH)-> Extent of use of innovative technologies (EUT)	12.004	0.000	Significant
Hypothesis 4: Company characteristics (CHC)-> Challenges (CH)-> Extent of use (EU)			
SH4.1: Company characteristics (CHC)-> Challenges (CH)-> Extent of use of sustainable methods in design (EUD)	5.387	0.000	Significant
SH4.2: Company characteristics (CHC)-> Challenges (CH)-> Extent of use of sustainable methods in construction (EUC)	5.869	0.000	Significant
SH4.3: Company characteristics (CHC)-> Challenges (CH)-> Extent of use of new materials (EUM)	5.365	0.000	Significant
SH4.4: Company characteristics (CHC)-> Challenges (CH)-> Extent of use of innovative technologies (EUT)	5.842	0.000	Significant
Hypothesis 5: Project characteristics (CHP)-> Challenges (CH)-> Extent of use (EU)			
SH5.1: Project characteristics (CHP)-> Challenges (CH)-> Extent of use of sustainable methods in design (EUD)	4.495	0.000	Significant
SH5.2: Project characteristics (CHP)-> Challenges (CH)-> Extent of use of sustainable methods in construction (EUC)	4.738	0.000	Significant
SH5.3: Project characteristics (CHP)-> Challenges (CH)-> Extent of use of new materials (EUM)	4.294	0.000	Significant
SH5.4: Project characteristics (CHP)-> Challenges (CH)-> Extent of use of innovative technologies (EUT)	4.508	0.000	Significant

Based on the results from the testing of the hypotheses as provided in Table 6, the study deduced that the company and project characteristics have a significant positive effect on the extent of use of sustainable methods in design, sustainable construction methods, new materials, and innovative technologies in affordable housing projects. On the other hand, the challenges have significant negative effects on the extent of use of sustainable methods in design, sustainable construction methods, new materials, and innovative technologies.

Moreover, the results of indirect effect testing of the research hypotheses proved that the challenges negatively mediating the effects of project and company characteristics on extent of use of methods, materials, and technologies. Therefore, the total effects of project and company characteristics were significantly reduced as illustrated in the final SIAH causal model in Figure 7. The results of the research hypotheses tests validated the developed SIAH causal model.

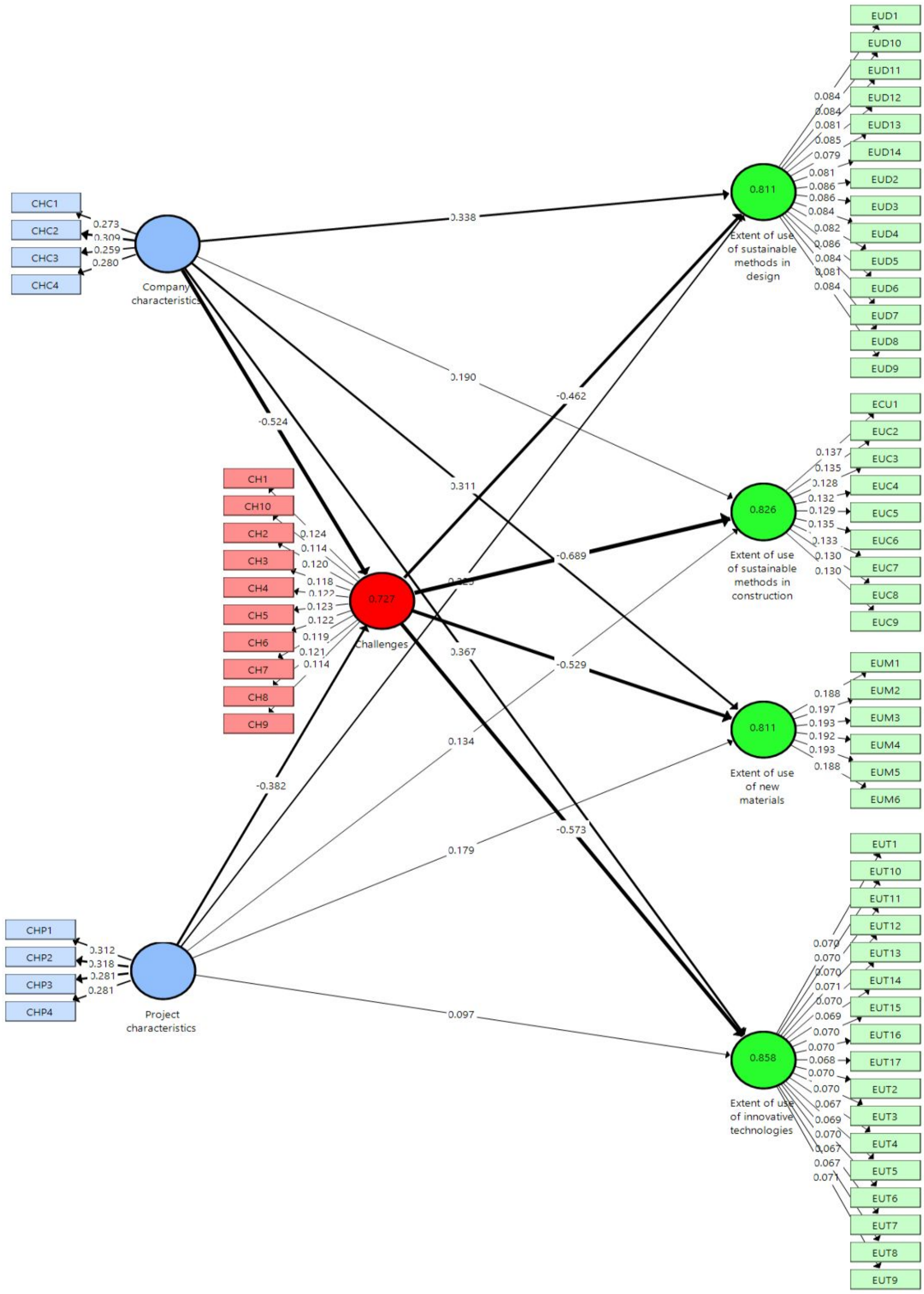

Figure 7: Final SIAH causal model (relative contribution of variables on the constructs alongside total effect coefficients).

The Figure 7 shows the total effect coefficient among constructs. The project and company characteristics have small (e<0.5) positive effect on the extent of use of sustainable methods in design and construction, new materials, and technologies in affordable housing projects. The results of total effect coefficient also reveal the challenges have moderate (-0.8<e<-0.5) negative effects on the extent of use of sustainable methods in construction, new materials, and technologies, although the challenges have a small (-0.5<e<-0.2) negative effect on the extent of use of sustainable methods in design.

Finally, the outer weights of each dependent variable are estimated, and the results are ranked according to the relative importance in Table 7. Outer weights are the results of a multiple regression of a construct on its set of indicators which assess each indicator's relative importance in formative measurement models. The outer weights of variables indicate that experience in affordable housing projects (CHC2), familiarity and awareness with innovation (CHC4), size of company (CHC1) and establishment of the company (CHC3) are the most effective company characteristics respectively whilst type of housing (CHP2), size of project (CHP1), client of project (CHP3) and procurement of project (CHP4) are the most important project characteristics. The most influential challenges consisted of high cost of methods and technology (CH1), lack of incentives (CH5), tendency to use conventional methods/ materials/ technologies (CH4) and lack of technical knowledge (CH6).

Table 7: Outer weights of internal and external variables

Variables	Company characteristics	Project characteristics	Challenges
Experience in affordable housing projects (CHC2)	0.309		
Familiarity and awareness with innovative methods, technologies, and materials (CHC4)	0.28		
Size of company (CHC1)	0.273		
Establishment of the company (CHC3)	0.259		
Type of housing (CHP2)		0.318	
Size of project (CHP1)		0.312	
Client of project (CHP3)		0.281	
Procurement (CHP4)		0.281	
High cost (initial/ maintenance/ operation) (CH1)			0.124
Low availability in local market (CH10)			0.114
Lack of public incentives (CH5)			0.123
Tendency to use conventional methods/materials/technologies (CH4)			0.122
Lack of technical knowledge and skill (CH6)			0.122
Lack of policy and regulation (CH8)			0.121
Lack of technical guidelines and standards (CH2)			0.120
Lack of awareness of the availability (CH7)			0.119
Incompatibility with other methods/materials/technology (CH3)			0.118
Low social acceptance (CH9)			0.114

Overall, the outer weights of variables of each influence are very close (~0,280 for company characteristics, ~0.300 for project characteristics and ~0.120 for challenges), which validate the importance of all selected variables on the adoption of SOI on South African affordable housing, as listed in Table 10.

6. Discussion

The main objectives of this study were to examine the causality and evaluate the effects of company and project characteristics as internal variables and challenges as external variables on the extent of use of SOIs on affordable housing projects. Based on the results from this evaluation, a SIAH causal model was developed and validated using SEM.

6.1 Level of SOI adoption and associated challenges

The analysis of questionnaire responses revealed that the extent of use of SOIs in design and construction of South African affordable housing projects remained relatively low. This is because of the low levels of knowledge and expertise possessed by home designers and developers on sustainable methods of design and construction, new materials, and innovative technologies. This aligns with the findings of the studies by Jamaludin et al.,(2018) and Pablo and London (2020). The conventional procurement systems used in the South African housing sector further exasperate the adoption of SOIs on affordable housing projects, emulating the findings of Karji et al. (2019).

Further analysis of the data verified that the passive methods remained the most used sustainable method by designers because of low cost, high familiarity of designers with these methods and good amount of policy and incentives that encouraging use of these methods. The findings corroborated the observation in previous studies on the effect of high cost and lack of technical guidelines and standards on low adoption of new methods such as life-cycle carbon footprint assessment, renewable energy and lean design in affordable housing project (Junior *et al.,* 2017).

The increasing consideration of environmental sustainability performance due to the negative impact of construction on the environment appear to have encouraged home developers to adopt several resource-efficient methods during the construction of affordable housing. Moghayedi *et al*., (2022) suggests that the relatively high cost of water and energy in South Africa has also played a role. Current public incentives centre on labour-intensive construction practices to stem the high unemployment rate in South Africa (Osunsanmi *et al.*, 2020) thus explaining the limited use of automated construction methods by developers.

The high level of awareness of designers and developers and availability of local and light materials clarify the high level of use of these materials in affordable housing projects. Also, variables such as high cost, unfamiliarity of designers and developers, as well as reluctance to use new materials resulted in the low level of using new materials, such as nano and green materials in affordable housing projects (Windapo et al., 2021).

The familiarity of designers and developers with limited technologies such as Computer Aided Design (CAD) and Project portfolio management software, promoted the high extent of use of these technologies in housing projects. However, as suggested by Adabre *et al.* (2021), the high cost of technologies, lack of awareness and technical knowledge caused the limited used of other innovative technologies in the design and construction of affordable housing. Certainly, this illustrates that the level of adoption of technology in housing projects in developing countries is considerably limited as established by Patel and Padhya (2021), Eng and Zainal, (2021) and Ge *et al.*, (2020) .

The respondents perceived that legislative reform is need to prevent the existing regulations, guidelines and building standards to continue as significant barriers to the adoption of SOI in affordable housing projects, a phenomena observed by Jamaludin *et al*. (2018) and Patel and Padhya (2021) as well.

The main challenge, in delivery of SIAH, is how to make innovative and sustainable houses more affordable (Moghayedi *et al.*, 2021). Chan and Adabre (2019) conclude that appropriate innovation is able to bridge the gap between sustainable housing and affordable housing. For instance, in low-income affordable units, instead of incorporating costly and complex methods and innovative products, the focus could be on maximising natural resources in designing the affordable housing, such as passive design, efficient resources methods, inexpensive technologies and local materials, etc. as proven by level of extent of use of sustainability and innovation results.

Furthermore, the study established that SOI was not a priority as many home designers and developers are unwilling to push the boundaries in this regard particularly when it means having to move from the conventional way of construction and venture into an innovative realm of technology which may lead to increased upfront costs and skill. Producing or manufacturing materials and technologies locally can reduce the cost of new materials and consequently improve the local economy in developing countries. Therefore, local company and manufacturers need to be encouraged towards producing new materials and innovative technologies to cater for local demand.

However, to stay relevant and continue in the business, the home designers and developers would have to follow the market trend. If more private and public clients are demanding SIAH or if the market is lucrative, more designers and developers will use innovative methods, materials and technologies in both design and construction of affordable housing. By educating housing stakeholders including the clients and end users, public awareness regarding the long-term benefits of SIAH, will increase, and consequently enhance the demand for such housing. To utilise knowledge from across many disciplinary boundaries in housing projects, all affordable housing stakeholders should collaborate effectively to facilitate the adoption of sustainable methods, new materials, and innovative technologies in affordable housing projects.

6.2 Causal model of SOI on affordable housing

The results of the SEM show an acceptable validity of the developed model. The total effect coefficients in the final SIAH causal model, as shown in Figure 2, confirmed the positive small effect of internal variables on the extent of use of SOIs in affordable housing projects. The existence of positive relationships among company and project characteristics and extent of use mean that the level of use of sustainable methods, new materials and innovative technologies in affordable housing projects directly depends on the size of company and project, experience of company in affordable housing projects, familiarity and awareness of technical staff of company with SOIs, type of housing project, the client of project and project procurement.

The results of total effect coefficients in the final SIAH causal model also validated the small to moderate negative effect of challenges on the extent of use of SOI on affordable housing projects. Moreover, the comparison of path coefficient (Figure 6) and total effect coefficients (Figure 7) proved the negative mediating effect of challenges on the relationship between internal variables (company and project characteristics) and extent of adoption of SOI on affordable housing projects. The negative relationships among challenges and extent of use of sustainability and innovation indicates that the extent of use of sustainable methods, new materials and innovative technologies could be increased by addressing the challenges on adoption. These aligned with the propositions in the developed causal model (Figure 1). However, the findings in total effect analysis and Table 6 reveal that extent of use of SOI are strongly associated with external challenges. The implication of this finding is that by reducing the external challenges on SOI adoption, the extent of use will significantly improve. This is not only because of the direct negative effect of challenges on extent of use but also the negative mediator impact of challenges on relationship between internal variables and extents of use of SOIs. The findings are consistent with those of previous studies by Patel and Padhya, (2021) and Syed Jamaludin et al., (2018), who acknowledge that the external variables challenges influence the level of adoption of innovation in construction projects and particularly housing projects, the most.

The influential factors at both company and project levels provide the resources and capability to enhance the sustainability of affordable housing and deliver SIAH. While government incentives and strategies create an environment which stimulates and enforces design and development of SIAH, educating housing stakeholders will affect the demand for SIAH.

The validation of the SIAH causal model attests to the applicability of this model as a mechanism for enhancing the extent of use of SOIs in affordable housing projects in furtherance to actualizing SIAH design and construction. Also, it implies that the model can be used to understand and identify the influential internal and external variables, and challenges negating the adoption of methods, materials, and technologies on affordable housing projects. In practice, the model not only serves guideline for the affordable housing designers and developers in selecting methods, materials, and technologies in their projects, but also acts as a roadmap for local and national housing policymakers, to reduce the challenges preventing the adoption of SOIs in affordable housing projects.

The current study is one of the pioneer studies modelling the SOI adoption in affordable housing using SEM. The developed SIAH causal model was validated in part through hypotheses testing. Previous studies and models in this field mainly tested the existing theories. In contrast, the current study used SEM as an appropriate method for the exploration of the SIAH conceptual model.

The research presents several practical and theoretical implications for researchers and practitioners. The findings of this study will provide valuable awareness of the critical role and effectiveness of technological innovations on the sustainability of affordable housing. Practically, the findings of this research help understand the planning scope and organisational and project requirements towards a continuous and consistent SOI adoption to achieve superior sustainability in affordable housing. Theoretically, this research extends the postulations on the internal and external influences on SOIs adoption as the primary driver of developing SIAH.

7. Conclusions

The study establishes the existence of causality and effects between SIAH influential internal and external variables and validates the effect of these variables, on the extent of use of SOI on affordable housing projects; by empirically examining the nexus between company and project characteristics, challenges, and extent of use of sustainable methods, new materials, and innovative technologies.

The study’s results show that; extent of use of SOI in affordable housing projects are positively associated with internal variables and negatively associated with external challenges. The positive correlation between company and project characteristics and extent of use makes it possible to conclude that the level of sustainability and innovation in affordable housing projects not only depend on the experience, knowledge and competency of designers and developers of affordable housing but also the size, type, and the client of projects. However, the finding of study reveals that company characteristics that contribute to experience and knowledge have a greater influence on extent of use, than project-specific factors such as project procurement.

To address current issues of affordable housing and enhance the level of sustainability performance of such houses and well-being of residents, the extent of use of appropriate sustainable methods, new materials and innovative technologies in affordable housing must be improved. Hence, the knowledge, advantages, and opportunities of adoption of SOI in affordable housing should spread among all housing stakeholders. Therefore, policymakers, designers and developers must ensure that the executives in the affordable housing sectors and their organisations become conversant with change and ensure that all parties acquire necessary understanding and awareness on adopting sustainability and innovation.

Furthermore, it can be concluded from the findings of this study that appropriate strategic national and local plans are required for design and develop SIAH by enhancing the extent of use of SOI on affordable housing projects. Government's strong commitment and political willingness is crucial in instigating affordable housing projects developers to contribute to responsible production through adoption of SOI on their projects.

The research contributes to sustainability of affordable housing by providing a new perspective for understanding SOI adoption and barriers in affordable housing projects. It brings about the insights that the development of SIAH cannot be prosperous until it ensures a continuous and consistent innovation adoption to resolve the sustainability issues of affordable housing projects.

Summarily, this study which focuses on the delivery of affordable housing within the South African context, makes a salient contribution to improving housing delivery efficiencies and enhancing cleaner production through the design of a framework for facilitating SOI adoption at company and project levels. However, this study is focused on South African affordable housing projects. Hence, it does not entirely represent the state of SOIs adoption in the housing sector or the construction industry in South Africa.

The research provides a systematic basis for future studies to assess the actual effectiveness of internal and external influences as well as challenges and barriers as a mediator on the sustainability performance of SIAH through a multi-case study approach. Future studies should also consider measuring the impact of various SOIs on the sustainability of affordable housing projects. Moreover, future studies could focus on the investigation of essential SOIs implementation strategies that overcome the barriers to SOIs adoption in affordable housing projects. A case study of the difficulties experienced by developers in adopting SOIs in affordable housing could contribute to deeper understanding of the findings of this research.

Finally, due to the high similarity of construction industry and affordable housing projects in developing countries, as shown in the study, the SIAH conceptual framework could be generalised in similar developing country contexts.

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