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# AN INTEGRATED SUSTAINABLE BUILDING CONSTRUCTION MODEL FOR PROJECT DELIVERY IN SOUTH AFRICA

A thesis

by

**Chijioke Emmanuel Emere**

to the

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SOUTH AFRICA

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2024

# DECLARATION

I, **Chijioke Emere**, hereby certify that this thesis was compiled by me and is my own work and the outcome of my investigation. A list of references is provided at the end of the report, and information gleaned from books and other sources has also been fully acknowledged in the text. I also affirm that no portion of this thesis has ever been submitted by me to any other institution.

Author's signature _____ __

# DEDICATION

This thesis is devoted to the Emere's family particularly to my dear wife, Mrs. Deborah Ifechinalu Emere, and my beloved daughter, Ms. Chizitere Reign Emere.

# ACKNOWLEDGEMENT

I thank God almighty for his grace, strength, and provisions to carry out this study. Praise be to His name.

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May God almighty continually bless every one of you in Jesus' Name, Amen.

# ABSTRACTS

Effective construction of sustainable buildings is linked with project delivery performance success. However, the literature suggests that sustainable building construction (SBC) is fraught with challenges such as lack of requisite knowledge, skills, and capacity of relevant personnel and stakeholders, lack of public awareness of sustainable principles, non-compliance with policies, poor procurement strategy, the misconception of construction cost overrun, lack of financial assistance for technological changes, lack of top management support and consequence management at the executive level, as well as inadequate monitoring and evaluation. Additionally, poor implementation of SBC has partly contributed to shortcomings such as inefficiency and poor quality in project delivery, a massive amount of waste generation, excessive usage of natural resources, pollution of air and water, and other damages to the environment.

The current study investigated and modelled the extent to which regulatory environment (RE), knowledge sharing (KS), corporate disposition (CD), project delivery strategies (PDS), project management techniques (PMT), and modern building techniques (MBT) predict the effective implementation of SBC for project delivery success in South Africa. The predicting factors formed the six-factor exogenous construct for the current study. An extant review of the literature was done to apprise the study. The study adopted a quantitative approach and used a structured questionnaire to elicit data from 281 built environment professionals, predominantly based in the Gauteng province of South Africa. Data were analysed using the Statistical Package for the Social Science software version 29 and Amos software version 29. Exploratory factor analysis was employed to explore the data and correlations between variables and refine the variables between each construct. Structural equation modelling (SEM) was used to determine the causal relationships of the constructs and for the validation of the integrated SBC model. Confirmatory factor analysis, a crucial part of SEM was used to test the specific hypotheses concerning the structure of the set of variables and was essential for determining the best-fit model for the study. Findings revealed that the structural model data were acceptable. Five out of six latent exogenous constructs had a statistically significant relationship in predicting the effective implementation of SBC. The significant exogenous constructs included knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques. Additionally, SBC implementation (SBCI), a mediating

construct, had a statistically significant influence in actualising integrated SBC project delivery outcome variables.

This study adds to the body of knowledge by addressing the dearth of theoretical information regarding the factors that are most significant in predicting the effective implementation of SBC and achieving project delivery success outcomes. Additionally, the developed integrated sustainable building construction (ISBC) model is a contribution to the body of Knowledge. Notably, no study has developed an ISBC model for South Africa. The study recommended that the developed multi-factor ISBC model form the basis regarding SBC implementation for project delivery success, especially in South Africa. It also stressed that knowledge sharing, corporate disposition, project management techniques, and modern building techniques should be prioritised for integration in further studies. Furthermore, project delivery strategies like early involvement of stakeholders, collaboration of project participants, integrated project delivery system, and public-private partnerships were recommended for effective implementation of SBC for project delivery success in South Africa.

Due to time constraints and difficulty reaching experts from other South African provinces, the study was predominantly conducted in the Gauteng province. The circumstances contributed to the use of a convenience sampling technique, which suggests the findings of this study may not be generalised to the South African built environment. Hence, more research can be done on ISBC to have an overall view using data from other provinces in South Africa. Similarly, although the ISBC model achieved an accepted fit and construct validity, further validity is recommended in future research to substantiate the model. Nevertheless, the model provides a reference for future research.

**Keywords:** South Africa construction industry, Sustainable building construction, project delivery strategies, project management techniques, project performance, structural equation modelling

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AEC | Architecture, Engineering, and Construction |
| AIA | American Institute of Architects |
| ANOVA | Analysis of Variance |
| ASCE | Association of Civil Engineers |
| ASSAF | Academy of the Science of South Africa |
| AVE | Average Variance Extracted |
| BA | Bagasse Ash |
| BCA | Building Construction Authority |
| BCA-GM | Building and Construction Authority Green Mark |
| BCFB | Burnt Clay Flyash Brick |
| BEE | Building Environmental Efficiency |
| BIM | Building Information Management/Model |
| BOOT | Build-Own-Operate-Transfer |
| BOT | Build-Own-Operate |
| BRE | Building Research Establishment |
| BREEAM | Building Research Establishment Environmental Assessment Method |
| BTO | Build-Transfer-Operate |
| CABR | China Academy of Building Research |
| CASBEE | Comprehensive Assessment System for Building Environment Efficiency |
| CBE | Council for the Built Environment |
| CD | Corporate Disposition |
| CFA | Confirmatory Factor Analysis |
| CFI | Comparative Fit Index |
| CFRP | Carbon Fiber Reinforced Polymers |
| CI | Construction Industry |
| CIDB | Construction Industry Development Board |
| CM | Construction Manager |

| | |
|---|---|
| CPM | Critical Path Method |
| CRS | Crushed Rock Sand |
| CSIR | Council for Scientific and Industrial Research |
| CWA | Concrete Waste Aggregate |
| DB | Design and Build |
| DBB | Design-Bid-Build |
| DBIA | Design-Build Institute of America |
| DBFO | Design-Build-Finance-Operate |
| DBM | Design-Build-Maintain |
| DBOM | Design-Build-Operate and Maintain |
| DBOT | Design-Build-Operate-Transfer |
| DBS | Deliverable Breakdown Structure |
| Df | Degree of Freedom |
| DPW | Department of Public Works |
| EFA | Exploratory Factor Analysis |
| EDGE | Excellence in Design for Greater Efficiencies |
| ESGB | Evaluation Standard for Green Building |
| ESP | Expanded Polystyrene |
| EVM | Earned Value Management |
| EWP | Energy Water Performance |
| FA | Fly Ash |
| FEPA | Federal Environmental Protection Agency |
| FG | Fine Glass |
| GA | Glass Aggregate |
| GAC | Glass Aggregate Concrete |
| GB | Green building |
| GBCA | Green Building Council of Australia |
| GBCN | Green Building Council of Nigeria |
| GBCSA | Green Building Council of South Africa |

| | |
|---|---|
| GBPs | Green Building Products |
| GBTool | Green Building Tool |
| GC | General Contractor |
| GCPOE | Global Construction Perspectives and Oxford Economics |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GhGBC | Ghana Green Building Council |
| GLM | General Linear Modellings |
| GMP | Guaranteed Maximum Price |
| GOBAS | Green Olympic Building Assessment System, China |
| GPM | Green Project Management |
| GRI | Global Reporting Initiative |
| G-SEED | Green Standard for Energy and Environmental Design |
| HK-BEAM | Hong Kong Building Environment Assessment Method |
| HPC | High Performance Concrete |
| HQE | High Environmental Quality |
| IDD | Integrated Digital Delivery |
| IEQ | Indoor Environmental Quality |
| IBS | Industrialised Building System |
| IFI | Increment Fit Index |
| IPD | Integrated Project Delivery |
| ISBC | Integrated Sustainable Building Construction |
| ISBCPD | Integrated Sustainable Building Construction Project Delivery |
| ISO | International Organisation for Standardisation |
| IT | Institutional Theory |
| JaGBC | Japanese Green Building Council |
| KMO | Kaiser-Meyer-Olkin |
| LEED | Leadership in Energy and Environmental Design |
| MOHURD | Ministry of Housing and Urban-Rural Development |

| | |
|---|---|
| MBT | Modern Building Techniques |
| MS | Mean Score |
| NABERS | National Australian Building Environment Rating System |
| NBRBSA | National Building Regulation and Building Standard Acts |
| NEMA | National Environmental Management Act |
| NFI | Normed Fit Index |
| NPE | National Policy on Environment |
| NZEB | Net-Zero-Energy-Building |
| OECD | Organisation for Economic Co-operation and Development |
| OPS | Oil Palm Shell |
| PCA | Principal Component Analysis |
| PCCV | Prestressed Concrete Containment Vessels |
| PDS | Project delivery strategies |
| PERT | Program Evaluation and Review Technique |
| PESTEL | Political, Economic, Social, Technological, Environmental, and Legal factors |
| PHIUS | Passive House Institute United States |
| PMBoK | Project Management Body of Knowledge |
| PM | Project Manager |
| PMI | Project Management Institute |
| PMO | Project Management Office |
| PMP | Project Management Professionals |
| $PM^2$ | Project Management Methodology |
| PMT | Project Management Techniques |
| POFA | Palm Oil Fuel Ash |
| PPP | Public Private Partnership |
| PRISM | Project Integrating Sustainable Methods |
| P-Value | Probability Value |
| RE | Regulatory Environment |

| | |
|---|---|
| RHA | Rice Husk Ash |
| RHBA | Rice Husk-Bark Ash |
| RMSEA | Root Mean Square Error of Approximation |
| RPMW | Recycled Paper Mill Waste |
| KS | Knowledge Sharing |
| SA | South Africa |
| SAPOA | South African Property Owners Association |
| SB | Sustainable Building |
| SBAT | Sustainable Building Assessment Tool |
| SBC | Sustainable Building Construction |
| SBCI | Sustainable Building Construction Implementation (Features) |
| SBEM | Simplified Building Energy Model |
| SBM | Sustainable Building Materials |
| SBTool | Sustainable Building Tool |
| SCBA | Sugarcane Bagasse Ash |
| SCM | Supply Chain Management |
| SCT | Social Cognitive Theory |
| SD | Standard Deviation |
| SEM | Structural Equation Modelling |
| Sig | Significance |
| SMEs | Small and Medium Enterprises |
| SPSS | Statistical Package for the Social Sciences |
| SRMR | Standardised Root Mean-Square Residual |
| SSCM | Sustainable Supply Chain Management |
| TCC | Target Price Contracts |
| TL | Transcendent Leadership |
| TLI | Tucker-Lewis's Index |
| TP | Targeted Procurement |
| TRC | Textile Reinforcement Concrete |

| | |
|---|---|
| UNEP | United Nations Environment Programme |
| USA | United States of America |
| UK | United Kingdom |
| VDC | Virtual Design and Construction |
| VE/VM | Value Engineering/Management |
| WBS | Work Breakdown Structure |
| WCBs | Waste-Create Bricks |
| WGBC | World Green Building Council |
| $x^2$ | Discrepancy |
| $x^2/df$ | Chi-square |

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# CHAPTER ONE

# INTRODUCTION

## 1.0 Prologue

This thesis studied sustainable building construction (SBC) for project delivery success in developing nations, using South Africa as a case study. The first chapter introduces the background of the study, research questions, objectives, and problem statement. Additionally, it presents the study's rationale, significance, and scope. Moreover, it delineates the research process and methodology. Furthermore, it discusses the overview of the study in chapters.

## 1.1 Background

The construction industry is one of the prominent participants in the world economy, contributing about 6% to the gross domestic product (GDP) and provides employment for 7% of the world's working-age populace (World Economic Forum, 2018; Craveiroa, Duartec, Bartoloa and Bartolod, 2019). It has also been forecasted that its contribution to the world economy can rise to about 14.7% by 2030 ((Global Construction Perspectives and Oxford Economics (GCPOE), 2015; Craveiroa et al., 2019). The construction industry also plays its role in African developing countries' economies. For instance, in Ghana, the construction industry contributes about 8.2% to its GDP (Ofori-Kuragu et al., 2016). In Nigeria, it represents 3.1% of the GDP and employs approximately 20% of the total workforce (Muhammad, Ahmed, and Yakasai, 2017). In South Africa, it represents about 4% of the GDP and employs approximately 8% of the national labour force (Statistics South Africa, 2014; Statistics South Africa, 2019). Nevertheless, there is still a great need for improvement in the construction industry considering the world's increasing population and the need for overall sustainability, including economic viability, social responsibility, and environmental safety.

Despite the contributions of the construction industry, it still poses a significant threat and deleterious effects on the climate, environment, human health, and national economies (Zhang, Platten, and Shen, 2011). For instance, it is acknowledged globally that the construction sector consumes about 40% to 50% of the world's raw materials, and 40% to 45% of energy (World Energy Outlook, 2011; Tabassi et al., 2016; Murtagh, Scott, and Fan, 2020). Wood consumption accounts for around 25% to 70%, including construction and maintenance (World Energy Outlook, 2011; Tabassi et al., 2016; Anzagira, Badu, and Duah, 2019.) In terms of the world's freshwater withdrawals and land usage, it accounts for 17% and 60%, respectively (World Energy Outlook, 2011; Tabassi et al., 2016). Furthermore, it emits about 35%-40% carbon dioxide and generates 65% of waste materials globally (Son, Kim, Chong, and Chou, 2011; Anzagira et al., 2019). The authors affirm that the construction of buildings is primarily to blame for these challenges (Saad, 2016; Tabassi et al., 2016; Anzagira et al., 2019; Murtagh et al., 2020). Besides, "buildings in their unique state are the main users of electrical energy, and thus play a critical role in contributing to global warming and the depletion of our natural resources" (Saad, 2016:183).

In South Africa, building activity is responsible for about 23% of emanations of ozone-depleting substances. In contrast, the manufacturing of significant materials for the building sector adds to these emissions to about 18mt$CO_2$ annually, or around 4% of the total $CO_2$ emissions (CIDB, 2009; Owoha, 2019). Therefore, there is a dire need to curtail these harmful effects by building sustainably, which, in turn, contributes to overall project success.

However, the construction industries in developing countries, especially in Africa, are still lagging behind in embracing innovative approaches that will improve project delivery performance and enhance project success and productivity (Muhammad et al., 2017; Gurung, 2020). Additionally, there has been a concern for inefficiency and ineffectiveness towards the actualisation of the project objectives, a lack of requisite skills among personnel, and poor stakeholder collaboration (Rwelamila and Purushottam, 2012; Ameh and Daniel, 2013). Not only that, sustainable performance objectives are rarely met in developing countries, but also the project delivery performance is fraught with cost and time overruns, poor quality, health and

safety deficiency, and client dissatisfaction with the project outcome (Farooqui, Ahmed and Lodi, 2008; Ahsan and Gunawan, 2010; Oyewobi and Ogusemi, 2010; Memon, Rahman, and Azis, 2012; Bentil, Nana-Addy, Asare, and Fokuo-Kusi, 2017; Mulalo, Ibrahimu, and Anyadiegwu, 2018; Emere, 2020). Patah (2010) indicates that performance efficiency and effectiveness result to project success. Performance efficiency and effectiveness are described as the accomplishment of the designed outcome and the degree to which the objectives are achieved (Dweiri and Kabian, 2006; Patah, 2010; Emere, 2020). Project delivery performance, therefore, identifies with project success which is the actualisation of the proposed project outcome, especially the highest priority criteria (Muller and Turner, 2010). The role of effective sustainable building construction is therefore essential in contributing to improving project delivery performance in developing nations.

Construction project delivery performance success is linked with effective sustainable building construction (Popaitoon, and Siengthai, 2014; Olanipekun, Xia, and Nguyen, 2017). Delivery performance criteria includes both traditional metrics (time, cost, and quality) and sustainable metrics (level of sustainability rating, the level of energy efficiency or energy savings, and the comfortability or the quality of indoor air) (Daim et al., 2009; Smith, and Earl, 2009; Korkmaz, Riley, and Horman, 2010; Rosenbaum et al., 2013; Popaitoon, and Siengthai, 2014; Olanipekun et al., 2017). Other success criteria include environmental factors, value for money, client satisfaction, and health and safety (Akanni, Oke, and Akpomiemie, 2015; Das and Ngacho, 2017; Tengan, Aigbavboa, Guribie, and Annor-Asubonteng, 2019; Emere, 2020). According to Häkkinen, Rekola, Ala-Juusela, and Ruuska (2016:651), "sustainable building, aims at the required building performance with minimum adverse environmental impact, while encouraging improvements in economic, social, and cultural circumstances". Additionally, "sustainable buildings contribute to meeting global goals in terms of climate change and human rights, as well as national and local goals of poverty reduction, job creation, economic growth, energy security, public health and others" (Krizmane, Slihte, and Borodinecs, 2016:98).

Similarly, DuPlessis (2002) defined sustainable construction as the "*process applied to the comprehensive construction cycle from the extraction and beneficiation of raw materials,*

*through the planning, design, and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste*." (Du Plessis 2002:6). Du Plessis further indicates that "*it is a holistic process aiming to restore and maintain harmony between the natural and Built Environments while creating settlements that affirm human dignity and encourage economic equity*" (Du Plessis 2002:6). Hence, the term "*sustainable building construction*" (SBC) can be defined as the construction of buildings in a sustainable and green way (Nelms, Russell, and Lence, 2005; Tabassi et al., 2016). The terms "*sustainable*" and "*green*" highlight ecological mindfulness and the protection of natural resources. "*Sustainable*" is majorly concerned with environmental health, economic vitality, and social benefits, while "*green*" focuses on environmental health only (World Atlas, 2021: online). In other words, "*green*" is a subset of sustainability.

Similarly, in achieving sustainable building construction, conventional construction methods and technologies should be changed to those that align with the concepts of sustainable development regarding buildings' design, construction, operation, and maintenance (Nelms et al., 2005; Tabassi et al., 2016). Hence, sustainable building construction practices are described as practices that strive for excellence in the environmental, social, and economic performance of a building (Manoliadis, Tsolas, and Nakou, 2006). Additionally, Lu and Zhang (2016) propose that the construction industry should ensure that green/sustainable projects are delivered in alignment with corporate sustainability that would engage governance, different stakeholders, corporate decision-makers, project managers, and others of similar interest. Therefore, considering the mentioned challenges surrounding the construction industry and the benefits of sustainability, effective sustainable building construction is relevant to achieving a broader spectrum of delivery performance criteria for project success. Consequently, the current research contributes by establishing the impact of effective, sustainable building construction on project delivery success. It considers both the traditional metrics performance criteria and sustainable metrics towards environmental safety, social responsibility, and economic viability in South Africa.

It is noteworthy that the South African government has put in place initiatives and policies to support sustainable approaches, which include "*the Integrated Sustainable Rural Development*

*Strategy*", the "*State of the Environment Reports*", "*Driving Competitiveness: An integrated Industrial Strategy For Sustainable Employment and Growth*", the "*New Partnership for Africa's Development, the White Paper on Integrated Pollution and Waste Management*", the "*White Paper on Environmental Management Policy*", and the "*South Africa Human Development Report*" (Gibberd, 2002:2). Besides, efforts have been made by the Department of Public Works, and the Green Building Council of South Africa to ensure that green building practices are implemented (within the framework of the South African government's green building policy). Although the appreciation of sustainable principles is a step further in South Africa, compared to other African countries, it has been acknowledged that sustainable building construction is still not at an adequate level (Windapo and Goulding, 2015; Owoha, 2019; Marsh et al., 2021; Simpeh et al., 2023). There remain significant challenges to implementing sustainable approaches in the building construction industry. The predominant challenges include inefficiency in the implementation of green building concepts, lack of public awareness of sustainable principles, lack of requisite knowledge, skills, and capacity in most of the relevant personnel and stakeholders (Mashwama et al., 2020; Masia et al., 2020; Aghimien et al., 2021; Marsh et al., 2021; Simpeh et al., 2023; Ebekozien et al., 2024). Similarly, there is lack of legal mandate on sustainable practices, non-compliance with policies, poor procurement strategies, a misconception of construction cost overrun, and a lack of financial assistance for technological changes (Windapo and Goulding, 2015; Saad, 2016; Mashwama et al., 2020; Masia et al., 2020; Aghimien et al., 2021; Simpeh et al., 2023; Ebekozien et al., 2024). Additional challenges include the lack of top management support and consequence management at executive level, as well as inadequate monitoring and evaluation to ensure compliance to the rules (Ambe and Badenhorst-Weiss, 2012; Wessels, 2014; Windapo and Goulding, 2015; Saad, 2016; Aigbavboa, Ohiomah, and Zwane, 2017; Agyepong, and Nhamo, 2017; Naicker, 2018; Aigbavboa, and Thwala, 2019; Masia et al., 2020; Simpeh et al., 2023).

Likewise, in research, many scholars have concentrated on the barriers to sustainable buildings (Coetzee and Brent, 2019; Ojo-Fafore, Aigbavboa, and Thwala, 2019; Owoha, 2019; Masia et al., 2020; Marsh et al., 2021; Ogunmakinde et al., 2023; Simpeh et al., 2023; Ebekozien et al., 2024). However, very little has been explored concerning the factors that will possibly bring

about effective sustainable building construction that tackles the challenges surrounding sustainable development,especially in South Africa. Very few pieces of literature exist which highlight these (Tabassi et al., 2016; Darko, Zhang, and Chan, 2017; Moghayedi et al., 2022). Notably, no study has carefully modelled and integrated the factors that will bring about effective SBC for project delivery success for the South African construction industry. According to Ling and Tran (2016), current construction management models have not been able to adequately handle sustainability goals and project delivery success measures at the same time. Models that emphasise sustainability or project management efficiency are available in the literature currently in publication, but they rarely offer an integrated strategy that is appropriate for the South African context (Oyewobi et al., 2011; Aigbavboa and Thwala, 2012; Moghayedi et al., 2021; Agbajor and Mewomo, 2024). Consequently, this study seeks to fill this gap.

## 1.2 Problem Statement

Despite ongoing efforts to improve construction practices in South Africa, the sector faces significant challenges, particularly concerning sustainability and project delivery (Bowen et al., 2014). Traditional building methods often result in environmental degradation, excessive energy consumption, and waste, undermining the country's sustainability goals (Ofori, 2019). Concurrently, project delivery often suffers from inefficiencies such as cost overruns, delays, and quality issues (Windapo and Cattell, 2013). The need for sustainable building construction is therefore becoming increasingly urgent.

Effective implementation of sustainable building construction is linked with project delivery performance success (Olanipekun, Xia, and Nguyen, 2017). Sustainable building construction is a holistic approach to building design, construction, and operation that minimizes the environmental impact of buildings (Du Plessis, 2007). However, there are several barriers to the adoption of sustainable building construction practices in South Africa. These barriers include a lack of awareness of sustainable building construction practices among stakeholders in the construction industry, a lack of access to information on sustainable building construction materials and technologies, and the perceived high cost of sustainable building construction

(Mashwama et al., 2020; Masia et al., 2020; Aghimien et al., 2021; Marsh et al., 2021; Agbajor and Mewomo, 2024). Additional obstacles include the lack of incentives for adopting sustainable building construction practices, non-compliance with policies, poor procurement strategy, inadequate project monitoring, evaluation, and management, and so on (Ambe and Badenhorst-Weiss, 2012; Wessels, 2014; Windapo and Goulding, 2015; Aigbavboa et al., 2017; Naicker, 2018; Ogunmakinde et al., 2023; Simpeh et al., 2023; Agbajor and Mewomo, 2024).

To address these barriers, there is a need for an integrated sustainable building construction model for project delivery in South Africa. Existing models for construction management have proven inadequate in simultaneously addressing sustainability objectives and project delivery performance metrics (Ling and Tran, 2016). Current literature offers models emphasising either sustainability or project management efficiency but rarely provides an integrated approach suitable to the South African setting (Oyewobi et al., 2011; Aigbavboa and Thwala, 2012; Moghayedi et al., 2021; Agbajor and Mewomo, 2024). The absence of such an integrated model hampers the ability of construction stakeholders to meet both sustainability and efficiency targets, thereby stalling progress toward achieving comprehensive sustainable development in the South African construction industry. Therefore, there is a pressing need for an integrated sustainable building construction model specifically tailored to South Africa's unique economic, environmental, and social context. This model would provide a framework for the planning, design, construction, and operation of sustainable buildings. The model would harmonise sustainability imperatives with cost, time, and quality considerations for better project delivery outcomes.

Furthermore, this model seeks to confirm the proposition that effective implementation of sustainable building construction will enable successful project delivery. This will be achieved by investigating the impact of essential factors (such as knowledge sharing, regulatory environment, corporate disposition, project delivery strategies, the use of project management techniques, and modern building techniques) on the implementation of sustainable building construction for project delivery in South Africa.

## 1.3 Purpose of the Study

This study sought to develop an integrated Sustainable Building Construction (SBC) model for project delivery in South Africa. In so doing, it examines the relationship between factors that can bring effective SBC to actualising project success. The elements (also known as SBC determinants) are, therefore, modelled to tackle the shortcomings regarding sustainable building construction (SBC) and actualise project delivery success in South Africa. The factors include knowledge sharing, regulatory environment, corporate disposition, and the gaps in knowledge like the choice of project delivery strategy, the use of project management techniques, and modern building techniques. The rationale was highlighted in section 1.6 and extensively discussed in section 3.3.7 to 3.4.

## 1.4 Research Questions

The following questions are formulated to respond to the research problem statement and achieve the stated objectives:

1. What are the existing factors that influence successful delivery of sustainable building construction projects in South Africa?
2. To what degree do project delivery strategies influence sustainable building construction for project delivery in South Africa?
3. To what degree do project management techniques influence sustainable building construction for project delivery in South Africa?
4. To what degree do modern building techniques influence sustainable building construction for project delivery in South Africa?
5. To what degree does the hypothesised integrated sustainable building construction project delivery framework fits into the identified factors?

## 1.5 Research Objectives

The following objectives are formulated to answer the research questions:

1. To determine the existing factors that influence the delivery of sustainable building construction projects in South Africa;
2. To evaluate the impact of the factors that will bring about effective implementation of sustainable building construction for project delivery in South Africa;
3. To evaluate the extent to which sustainable building construction implementation influence project delivery outcomes in South Africa;
4. To develop an integrated sustainable building construction model for project delivery in South Africa;
5. To determine the extent to which the hypothesised model for sustainable building construction for project delivery fits into the identified factors.

## 1.6 Rationale for the Study

The motivation for this study is based on the need to effectively implement sustainable building construction and improve project delivery performance (including traditional and sustainable metrics) in the South African construction industry. No study has carefully modelled the factors that determine the effective implementation of sustainable building construction (SBC) for project delivery success in South Africa. Additionally, this study establishes the impact of SBC features on project performance in South Africa. In achieving this, to this end the study examines the vitality of the factors that will bring about effective implementation of SBC (SBC determinants) and the principal components of the identified factors. The factors include knowledge sharing, regulatory environment, corporate disposition, choice of project delivery strategy, the use of project management techniques, and modern building techniques. These factors will aid the construction of buildings in a way, inter-alia, that is economically viable, environmentally safe, and socially responsible in South Africa. Besides, these factors will aid in ensuring that sustainable buildings are delivered successfully without unnecessary overruns.

## 1.7 Research Method

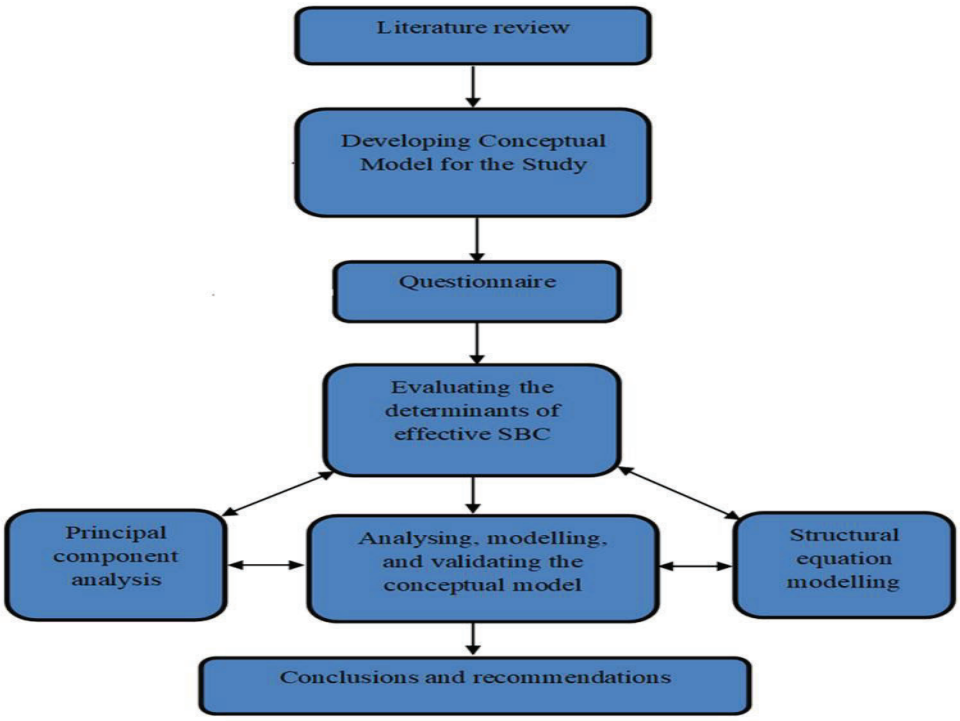


**Figure 1. 1:**The research process

The current study was based on the process depicted in Figure 1.1. The study adopted a quantitative approach. Hence, a structured quantitative questionnaire with closed-ended questions and a 5-point Likert scale was developed. The structured quantitative questionnaire (survey) was circulated to the sample population. As indicated by Creswell (2012), a survey in quantitative research is designed and distributed to a sample or the whole population to portray their perspectives, opinions, attitudes, behaviours, or characteristics. Besides, this technique is known for simplifying situations and reducing complexity to where they can be analysed and tested with statistical methods (McCuen, Ezzell, and Wong, 2011).

The study population include construction stakeholders in the Gauteng province of South Africa. The target respondents were mainly Built Environment professionals within the region, such as project

managers, project engineers, construction managers, architects, quantity surveyors, and engineers (civil, electrical, and mechanical). The researcher used the convenient sampling technique considering the availability of the respondents whose characteristics, knowledge and experience towards SBC were required, their willingness to participate and the generalisability of the findings (Creswell and Clark, 2011; Etikan, Musa, and Alkassim, 2016).

The primary data was analysed using the Statistical Package for the Social Sciences (SPSS) version 29.0 software and Amos software packages. The quantitative analysis included Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Structural Equation Modelling (SEM). Besides, the researcher used the principal component technique in refining and resizing the number of variables into components (Tabachnick and Fidell, 2013; Pallant, 2020), which was done with the SPSS software. On the other hand, the researcher used SEM to determine the extent to which SBC determinants (factors) influence effective SBC and the effects of effective SBC on sustainable project performance (success) outcomes. Furthermore, the researcher used SEM to develop an integrated SBC model for project delivery in South Africa and determine the hypothesised model's goodness of fit. The SEM represents an extension of general linear modelling (GLM) procedures, such as the analysis of variance (ANOVA) and multiple regression analysis, which are inferential statistics. Additionally, frequencies, mean values, and standard deviations are used as descriptive statistics outputs.

Generally, the researcher used Cronbach's alpha $\alpha$ 0.70 to adjudicate the reliability and internal consistency of the collected data. The reliability analysis can be defined as the extent to which one's collected data would produce an accurate or similar result if the study is repeated (Bell, 2014). This also assisted in validating the collected data. By validity, we mean the degree to which the collected data measures what is intended to measure (Bell, 2014). Additionally, through the literature review, reviews of the question survey by the supervisors, and the field investigation, the study's content validity were enhanced (Olson, 2010).

## 1.8 Significance of the Study

This study seeks to improve sustainable building construction (SBC) and project delivery performance in South Africa by providing an integrated model which will facilitate the effective construction of sustainable buildings. This is because the effective construction of sustainable buildings is linked with delivery performance success (Olanipekun, Xia, and Nguyen, 2017). Therefore, this study provides insight into the various factors essential in bringing about effective SBC in the South African construction industry. Besides, it seeks to determine the effects of effective SBC practices on broader aspects of project performance, including traditional metrics (time, cost, quality) and sustainable metrics (financial, environmental, and social performance), overall health and safety, client's/customer satisfaction and so on. Hence, it does not rely solely on the triangular constraints of time, cost, and quality performance. The knowledge of the effects of sustainable building construction practices on the performance measures will help improve the level of construction project performance among the organisations. Furthermore, the knowledge of the factors that will facilitate effective construction of sustainable buildings and the extent of their influence will assist policy and decision-makers in directing improvement initiatives appropriately for efficiency and effectiveness of project delivery performance. Hence, an increase in performance will positively impact the overall productivity and the sustainability of business growth. The success of the construction companies is pivotal and contributes to the economic abundance of the nation. Thereby, it would provide more platforms for job creation and employment opportunities for the populace.

## 1.9 Overview of Chapters

Chapter 1: Introduction

This section presents the background of the study and states the research problem, questions, objectives, scope, and significance of the study. It also briefly discussed the methodology for tackling the research problem.

Chapter 2: Understanding Sustainable Building Construction Research

This chapter presents a discourse on sustainable building construction (SBC). Hence, it discusses sustainability concerning building construction and the principles and the importance of sustainable building construction to project delivery. It also presents a discourse on sustainable building design and using sustainable building materials. Furthermore, it discusses the standard criteria (assessment tools) for evaluating the performance of buildings in terms of sustainability. Lastly, it discusses the benefits and barriers to SBC.

Chapter 3: Theoretical and Conceptual Perspectives of Sustainable Building Construction Research

The various theories and models associated with sustainable building construction was addressed in this chapter. Similarly, the study's conceptual framework was developed from the review of the determinants of SBC, and the identified gaps form the additional new construct.

Chapter 4: Gaps in Sustainable Building Construction Research

This chapter discusses in detail the identified gaps from the theoretical framework used as part of the conceptual framework, including the adoption of modern building techniques, Here the choice of project delivery strategy, and the use of project management techniques is indicated. Bridging the gap can effectively improve sustainable building construction in a developing country such as South Africa.

Chapter 5: Sustainable Building Construction (SBC) in Developing Countries: African Experience

SBC in developing countries such as Ghana and Nigeria were also reviewed. It outlines the lesson learned for consideration in the South African construction industry.

Chapter 6: A Review of the South African Construction Industry and the Practice of Sustainable Building Construction

This chapter presents an overview of the South African construction industry as it is the focal point for this study. It also discusses sustainable building construction (SBC) practices, including the policies and frameworks on sustainable building projects, the barriers and specific benefits of SBC to South Africa, and the implications on the economy of the South African nation.

Chapter 7: Research Methodology

The outline of the research process and a discussion on the methodology of the research study was addressed in this chapter. It involves a detailed description of the research approaches, survey instrument design, data collection procedure, and data analysis.

Chapter 8: The Conceptual Integrated Sustainable Building Construction Model

This section discusses the proposed integrated SBC model. It also indicates the constructs, the measurement indicators and explains the variables in detail.

Chapter 9: Results Presentation

This chapter presents the quantitative analysis of the findings from the survey. Its analysis includes descriptive and inferential statistics.

Chapter 10: Discussion of the Results

This chapter discusses and interprets the findings of the respondents presented in chapter 9 and relates these findings to the literature review.

Chapter 11: Conclusions, Contributions, and Recommendations

Here the conclusions drawn from the findings regarding the specific objectives of the research are presented. It will also discuss the study's contributions to both research and practice. Furthermore, recommendations for further research and investigations will be highlighted.

## 1.10 Research Delimitations

The study evaluated the influence of the six constructs (independent variables) of the conceptual framework (knowledge sharing, regulatory environment, corporate disposition, choice of project delivery strategy, the use of project management techniques, and modern building techniques) on SBC (dependent variable). It adopted a quantitative approach with questionnaire survey. Similarly, the study used Structural Equation Modelling (SEM) to establish the relationships between the independent and dependent variables, predicting the factorability validity of the measuring scale and scores, as well as determining the model's reliability. Data collection was limited to the experiences and practice of sustainability in building construction and green building construction among construction stakeholders in South Africa. The samples were predominantly obtained from the Gauteng Province of South Africa where a large volume of construction of residential, industrial, educational and office buildings occur.

## 1.11 Ethical Consideration

The researcher ensured that all ethical obligations were observed. Hence, ethical clearance was obtained from the ethics committee of the University of Johannesburg, Faculty of Engineering, and the Built Environment. A consent letter was issued for permission to collect data. Besides, anonymity was observed regarding the participants' input; and their participation was based on free will. Notably, the reviews from the literature were appropriately cited. The ethical clearance certificate can be found in appendix D.

## 1.12 Chapter Conclusion

This chapter presented the study's background, which reflects the study's requirements. Moreover, it gave a short clarification of the various parts of this research, which includes the research problem, research questions, research objectives, hypotheses of the study, research rationale, scope of the study, significance of the study, research methodology, the structure of the thesis, and the ethical considerations for the study.

Chapter two presents an overview of sustainable building construction (SBC) and discusses the principles and importance of sustainable building construction to project delivery. Additionally, it offers a discourse on sustainable building design and the use of sustainable building materials. Furthermore, it discusses the standard criteria (assessment tools) for evaluating the performance of buildings in terms of sustainability. Lastly, it discusses the benefits and barriers to SBC.

# CHAPTER TWO

# UNDERSTANDING SUSTAINABLE BUILDING CONSTRUCTION RESEARCH

## 2.0 Introduction

This chapter presents a discourse on sustainable building construction (SBC). Hence, it discusses sustainability regarding building construction and the principles and importance of sustainable building construction to project delivery. Additionally, it presents a discourse on sustainable building design and the use of sustainable building materials. Furthermore, it discusses the standard criteria (assessment tools) for evaluating the performance of buildings in terms of sustainability. Lastly, it discusses the benefits and barriers to SBC.

## 2.1 Overview of Sustainable Building Construction Research

### 2.1.1 Sustainability and Sustainable Development Theory

Sustainability is a concept that can be applied in various disciplines. It widely focuses on meeting the present's needs without compromising future generations' ability to meet their needs (Serpell et al., 2013; Alwan and Saleh, 2020). This definition is associated with sustainable development from the Brundtland Commission Report (Our Common Future: The Report of the World Commission on Environment and Development) advertised in 1987. This report defines sustainable development, as cited in Alwan and Saleh (2020:3), as the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Additionally, the "Brundtland Commission" contended that “social and economic systems could not be separated from the carrying capacity of the environment – the possibility that the preservation of ecological assets must adjust development and social welfare by the present age to assist people in the future” Alwan and Saleh (2020:3). Hence, the "sustainability movement" does not only focus on protecting the environment, but instead focuses on finding a

careful balance between the economics, environment, and social justice (society) (Häkkinen et al., 2016; Alwan and Saleh, 2020). These three factors form the core pillars of sustainability (United States Environmental Protection Agency (EPA), 2015).

#### *2.1.1.1 Environmental sustainability*

The environmental aspect of sustainability deals with the maintenance of ecological integrity. That ensures that humans use the natural resources at a rate where they can replenish themselves. This approach helps balance all the earth's environmental systems, hence, maintaining a healthy ecosystem beneficial to humans and other organisms (Mcgill University, n.d). There are two primary ways to reduce human impact and enhance ecosystem services. These include environmental management and human consumption management. Environmental management at a broader scale includes land, atmosphere, oceans, freshwater systems or any ecosystem. In contrast, management of human consumption of resources is an indirect approach generally based on information acquired from economics (Buchenrieder and Göltenboth, 2003).

#### *2.1.1.2 Economic sustainability*

Economic sustainability focuses on ensuring that resources (financial and other) are made available to human communities across the globe to meet their needs while maintaining their independence (Mcgill University, n.d). It accommodates the implementation of sustainable business practices, which also helps in the expansion of business opportunities and, in turn, job creation (Hickman, 2009).

#### *2.1.1.3 Social sustainability*

Social sustainability focuses on ensuring that all people have access to enough resources to keep their families and communities healthy and secure (Mcgill University, n.d). Mcgill University (n.d) This also states that healthy communities are characterised by leaders who strive to respect all people's personal labour and cultural rights and ensure they are protected from discrimination (Mcgill University, n.d). According to Cohen (2006), social sustainability systems can be improved in a broader view through education and empowering women politically, especially in

developing countries. It also includes respecting social justice, striking a balance between the rich and poor, and intergenerational equity (Cohen, 2006).

### 2.1.2 Building construction

Building construction can be described as the technique and industry involved in the assembly and erection of structures, primarily those used for shelter (Swenson and Chang, 2020). Construction is a human activity that has been around for ages and initiated to moderate the effects of climate through a controlled environment. Consequently, by constructing shelters, humans are opportune to adapt to climate changes and become a global species (Swenson and Chang, 2020). On a broader note, Du Plessis et al. (2002:4) defines construction as the

> *"broad process/mechanism for the realisation of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of raw materials, the manufacturing of construction materials and components, the construction project cycle from feasibility to deconstruction, and the management and operation of the built environment*".

Globally, the building construction sector has been recognised as pivotal in satisfying a high level of human needs and facilitating societal change toward sustainable development (Lu and Zhang, 2016; Tabassi et al., 2016). According to Ofori (2007) cited in Serpell et al. (2013), the construction industry (including the building sector) contributes to socio-economic and environmental impact in four ways. Firstly it is the contribution to building infrastructures and houses in high demand in developing countries, hence improving the standard of living (Gomes and Silva 2005). The second is that it contributes to the Gross Domestic Product. Thirdly, it provides direct employment opportunities to millions of people globally. The Fourth way is the spreading of construction products throughout the country and collaboration to develop entrepreneurship and transfer technology to all citizens of the country (Serpell et al., 2013).

Nevertheless, the construction industry's activity harms the climate, environment, human health, and national economies (Zhang et al., 2011). For example, it consumes about 40% -50% of the

world's raw materials and 40%-45% of the energy (World Energy Outlook, 2011; Tabassi et al., 2016; Murtagh et al., 2020). Additionally, it consumes about 25% to 70% of the wood for construction and maintenance (World Energy Outlook, 2011; Tabassi et al., 2016; Anzagira et al., 2019.) Regarding the world's freshwater withdrawals and land usage, the construction sector accounts for 17% to 60%, respectively (World Energy Outlook, 2011; Tabassi et al., 2016). Furthermore, it emits about 35%-40% carbon dioxide and generates 65% of waste materials globally (Son et al., 2011; Anzagira et al., 2019). Notably, it is acknowledged that the construction of buildings is primarily to blame for these challenges (Saad, 2016; Tabassi et al., 2016; Anzagira et al., 2019; Murtagh et al., 2020). Besides, "buildings in their unique state are the main users of electrical energy, and thus play a critical role in contributing to global warming and the depletion of natural resources" (Saad, 2016:183). Therefore, it is essential to explore sustainable alternatives for buildings from an environmental, social-psychological, and economic point of view, as well as to increase global experience and apply it creatively to reach higher standards of economic and social welfare (Roufechaei et al., 2014). Consequently, construction, especially building, must be done in a way that aligns with sustainable development goals.

## 2.2 Principles and Importance of Sustainable Building Construction Toward Project Delivery

The basic principles of sustainability that tackle environmental, economic, and social issues must be incorporated into the construction of buildings towards actualising a successful project delivery in alignment with sustainable development goals. Infrastructure development, like building construction, is part of national development. It can drive a nation's economic growth and improve the community's welfare when successfully aligned with sustainable development. By 2056, the world population, economic activity, and energy utilisation will have expanded by at least 50%, fivefold, and triple, respectively, as estimated (Ilha et al., 2009; Akadiri, Chinyio, and Olomolaiye, 2012). Building sustainably is, therefore, in increasing demand and essential to ensure that the depletion of resources is mitigated. The building industry is known to be one of the most resource-intensive industries in the use of raw materials, water, and energy and is a

significant contributor to environmental pollution, ozone layer depletion, and waste (Osmani, Glass, and Price, 2008; Ilha et al., 2009; Willar et al., 2020). Building construction impacts on the environment, climate, society, and economy. Hence, sustainable building construction (SBC) is an approach to guaranteeing that all construction activities are being done sustainably across all the project stages while having in mind the environmental, social, and economic implications (Ismail et al., 2017). Besides, the sustainable construction of buildings should improve ecological objectives by integrating economic and social issues to pursue quality of life, work efficiency, and a healthy work environment (Abd Jamil and Fathi, 2016).

Additionally, the practice of sustainable building construction alludes to different strategies, tools, and techniques used to implement building projects that are less harmful to the environment, reduce or prevent waste production, increase waste management (reuse of waste in the production of building material), be advantageous to the society, and profitable to the company (Asokan, Osmani, and Price, 2009; Ruggieri et al., 2009; Tam, 2009; Willar et al., 2020). Sustainable building construction not only starts from the inception and planning stage of the building but extends to its life cycle and possible deconstruction and waste recycling (Tam, 2009; Willar et al., 2020). Sustainable building construction also focuses on reducing the rate of energy consumption during construction and the entire life of the building considering the materials used, building components, construction technologies, and energy-related design concepts (Abd Jamil and Fathi, 2016; Ismail, Halog and Smith, 2017; Oke, Aigbavboa, and Semenya, 2017; Balasubramanian and Shukla, 2017). Furthermore, sustainable building construction considers issues regarding safety, efficiency, and productivity (Abd Jamil and Fathi, 2016; Willar et al., 2020).

Hussin, Rahman, and Memon (2013) enlisted sustainable principles that can be applied in construction project delivery under environmental, economic, and social dimensions. Environmental dimensions include increment in the efficient use of materials by minimising the material demand for non-renewable goods. This is through reducing material intensity by replacement technologies; improving material recyclability; diminishing and controlling the usage and disposal of toxic materials. In this manner lessening the amount of energy needed for

transforming, supplying goods and services; supporting the instruments of worldwide conventions and agreements; maximising the sustainable utilisation of biological and renewable resources; and considering the effect of planned projects on air, soil, water, flora, and fauna. Economic dimensions involve life-cycle cost consideration, internalisation of external cost; consideration of alternate funding system; fostering of proper monetary instruments to advance sustainable consumption and consideration of the economic effect on local structures. Social dimensions involve improving a participatory methodology by including stakeholders, promoting public interest, advancing the development of suitable institutional frameworks, considering the influence on the current social background, and assessing the effect on health and the quality of life (Hussin et al., 2013).

Ochieng et al. (2014) also mentioned ten key themes of sustainable principles that can be integrated into construction project delivery. These principles include designing for minimum waste (using recyclable materials); renovating an existing building to improve its sustainability if possible; aiming for leaner construction; minimising energy in construction and usage and eliminating pollution. The other five include preserving and enhancement of biodiversity, minimising the use of water, responsiveness to local community and workforce, benchmarking performances and setting goals for constant improvement (Ochieng et al., 2014).

Nevertheless, sustainable principles cannot be successfully implemented without specific requirements. There should be objectives for innovation and technology enhancement (Abd Jamil and Fathi, 2016; Oke et al., 2017; Shurrab et al., 2019; Willar et al., 2020). In addition, strategies for implementing and practising waste management should be clearly defined (Tan, Shen, and Yao, 2011; Yates, 2013; Djokoto, Dadzie and Ohemeng-Ababio, 2014; Waidyasekara, De Silva, and Rameezdeen, 2017). Besides, there should be a responsibility to educate and transfer the knowledge of sustainable concepts to stakeholders for performance enhancement (Tan et al., 2011; Sfakianaki, 2015; Abd Jamil and Fathi, 2016; Schröpfer, Tah, and Kurul, 2017; Shurrab et al., 2019; Willar et al., 2020). According to Shurrab et al. (2019), sustainable practices should be applied in the projects and throughout the organisation. The authors also assert that there should be adequate monitoring for compliance with regulations of green practices (Shurrab

et al., 2019). Project management knowledge and skills should be emphasised for effective methods of sustainable building construction (Agyekum-Mensah et al., 2012; Ismail et al., 2017). Besides, good intra-organisational leadership is needed for policy formulation, promotion, and implementation of best sustainable practices throughout the organisation (Opoku et al., 2015; Willar et al., 2020). According to Sfakianaki (2015) and Balasubramanian and Shukla (2017), there should be training and investment in the building's methods and practices which are resource efficient. Also, Sfakianaki (2015) mentioned that supply chain actions should be well coordinated and managed to suit the project complexity and the stakeholders involved. Therefore, ensuring project efficiency and that supplies, resources, and information are delivered without delay (Sfakianaki, 2015). Furthermore, to implement sustainable principles, assessment tools and rating systems are required to ascertain the effects on the environment (Presley and Meade, 2010; Attallah et al., 2013) as well as a sustainable building index for potential improvement (Hassan, 2016; Willar et al., 2020).

## 2.3 Sustainable Building Design

This aims to apply sustainability to the Built Environment, while considering buildings' economic, social, and ecological impact on their surroundings (Wang and Adeli, 2014). Additionally, the sustainable design considers the whole life cycle of a building and investigates approaches to decreasing the adverse environmental effects of building activities (Efthymiou, Cöcen, and Ermolli, 2010; Wang and Adeli, 2014). Furthermore, according to Efthymiou et al. (2010:3102), it accommodates "*the choice of recyclable construction materials and products since saving energy is a major objective, and the removal or not of materials at the end of their life cycle depends on this choice.*" Some of the applications regarding sustainability in design and materials are discussed in the following subsections.

### 2.3.1 Sustainable building materials (structural materials)

Researchers and practitioners have started exploring strategies for sustainable construction due to environmental concerns and depleting resources (Asdrubali, Schiavoni, and Horoshenkov, 2012).

A vital part of these strategies is the selection of sustainable materials for building construction. Hussain and Kamal (2015:38) defined sustainable building materials (SBM) as "those materials which reduce the use of resources, materials that minimise the environmental impacts, materials that pose no or low human health risks, materials that assist with sustainable site design strategies and materials from companies with sustainable social, environmental and corporate policies". Hence, it is paramount to study some of the existing and latest advancements in materials that can sustainably complement the environment and improve quality of life, user health and comfort, energy efficiency, resources, water conservation, life cycle cost reduction, and durability.

#### *2.3.1.1 Timber and alternative lumber*

Wood can be utilised as a reused and innocuous item in low-rise buildings (Wang and Adeli, 2014). According to Austin Energy (2013), alternative lumber made of recycled materials such as composite or plastic lumber (a recyclable material made of virgin or waste plastic) has found increasing applications, especially for outdoor decks. "Compared with traditional woods such as yellow pine, untreated cedar, and redwood used in outdoor decks, alternative lumber has better aesthetics, slip-resistance, and durability. Alternative lumber can cost less in the long run because it requires little maintenance during its lifetime" (Wang and Adeli, 2014:3).

Guo et al. (2020) studied the use of mineralised struvite wood as a sustainable material in terms of mechanical and combustion behaviour. They found that struvite mineralisation treatment of woods increases their fire resistance ability compared to wood boards created with local timber. During the calorimeter test, the wood boards made with mineralised wood achieved a heat penetration rate of 0.6mm/min, which is half of the local wood panels. Also, the transverse strength and stiffness under compression were improved. Hence, they presumed that wood mineralisation by struvite might empower the more-broad utilisation of wood in the construction sector as a substitute for less eco-friendly building materials.

Al-Khattat (2008) demonstrated how a light prestressed segmented arch (LPSA) could be used for bridges as a sustainable structural engineering design. The segmental arch was made of

sustainable small diameter round woods or log members with their natural growth rings. The bridge is proven to be in harmony with its natural environment (Al-Khattat, 2008; Wang and Adeli, 2014). Similarly, cross-laminated timber (CLT) has been identified as a sustainable alternative for concrete and steel given its comparatively low carbon footprint, high strength-to-weight ratio, ease of installation, and aesthetic qualities (Sandoli et al., 2021; Younis and Dodoo, 2022). Younis and Dodoo (2022) discovered that utilising CLT instead of traditional building materials (concrete/steel) for multi-story buildings resulted in a 40% lower carbon footprint. CLT structures are advantageous for seismic resistance and environmental sustainability, which makes them a strong substitute for heavyweight constructions (Sandoli et al., 2021). Furthermore, CLT is considered a good option to assist in combating climate change and is very suitable in areas with erratic weather patterns (Ilgın, Karjalainen, and Mikkola, 2023).

#### *2.3.1.2 Masonry (composite bricks)*

Masonry is advantageous for sustainable construction in specific ways. Its thermal insulating characteristics enable it to keep warm or cool for a lengthy period (Wang and Adeli, 2014). Also, it is readily available in most parts of the world; and can provide a natural indoor environment without the requirement for painting. Masonry can be achieved for sustainable construction in different ways and even as a composite unit.

Rajput et al. (2012) used paper mills waste and cotton waste to make waste-create bricks (WCBs). The weight content of the paper mills and cotton of (1 to 5) % and (89-85) % were used, respectively, with a 10% fixed range of Portland cement by weight. The contents were prepared and tested per IS 3495 (Part 1–3): 1992 standards. Also results showed that the bricks are thermally stable and meet the standard (Rajput et al., 2012; Madurwar, Ralegaonkar, and Mandavgane, 2013). Raut, Mandavgane, and Ralegaonkar (2014) assessed the thermal performance of recycled paper mill waste–cement bricks using the small-scale model technique. In their study, three small-scale model houses comprising bricks made of recycled paper mill waste (RPMW), fly ash bricks, and ferrocement wall panels were built to evaluate the environmental and economic performance of the sustainable construction materials. Particularly,

the indoor temperature of the model houses was monitored for a year. Results showed that the model house made of RPMW cement brick was more thermally resistant and economical than the other houses made of fly ash and ferrocement wall panel. Hence, RPMW-cement brick was the best choice for construction in terms of energy efficiency as it minimises energy consumption by reducing indoor temperature (Raut et al., 2014).

Kumar, Chani and Deoliya (2015) affirmed Burnt Clay Flyash Bricks (BCFB) as low-energy building materials and technologies to substitute conventional burnt clay bricks. BCFB is a composition of the soil (with a minimum of 20% clay), fly ash, sand, and fuel coal. Compared with conventional burnt clay, BCFB is more environmentally friendly, energy-efficient, and has better thermal insulation. There is also a decrease in weight and emissions from kilns and a decrease in drying shrinkage and efflorescence. Besides, the unburnt carbon content in fly ash helps decrease fuel consumption (Kumar et al., 2015). The brick has properties as thus: compressive strength (75 - 150 kg /cm2), unit weight (2.5- 3.0 kg/brick), water absorption (12 - 18%) and density (1700-1900kg/m3) (Kumar et al., 2015). The innovation is created by CSIR-CBRI (Kumar, 2012) and for different subtleties, the code of practice IS - 13757, 1993 might be alluded (Kumar et al., 2015).

Another study by Taki, Gahlot and Kumar (2020) focused on fly ash amended sewage sludge as a brick for sustainable building material with particular emphasis on dimensional effect exhibits the usage of Fly Ash (FA) at varying rates (with an interval of 10%) with SS as a brick for sustainable building material. The impact of the dimensional effect is measured using compressive strength behaviour for a stress rate of 14 MPa/min of two different brick sizes (D1: 7 × 7x7 $cm^3$; D2:2 × 2x2 $cm^3$). D1, composed of 60% and 40% FA gave a maximum strength of 4.02 Mp,a while consisting of 40% SS and 60% FA gave a total strength of 7.6 MPa. From the results, D2 showed a better strength and was far above the required 3.5Mpa cut-off strength for a typical building brick by Indian Standards (13757: 1993). The additional advantage in the study was that the prepared fired brick had lower thermal conductivity (0.48 $Wm^{-1}K^{-1,}$) inferring its better insulation property.

There are also sand lime bricks from calcium silicate. These bricks are usually 229 x 114 x 76 mm, or 200 x 100 x 100mm and are used as substitutes for conventional burnt clay bricks. According to Kumar et al. (2015), they are environmentally friendly and energy efficient; they have better thermal insulation, reduction in weight and efflorescence with a compressive strength of 85 to 150kg/cm2 and density of 1500 to 1800kg/m3.

Djamaluddin, Caronge, Tjaronge, and Irmawaty (2021) experimented with fired clay bricks incorporating palm oil fuel ash as a sustainable building material. They found that a lighter brick was produced when mixed with palm oil fuel ash; however, the flexural and compressive strength diminished. The rate of water absorption expanded because of the presence of a more porous structure. Additionally, the specimen with palm oil fuel ash had a higher resistance to forming efflorescence than conventional bricks. Still, there was poor resistance when exposed to sulphate attack. In summary, the discoveries of this study propose that up to 5% POFA can be utilised as clay substitution for bricks manufactured in a local brick kiln industry to satisfy the ongoing international standards for traditional bricks.

Alami (2010) explored the impact of adding unburnt olive husk to clay bricks on its thermomechanical properties. The study added a varied amount of husk alongside the drying temperature. The specimen achieved a lower thermal conductivity than the conventional clay bricks. From the outcomes, the best-suggested drying temperature for samples was 75° C for all husk content except for 40%, while a temperature of 125° C was considered best. This specific mix of husk content and drying temperature created material with unrivalled properties as far as sturdiness and strength, which were concerned, these reflected incredibly in their manufacturability into sheets that can be utilised as an insulating material. Additionally, the specimen achieved the best thermal conductivity results (around 0.09 W/mK), which makes it incredibly appealing as a simple-to-deliver substitute for costly or dangerous insulating materials.

Ling and Teo (2011) studied the possibility of using waste rice husk ash (RHA) and expanded polystyrene (EPS) in producing lightweight bricks. In the mixes, cement was partially replaced

with RHA, while the aggregate was partially replaced with EPS. The design properties of the made bricks were examined. It was found that the properties were chiefly imparted by the content of EPS and RHA and the curing method adopted. The result showed that increased RHA resulted in decreased water absorption, less density, and improved compressive strength in most parts of the specimens.

Chiang et al. (2009) manufactured the lightweight bricks from the sintering mixes of dried water treatment sludge and rice husk. Specimens with up to 20%wt rice husks had been fired using a heating schedule that allowed effective organic burn-out. It was observed that adding about 15% wt. and sintering at 1100_C low density and relatively high strength bricks are produced, which comply with relevant Taiwan standards for lightweight bricks.

Another study from Bisht et al. (2020) revealed that bricks can be produced from bacteria-infused stabilised desert sand-cement and used as an alternative material for conventionally available bricks. The specimen achieved an unfired compressive strength ≥ 5MPa. Also, Demir (2008) tested the effect of organic residue addition on the technological properties of clay bricks. The organic residues used in the mix included long cellulose fibres like sawdust and tobacco. The outcome showed that the insulation capacity of brick is directly proportional to an increment in the porosity of the clay body. Additionally, no extrusion problems were created by the fibrous nature of the residue. Therefore, the residue component can be used as a sustainable building material.

According to Algin and Turgut (2007, 2008), limestone dust and sawdust, as well as cotton waste and limestone powder waste, produce bricks as a sustainable material. They are lightweight and low in cost. Additionally, they achieved at least the minimum required compressive strength and water absorption capacity for walls and can serve as an economical substitute for concrete blocks. Other benefits of the mix are the great potential of using them as sound barrier panels, wooden boards, alternative ceiling panels, and so on. (Madurwar et al., 2013).

#### *2.3.1.3 Masonry (composite blocks)*

A study by Kumar et al. (2015) identified that cellular lightweight concrete blocks could be an alternative to conventional bricks/blocks. They can be made with a mix of fly ash, cement, fine sand, and foaming agents in sizes of 600 x 200 x 200 /100 mm, 500 x 250 x 200 /100 mm, and 500 x 400 x 100 mm. Besides being lightweight, the specimen is environmentally friendly and energy efficient. Also, it has high thermal insulation suitable for air-conditioned buildings. They (Kumar et al. 2015) also mentioned that solid and hollow concrete blocks in sizes of 300 x 200 x 150 mm, and 400 x 200 x 200 mm/400 x 200 x 150 mm, respectively, can also be made with industrial wastes such as fly ash, blast furnace slag and the like. Along with cement, sand and aggregates. The salient features, inter-alia, include "environment-friendly and energy-efficient cost-effective walling option, simple manufacturing process, less consumption of mortar, faster masonry" (Kumar et al., 2015:16).

Lertsatitthanakorn et al. (2009) experimented with rice husk ash sand–cement block to reduce solar conduction heat gain to a building. Results showed that it reduces solar heat transfer by 46 W compared to standard commercial clay brick.

#### *2.3.1.4 Cementitious, pozzolana and binder material*

Gorospe, Booya, Adesina, and Das (2020) investigated the durability properties of mortar overlays with glass aggregates and determined the benefits of utilising glass to reduce early-age cracking of mortar overlays. Results showed positivity and proposed that glass aggregates can effectively mitigate the crack formation rate to about 98%. Additionally, at complete glass substitution, the initial water absorption rate decreased by 31% and secondarily by 63%. Cassar and Camilleri (2012) assessed the mechanical properties of concrete that contained crushed glass aggregate used to replace the cement in proportions from 10 to 50%. For 10–40% replacement, Results showed a compressive strength of about 30 MPa and flexural strength above 5 MPa after curing for 28 days and 90 days.

A study by Mokal et al. (2015) conducted in India utilised lime for cement replacement in building construction, showed that lime could bring about good air quality by absorbing the atmospheric carbon and emitting oxygen. Also, the specimen strengthened as time passed by in terms of quality and life span and hence, better than cement building.

Another study by Adesanya and Raheem (2009) examined cement production using corn cob ash (CCA) as a pozzolanic material. Corn cob ash was used to replace ordinary Portland cement. The produced blended cement meets the requirements of NIS 439:2000 and ASTM C 150 (Adesanya and Raheem, 2009; Madurwar et al., 2013).

Rodrigues et al. (2015) discovered that one of the mediums to diminish the environmental effects of cement production is by combining the cement clinker with supplementary cement materials (SCM), bringing about mixed cement. Rodrigues et al. (2015) used sugarcane bagasse ash (SCBA) and rice husk ash (RHA) as supplementary cement materials, which resulted in cement composites and concretes with improved properties. Also, the sugarcane bagasse ash and rice husk ash used resulted in composites that performed better and kept up with bending strength after wet drying cycles when applied to cellulose-cement composites. The performance improvement was attributed to the pozzolanic reaction of the SCBA and RHA that advances a less forceful matrix to the fibres and a superior fibre-matrix interface. Furthermore, Rodrigues et al. (2015) investigated the behaviour of the supplementary cement materials in concretes when subjected to severe acid attacks. Sugarcane bagasse ash brought about higher compressive strength in concretes. This shows that it may be applied in agro-industrial facilities with forceful conditions, for example, in pig farms. Therefore, the study concludes that supplementary cement materials are a viable substitute for more sustainable cement and concretes in construction.

Another study by Amin (2011) depicts that bagasse ash can be used as a cement replacement in concrete. In the survey, bagasse ash was found as an effective mineral admixture and pozzolana with the first proportion of 20% cement, which decreased the chloride diffusion by over half with practically no unfavourable consequences for different properties of the hardened concrete. Ganesan, Rajagopal, and Thangavel (2007) also explored the impacts of bagasse ash content as a

partial replacement of cement on hardened concrete's physical and mechanical properties. Both compressive strength and tensile strength were studied as well as water absorption, permeability characteristic, chloride diffusion and resistance to chloride ion penetration. Results showed that bagasse ash is an effective mineral admixture, with 20% as the ideal proportion for cement replacement. Similarly, Chusilp et al. (2009) found the same proportion of 20% as ideal for cement replacement in concrete. Hence, findings revealed that ground bagasse ash could be utilised as a pozzolanic material in concrete with adequate strength, lower heat evolution, and reduced water permeability regarding the control concrete. Furthermore, Fairbairn et al. (2010) found that sugarcane bagasse ash (SCBA) blended cement reduces $CO_2$ emissions and generally improves the behaviour of cementitious construction materials.

Likewise, Rukzon and Chindaprasirt (2012) partially replaced Portland cement type 1 in concrete mixtures with ground bagasse ash (BA) by 10%, 20%, and 30%, respectively. The aim was to examine the behaviour of BA when used as a pozzolanic material for delivering high-strength concrete. Findings revealed that 30% replacement with BA would enhance resistance to chloride penetration. Hence, the replacement was found suitable for creating high-strength concrete. Additionally, 10% of BA utilisation delivered concretes with good strength and low porosity. Suvimol and Daungruedee (2008) achieved similar results with ground ash held on “sieve no. 325 in the range of 3–28” in cement substitution percentages of between 20 to 40. Furthermore, Akram, Memon, and Obaid (2009) observed that the blending of BA with concrete was around 35.63% less expensive than control concrete after cost analysis. Also, the mix with BA had a compressive strength higher than 34 MPa.

Another study by Cordeiro et al. (2009) found that fusing ultra-finely ground ash in high-performance concrete improved resisting chloride ions penetration. However, there was no measurable change in mechanical behaviour. Similarly, Sata et al. (2007) used pozzolana agro waste products to partially replace high-strength concrete (Portland cement) to determine their effects on mechanical properties. The outcomes recommended that agro-wastes such as “ground rice husk–bark ash (RHBA), ground palm oil fuel ash (POFA), ground pulverised coal combustion fly ash (FA), and ground fluidised bed combustion fly ash (FB)” can be utilised as

an alternative to Portland concrete to deliver high-strength concrete without modifying the mechanical properties of concrete.

However, a study by Ramasamy and Biswas (2008) that used rice husk ash (RHA) as a cement replacement material indicated that the optimum quantity of RHA increases the mechanical properties of concrete. This is also in alignment with Xu et al. (2012), who suggests that RHA can partially replace cement as a mineral admixture for construction purposes. It was seen that the ideal burning temperature for acquiring highly reactive RHA is 600 _C. Furthermore, Memon, Shaikh, and Akbar (2011) used RHA as a viscosity modifying agent in self-compacting concrete (SCC). Results suggest that it is viable to use RHA in producing low-cost SCC. Cost analysis revealed that ingredients of specific SCC mix cost less than that of control concrete by 42.47%.

Jaturapitakkul et al. (2007) evaluated the sulphate resistance of concrete containing palm oil fuel ash. The outcomes proposed that ground POFA (medium and small specimen) could be utilised as a pozzolanic material and improve the sulphate resistance of concrete. Results also showed that by increasing the fineness of POFA, the concrete's expansion and loss in compressive strength were diminished.

Coloured lime plaster was identified by Mokal et al. (2015) as a better solution for replacing conventional paint in building construction, as it reduces the painting for the whole structural life. Also, it is maintenance-free, washable, and waterproof compared to cement plastering and paint work (Mokal et al., 2015). Although it costs more than regular paints, it is cheaper in the long run. Furthermore, it is odourless and provides better indoor quality. Generally, lime in the building was found to be essential for reducing the hazardous impact on the environment by its carbon absorption (Parashar, and Parashar, 2012; Mokal et al., 2015).

#### *2.3.1.5 Aggregate (fine and coarse) alternatives*

Richardson et al. (2011) investigated recycled aggregate concrete's freeze/thaw durability compared to concrete produced with virgin aggregates. Results showed equal durability with

both recycled aggregate concrete and virgin aggregates. Results, therefore, indicate that the recycled aggregate can be used as a suitable alternative/replacement to the natural/virgin aggregates.

Oil Palm Shell (OPS) was discovered as an alternative coarse aggregate to be used for structural concrete, having about1850kg/m3 bulk density and compressive strength of 20 to 24 N/mm2 (Madurwar et al., 2013). These properties were suitable for lightweight concrete (Madurwar et al., 2013).

Sugarcane bagasse ash (SCBA) was used by Sales and Lima (2010) to replace sand when preparing mortars, and concretes and performance tests were done. The specimens' results showed similar physical properties to that of natural sand. Besides, the mortars produced with SCBA in place of sand showed preferred mechanical outcomes over the ordinary mortar.

Crushed rock sand (CRS) was discovered as an excellent partial alternative for fine aggregate (natural sand) when preparing concrete (Kirthika, Singh, and Chourasia, 2020). Up to 30% replacement resulted in an improvement in the hardening properties of concrete. A denser microstructure was produced, having lesser voids. The concrete had higher carbonation resistance, low chloride penetration, and shrinkage. Besides, the crushed brick aggregate showed more increase in mechanical properties than crushed concrete (Kirthika et al., 2020).

The use of steel fibre (steel slag, steel sludge), imperial smelting furnace slag, copper slag, and waste foundry sand in concrete, increased the mechanical properties, especially palm-oil clinker, as it actuates a pozzolanic response in concrete (Roslan et al., 2016; Kirthika et al., 2020). The durability properties of the concrete were enhanced with the inclusion of bottom ash, imperial smelting furnace slag, steel slag, waste foundry sand, etc., up to 30% (Kirthika et al., 2020). Given the study by Biskri et al. (2017), including steel slag aggregate in high-performance concrete (HPC) can enhance its mechanical strength and durability. Nevertheless, high expansion steel slag ought not to be utilised in producing concrete without the treatment of free oxides to diminish its expansion ability (Biskri et al., 2017). Roslan et al. (2016) used steel slag and steel sludge generated from the melting process of metal scrap and steel wire production,

respectively. Results showed that including these steel fibres in concrete enhanced its compressive strength. Steel slag (10% to 20%) replacement was recommended in concrete, with 10% achieving the best compressive strength. Also, 15% of steel sludge was recommended for achieving the desired compressive strength. Besides, the steel fibres can enhance recycled aggregate concrete beams' maximum strain and shear behaviour (Chaboki et al., 2019).

Glass aggregate (GA) is also an option to produce concrete and helps reduce the extraction of primary resources and waste recycling (De Castro and De Brito, 2013; Zamora-Castro et al., 2021). Concrete was produced by De Castro and De Brito (2013) by replacing construction aggregate with different mixtures of glass aggregate (fine and coarse) with a percentage rate of 0%, 5%, 10%, and 20%. The results showed improved workability of glass aggregate concrete (GAC) for water–cement ratio between 0.55 and 0.58 and 20% of fine GA. Also, the water absorption of the GAC decreased between 14 and 24% for 5 and 10% replacement percentage of fine glass aggregate. Furthermore, there was no durability significance compared to using natural aggregate. Results on mechanical strength indicate that the concrete produced will be best suited for low mechanical strength concrete works.

Lee et al. (2013) recorded the impact of the proportion ratio, and size range of recycled fine glass (FG) aggregates on the properties of concrete blocks. About 17 blocks (size: 70 mm × 70 mm × 70 mm) were tested with different mixtures using the content of 25%, 50%, 75%, and 100% of FG. Results showed that concrete blocks replaced with 100% FG aggregate (size < 600 μm) increased in compressive strength (about 58.44 MPa) after 28days of curing more than the control concrete (43.51 MPa), while the other percentage replacements did not. The findings also aligned with De Rosso and de Melo (2020), who found that recycled glass aggregates can reduce mechanical properties in concrete blocks when not adequately replaced. Hence, to use recycled glass as aggregate in concrete blocks, it is critical to determine its ideal replacement content to actualise a better compressive and flexural strength without affecting the workability of the concrete (Zamora-Castro et al., 2021).

Ceramic powders can have pozzolanic activity and be used as a cementing agent or as an aggregate in concrete (Rashid et al., 2017; Zamora-Castro et al., 2021). Rashid et al. (2017) researched sustainable concrete employing ceramic waste and evaluating its efficiency as a replacement for aggregate to conserve natural resources. The results show that a concrete with a 30% replacement proportion generates high compressive strength compared to the control specimen. The compressive strength increased with time after curing for 28 and 63 days. The concrete volume was linearly reduced up to 17% with 30% replacement of ceramic waste. However, the water absorption rate of the concrete increased because of clay content but for only a difference of 3.34% compared to conventional concrete. The study concludes that ceramic waste has less impact on the environment and is, therefore, an option for sustainable concrete.

Mud content aggregate was also discovered as an option for aggregate replacement (De Almedia and Zulanas, 2016; Zamora-Castro et al., 2021). De Almedia and Zulanas (2016) studied the implementation and feasibility of hazardous waste (muds) produced from water purifying systems in manufacturing concrete. Results showed that 5% of mud content as an aggregate in concrete could be used in low mechanical strength constructions like sidewalks and concrete pathways. The study concludes that it can help preserve the environment and reduce the cost of aggregate used in concrete.

Adesina and Das (2021) propose that recycled asphalt obtained from recycling damaged pavements can be a viable alternative to replace conventional aggregates (silica sand), especially if partially replaced. Using recycled asphalt as an aggregate, benefits embodied carbon and cost reduction.

#### *2.3.1.6 Reinforced concrete/masonry alternatives*

Rahman et al. (2011) evaluated the performance of bamboo reinforced concrete beams and from stress-strain curves of bamboo. The result from the flexural test showed that using bamboo as reinforcement in concrete can increase the load-bearing capacity of a beam of the exact dimensions. Single and double bamboo reinforced concrete beams have a load bearing capacity of about 2 and 2.5 times, respectively, compared to the plain concrete beam with the exact

dimensions. However, bamboo has a low modulus of elasticity in contrast with steel and cannot prevent concrete cracking under ultimate load. Nevertheless, a study by Agarwal et al. (2014) reported that treated bamboo reinforcement could be as sound as the conventional steel reinforcement in ordinary concrete. Bamboo was also affirmed to have a relatively high tensile strength, up to about 370 Mpa and six times greater than steel in terms of tensile strength ratio to the specific weight of bamboo (Madurwar et al., 2013). Mahzuz et al. (2011) studied the strength properties of composite members made up of bamboo. The outcomes revealed that samples constructed as an aid of bamboo could offer a respectable amount of strength that can be safely used for low-cost housing. Mark and Russell (2011) conducted a comparative study of bamboo reinforced concrete beams with shear links made of different materials.

The other stirrup materials considered were bamboo, rattan cane, and steel. The study proposed using steel stirrups with bamboo to reinforce concrete beams will improve the load bearing capacity. Mali and Datta (2018) evaluated the behaviour of various concrete slab panels where steel reinforcement was supplanted by bamboo bars. Results showed better performance when bamboo is used as flexural support than steel reinforcement. Furthermore, (Moroz, Lissel, and Hagel, 2014) observed that when bamboo is used as reinforcement in a wall, there is an increase in the shear capacity similar to when steel is used, unlike unreinforced masonry.

Reinforcing fibres have reduced structural element crack (Choun and Park, 2015). Incorporating steel and polyamide fibres in conventional reinforced concrete enhances the structural and functional performance of structures like pressure tanks by increasing the pressure capacity. Also, steel fibres are better than polyamide fibres for improving the performance of prestressed concrete containment vessels (PCCV) (Zamora-Castro et al., 2021). It was found that fibre reinforcements are adequate at high loading pressure and low prestress levels and can be used in structural elements such as beams and columns (Choun and Park, 2015; Zamora-Castro et al., 2021). According to Choun and Park (2015), concrete elements reinforced with steel fibres present correlations that allow the estimation of basic mechanical properties of steel-reinforced concrete as indicated by the ACI-318 guidelines.

Glass fibre (a type of fibre reinforced plastic containing silica or silicate) (Zamora-Castro et al., 2021) can also be used as a composite in concrete reinforcement. Ali et al. (2020) investigated the mechanical behaviour of concrete specimens added with different volumes of glass fibre and concrete waste aggregate (CWA). The maximum results of compressive strength, flexural strength, and elastic modulus were measured for the concrete at 0.25–0.5% glass fibre with 30%, 50%, and 100% content of CWA. Compared to the control specimen, the compressive strength increased by 1.5 to 7%, flexural strength (0.5–5%) and elastic modulus (19–25%). Moghadam and Izadifard (2020) explored the effect of steel and glass fibre combinations on the durability and mechanical performance of concrete specimens exposed to temperatures from 28 to 800 degrees centigrade. Results showed that the steel fibres improved the compressive strength from 9% to 27%, tensile strength from 8% to 198%, and shear strength from 1 to 22%. The compressive strength for the specimen with glass fibre improved from 1% to 18%, and tensile strength from 19% to 213%. Mastali, Dalvand, and Sattarifard (2016) investigated self-compacting concrete's impact resistance, and mechanical properties with recycled glass fibre reinforced polymers (GFRP). The specimens were acquired with 0.25%, 0.75%, and 1.25% fibre content. Results showed that the glass fibre in concrete specimens enhanced their impact resistance and mechanical properties.

Similarly, Khan and Ali (2016) studied the utilisation of glass fibre and nylon in concrete to prevent microcracks in bridge decks. The specimen was compared with that of plain concrete. Results showed that the number of cracks, crack width, and length are less in concrete containing glass fibre and nylon fibres than in bare concrete. Furthermore, glass fibres can be utilised as rods in a wide range of applications in civil construction as reinforcement of concrete support elements. “These rods based on glass fibre can have a greater bearing capacity than steel rods. However, it is not recommended to replace steel rods with those of glass fibre considering only their diameter.” (Zamora-Castro et al., 2021:14). Hence, Jarek and Kubik (2015) suggest that further technical data on the rods is required for guaranteeing similar mechanical behaviour (Jarek and Kubik, 2015).

Another fibre alternative is that of Carbon fibre reinforced polymers (CFRP). CFRP can be applied in reinforced concrete structures as an externally bonded reinforcement or near-surface mounted technique (Zamora-Castro et al., 2021). CFRP is advantageous in ensuring low mass density, high strength, stiffness to weight ratios, non-susceptibility to corrosion, high durability, and the like. (Rezazadeh, 2015). Hence, it improves reinforced concrete structures' flexural and shear strength (Rezazadeh, 2015; Zamora-Castro et al., 2021).

Textile fibres can also be used in concrete as sustainable solutions for structural reinforcement and reconditioning. They can reduce the density, $CO_2$ emissions, and cost of concrete (Kong et al., 2017; D'Antino and Papanicolaou, 2017). Also, Textile reinforcement concrete (TRC) has good mechanical behaviour and is suitable for prefabricated structural components (Zamora-Castro et al., 2021). Besides, TRC can be transported easily and assembled on site because of its low thickness and weight and can be utilised in demountable, modular, and reusable systems (Valeri et al., 2020; Zamora-Castro et al., 2021).

Vegetable fibres can be utilised alone or as reinforcement in soil and cement composites (Madurwar et al., 2013). For example, it was found that sisal fibre is viable for composites because of its low cost, low density, high specific strength and modulus, no health risk, and so on. (Madurwar et al., 2013). Ashour et al. (2010) used straw as a reinforcement fibre in plaster material for wall plaster. The result indicated that an increase in straw fibre content and sand content decreases the thermal conductivity of materials. However, straw fibres on thermal conductivity are more significant than that of sand. The outcome uncovered that plaster reinforced by barley straw fibres has the highest thermal insulation values.

Nanacellulose is another fibre that can be utilised as reinforcement in concrete. It can be acquired through plants, microorganisms, natural chemical reactions, and enzymatic synthesis (Islam et al., 2017). Using nanofibers as a reinforcement material in concrete can increase the concrete's service life and mechanical strength (Aitomäki, and Oksman, 2014; Lee et al., 2014; Cengiz et al., 2017; Zamora-Castro et al., 2021). Its significant properties include low cost, lightweight, low hazard, biocompatibility, low toxicity, and low production cost of natural resources (Ruiz-

Palomero et al., 2017; Tardy et al., 2017; Islam et al., 2017). The utilisation of nano-cellulose to improve the performance of concrete leads to sustainable and environmentally friendly products. Furthermore, nano-cellulose can have future applications as self-repairing material to address buildings' structural problems (Hisseine et al., 2019; Zamora-Castro et al., 2021).

#### *2.3.1.7 Metals*

Steel is an essential sustainable material in construction. Notwithstanding, steel has a high recyclable rate of about 97.5% compared to concrete, not more than 70% (Steel Recycling Institute. 2013; Wang and Adeli, 2014). Also, when construction takes place with steel structures, there are minimal waste and site impacts like noise, dust, pollution, and traffic congestion by taking maximum advantage of offsite prefabrication (Andrade et al., 2016; Taha et al., 2017). Steel structures are entirely adaptable and versatile. Lightweight structures can beat the deficiencies of high thermal inertia that influences energy efficiency. Besides, steel frames are very compatible with high glazing areas. "When glazed openings, exposure, and shading are well-designed, the solar gains and heat losses are controlled" (Taha et al., 2017:129). Furthermore, the simplicity of dismantling is an advantage in steelworks at the end of their life span; bolted connections are better than welded connections (Wang and Adeli, 2014; Andrade, Bragança, and Camões, 2016).

Lightweight materials like aluminium give room for designing and constructing high-performance structures that are safe, energy-efficient, environmentally friendly, and much lighter than traditional designs (Radlbeck, Dienes, Kosteas, 2006; Efthymiou et al., 2010). Radlbeck et al. (2006) called attention to unrivalled properties of aluminium in sustainable design, such as low weight and maintenance, and high corrosion resistance and recycling. "Aluminium can justifiably be described as the ―green metal‖: it is non-toxic and recyclable, easily formed yet strong, durable yet modern. Large savings in energy usage can be achieved using Aluminium façades, which act as solar reflectors and thermal buffers. An aluminium facade can be integrated into the diversity of the architectural tradition" (Efthymiou et al., 2010:3103). Aluminium building materials can last for about 30 to 50 years, and because of this longevity, the upkeep

costs are meagre over the structure's lifetime. Radlbeck et al. (2006) attested that if designed and executed correctly, aluminium structures will surpass steel in terms of environmental and economic performance in the long run.

### 2.3.2 Sustainable energy systems

According to Rosen (2009:59), energy sustainability "incorporates the provision of energy services in a sustainable manner, which in turn necessitates that energy services be provided for all people in ways that, now and in the future, are sufficient to provide necessities, affordable, not detrimental to the environment, and acceptable to communities and people." Generating energy has been a great challenge considering the increasing global population and expanding communities that put demands on energy supply, especially electricity for their needs (Hosenuzzaman et al., 2015; De Amorim et al., 2018). Therefore, there is a great need to provide alternative energy supplies that are environmentally friendly, efficient, and healthy for society (Kannan and Vakeesan, 2016; Furlan and Mortarino, 2018; Rabaia et al., 2021). A few environmentally friendly and efficient replacements for the conventional energy market have been discovered, including renewable energy sources (Jouhara and Olabi, 2018; Malinauskaite et al., 2020; Abdelkareem et al., 2021; Rabaia et al., 2021). These energy sources include solar energy (thermal and photovoltaic), which was found to be one of the cheapest and used mainly in buildings (Souliotis et al., 2018; Fathy et al., 2019; Rezk et al., 2019; Ahmad et al., 2020). Others include wind energy (Mahmoud et al., 2020), hydro (Soudan, 2019; Wilberforce et al., 2019), geothermal (Olabi et al., 2020), and biomass energy (Malinauskaite et al., 2017; Inayat et al., 2019; Abdelkareem et al., 2019; Nassef et al., 2019).

#### *2.3.2.1 Solar energy*

This is one of the least expensive compared to other energy sources and can be applied in several ways. However, the generation of energy is subject to weather intermittency; therefore, it will need an energy storage system that will add to the general expense of the technology (Wilberforce et al., 2019). Solar cells were developed in the 1950s. The solar energy generated was first used by the USA, then by Japan, and thirdly by Germany. However, China remains the

leading solar electricity producing country (Jäger-Waldau, 2020; Rabaia et al., 2021). Energy from the sun can be used as a source of heat or indirectly used as electricity in concentrated solar power plants (Gonzalo et al., 2019; Wilberforce et al., 2019). It can also be used directly in generating electricity in Solar photovoltaic systems (Laib et al., 2018; Rezk et al., 2019; Zhou et al., 2019) and photo-assisted fuel cells (Antolini, 2018; Alami et al., 2020). "A solar-PV system normally consists of arrays and combinations of PV panels, a charge controller (DC to DC), a DC to AC inverter, power meter, breaker, and, most importantly, a battery or an array of batteries depending on the size of the system. The PV panel generates DC output regulated by the charge controller and stored in the battery. Once needed, the energy stored in the battery is inverted to AC through the (DC/AC) inverter for AC loads or directly feeds a DC load. A power meter is used to record and measure the electricity flow feeding the load" (Rabaia et al., 2021:2). In general, PV systems are environmentally friendly as they have low carbon emissions and require no petroleum derivatives to work. Also, there are passive solar energy designs for both cooling and heating in buildings hence not requiring mechanical means for their operation (Chel and Kaushik, 2018). However, some manufacturers still accommodate fossil fuels marginally in their operations. Additionally, they have less compensation time than other conventional and sustainable energy sources (Rabaia et al., 2021).

#### *2.3.2.2 Wind energy*

This energy as a sustainable power source has potential in tall buildings. "Tall buildings can be designed to channel wind into an area containing wind turbines without any effect on the structural performance such as acceleration, inter-story displacement, or lateral drift." (Wang and Adeli, 2014:6). Wang and Adeli (2014) also affirm that the use of wind energy and design for structural performance can be combined for achieving more sustainable buildings. Wang et al. (2017) estimated the wind energy of a building with a canopy roof and found that a double-pitched roof with a pitch of 20 degrees is the best in wind concentration. Wind energy movement can be captured in interior and exterior environmental conditions for passive cooling and ventilation in buildings (Leung and Weismantle, 2008).

#### *2.3.2.3 Geothermal energy*

Geothermal energy is derived from the heat within the earth. The name is from the Greek word geo (earth) and thermal (heat) (U.S. Energy Information Administration (EIA), 2021). It is another sustainable way of producing energy with heat pump technology for buildings because of its environmental friendliness (Wang and Adeli, 2014). The heat derived can be used for bathing, generating electricity, and heating small and tall buildings (Wang and Adeli, 2014; U.S. EIA, 2021).

#### *2.3.2.4 Combined heat and power system*

This system simultaneously produces electricity, heat, and chilled water for air conditioning. It is widely used in urban areas where the population is dense and has been recognised as an energy-efficient technology as it results in considerable cost savings and decreases $CO_2$ emissions (Ali and Armstrong, 2008; Wang and Adeli, 2014).

#### *2.3.2.5 Fuel cells*

According to Ali and Armstrong (2008), fuel cells comprising hydrogen and oxygen can be used in sustainable design like the 48-story concrete Conde Nast Building in New York City. However, their prices are exorbitant but will decrease with time (Ali and Armstrong, 2008).

#### *2.3.2.6 Smart houses*

These houses allow for efficient utilisation of energy. According to Ko et al. (2012), the idea of smart houses depends on utilising technologies that enhance efficient energy consumption, from automated systems to remote control of house conditions through the Internet.

## 2.4 Sustainable Building Assessment Tools

Sustainable building assessment tools are pivotal in implementing sustainable principles in the construction industry and are a fundamental piece of the sustainable construction delivery systems (Mao, Lu, and Li, 2009). As the sustainable building construction movement is

receiving significant attention from many countries, some national or international research organisations have developed many sustainable rating tools. The tools aim to assess and optimise building performance in alignment with sustainable goals (Mao et al., 2009; Reed, Wilkinson, Bilos, and Schulte, 2011; Kang, 2015). Fowler (2006) defined sustainable building rating tools/systems as the tools that examine the (expected) performance of a 'whole building,' translating this into an assessment scheme for comparison with other buildings (Fowler, 2006). The tools ensure that the sustainable building construction process is guided towards achieving environmental, economic, and social sustainability objectives. Hence, speeding up the changes of the conventional/traditional construction approach (Mao et al., 2009).

Different countries have developed sustainable assessment tools best suited to them based on their location. Although the sustainable assessment tools are not typically the same, there are similarities. The tools evaluate the buildings objectively by setting credible standards and ratings**.** The general aim is to have a typical arrangement of measures and targets to assist professionals in designing, constructing and managing the property more sustainably (Reed et al., 2011; Kang, 2015). "In many cases, the tools set criteria and standards which go beyond the building codes and regulations in the countries in which they are used. However, it is also possible to link the tools to government policies and regulations such as certification and labels and incentive initiatives." (Reed et al., 2011:6).

The popular sustainable building assessments tools include the: Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Sustainable Building Tool (SBTool), Comprehensive Assessment System for Building Environment Efficiency (CASBEE), Hong Kong Building Environment Assessment Method (HK-BEAM), Building and Construction Authority Green Mark (BCA-GM), HQE (High Environmental Quality) method, and Green Standard for Energy and Environmental Design (G-SEED). Additionally, there is Green Star, Sustainable Building Assessment Tool (SBAT), Evaluation Standard for Green Building (GB/T 50378-2006, China) (ESGB), the VERDE method, GOBAS (Green Olympic Building Assessment System), NABERS (National Australian Building Environment Rating System) and Green Calc (Darus et al., 2009; Mao et al.,

2009; Alyami, Rezgui and Kwan, 2015). Other tools becoming common include DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), Passivhaus, High quality mark, and Ecological footprint analysis (Doan et al., 2023; Ferreira et al., 2023). Some of these tools are discussed as follows.

### 2.4.1 Building Research Establishment Environmental Assessment Method (BREEAM)

This rating system is fundamentally standard in the United Kingdom (U.K.) but is only applied somewhat in the nations of the European Union (Darus et al., 2009; Alyami et al., 2015). BREEAM is a rating system primarily used to assess the environmental performance of a building and sets the norm for best practices in sustainable design (BREEAM, 2011; Alyami et al., 2015). It is the world's first genuinely significant assessment tool and was developed by BRE (Building Research Establishment Ltd.) in the 1990s. BRE was established in 1921 to start headways and enhancements in building conditions (Darus et al., 2009). According to Darus et al. (2009), BRE is engaged with certifying and testing the built environment for its quality of space and ecological cognisance, giving consultancy to the utilisation of new technologies, research in regions related to building regulations in the U.K., fire safety issues, structural integrity, building-occupant interaction, and training individuals on a broad scope of points associated with the Built Environment. Hence, BRE developed BREEAM to rate building performance according to the environmental categories in Table 1 in alignment with sustainable objectives.

The weighting system in Table 1 was established through the national consultative process (Sev, 2011). “The assessment includes comparing key issues with predictable practices and performance levels, after which credits are granted in ten categories. Every classification has various assigned criteria, with pre-weighed credits that can either be cumulative or subject to performance against specific determined standards like Standard Assessment Procedure (SAP 2009)” (Alyami and Rezgui, 2012:54). The building is evaluated for its performance in every class considering the assigned credits and afterwards added up to a general score. The general

score is the ultimate rating of the building, which is assessed on a scale of Pass (25 to 39 points), Good (40 to 54 points), Very Good (55 to 69 points), Excellent (70 to 84 points) and Outstanding (85 points and above) (Darus et al., 2009; BREEAM, 2011; Alyami et al., 2015).

**Table 2. 1**: BREEAM environmental weightings

| Category | Weightings | Credits |
|---|---|---|
| Management | 12% | 10 |
| Health and wellbeing | 15% | 14 |
| Energy | 19% | 21 |
| Transport | 8% | 10 |
| Water | 6% | 6 |
| Materials | 12.5% | 12 |
| Waste | 7.5% | 7 |
| Land use and ecology | 10% | 10 |
| Pollution | 10% | 12 |
| Innovation | 10% | 10 |

(Sev, 2011).

### 2.4.2 Leadership in Energy and Environmental Design (LEED)

This assessment tool is used as a national standard for rating sustainable buildings, especially in the United States of America (USA) (Darus et al., 2009). It was developed by the United States Green Building Council (USGBC) and is used as a voluntary rating system for evaluating building performance and meeting sustainability goals (Zimmerman and Kibert, 2007; Alyami et al., 2015). LEED is regarded as one of the planet's most successful and widely used green building assessment tools mainly because of its strong market penetration (Mao et al., 2009; LEED, 2021). “LEED provides a framework for healthy, efficient, carbon and cost-saving green buildings.” (LEED, 2021: online). The first version (LEED V1.0) was developed in 1998 and has progressed to LEED V4.1, made available in 2019 (Sarah, 2019). “LEED applies to new commercial construction and major renovation projects (LEED-NC), existing buildings operations (LEED-EB), commercial interiors projects (LEED-CI), core and shell projects

(LEED-CS), homes (LEED-H) and neighbourhood development (LEED-ND).” (Darus et al., 2009:264).

LEED has proved versatile in various US environments, making it simpler to adjust to different nations (Howard, 2005; Díaz-López et al., 2019). Hence, LEED is authorised by Canada and India Green Building Councils, and there is interest from a few different nations (Howard, 2005; LEED Canada, 2010; LEED India, 2010; Díaz-López et al., 2019).

**Table 2. 2**: LEED credits distribution

| **Categories** | **Possible points** |
|---|---|
| Integrative Process | 01 |
| Location and Transportation | 16 |
| Sustainable sites | 10 |
| Water efficiency | 11 |
| Energy and atmosphere | 33 |
| Materials and resources | 13 |
| Indoor environmental quality | 16 |
| Innovation in design | 6 |
| Regional priority | 4 |

(LEED, 2021).

The categories in Table 2.2 are used to rate the environmental performance of a building (Alyami and Rezgui, 2012). Alyami and Rezgui (2012) mentioned three essentials usually considered in any given LEED standards. They are Prerequisites (measures that should be incorporated before assessing a project), Core credits (given for achieving or surpassing the requirements in the given categories), and Innovation credits (given for exemplary performance beyond core credits). Credit is associated with each category, and by adding all the credits achieved by the building in each class, the final rating point(s) is reached. Therefore, the building with the maximum number of points is the building that best achieved the LEED environmental design objectives (Darus et al., 2009; Alyami and Rezgui, 2012). The environmental performance of a building is rated on a scale of 0 to 80 points and classified at four levels. They include certified (40 – 49 points), silver (50 – 59 points), gold (60 – 79 points), and platinum (80 points and above).

### 2.4.3 Sustainable Building Tool (SBTool)

This assessment tool is a software system used for evaluating the performance of buildings in alignment with the environmental and sustainability objectives (Darus et al., 2009). SB Tool was previously known as GBTool (Green Building Tool) and was developed because of the Green Building Challenge (GBC) process, which was started in 1996 by a gathering of over twelve groups (Darus et al., 2009; Mao et al., 2009). Natural Resources Canada launched the GBC. However, in 2002, IISBE was responsible for chairing the process (Darus et al., 2009; Mao et al., 2009). Hence, it was developed by International Initiative for a Sustainable Built Environment (IISBE) in 2007 (Mao et al., 2009). Unlike the previous version (GBTool), SB Tool focuses more on the issues regarding economic/social considerations and urban planning. Hence, it is an improved version compared to GBTool. GBTool is only designed to allow users to mirror the different priorities, technologies, building customs, and cultural values in different areas and nations in the assessment process. It consists of a Microsoft Excel workbook arranged to suit practically any local condition or build type. However, GBTool becomes a proficient rating device after a Third-party aligns it for their locale by defining the scope and setting weights, context, and performance benchmarks (Nils Larsson, 2007; Mao et al., 2009).

Table 2. 3: SBTool environmental weightings

| **Categories** | **Weightings** |
|---|---|
| Site selection, project planning and development | 7.6% |
| Energy and resource consumption | 21% |
| Environmental loadings | 25.2% |
| Indoor environment quality | 21% |
| Service quality | 15.1% |
| Social and economic aspects | 5% |
| Cultural and perceptual aspects | 5% |

(Alyami and Rezgui, 2012).

Table 2.3 presents the categories and weights of SB Tools for measuring the sustainable performance of a building. The measures and sub-measures of each performance objective are scored using a linear scale from −2 to +5 (Alyami and Rezgui, 2012). Where 0 is the minimum

acceptable performance and 3 (good practice), and five and above (best practice) (Darus et al., 2009). It is important to note that countries like Canada, the USA, Germany, Poland, Spain, and China have used this tool in assessing the sustainable performance of a building.

### 2.4.4 Comprehensive Assessment System for Building Environment Efficiency (CASBEE)

CASBEE is a unique assessment method in the sense that it utilises the value of Building Environmental Efficiency (BEE) to evaluate the sustainability of green buildings (Alyami and Rezgui, 2012). CASBEE was developed by the Japanese Green Building Council (JaGBC) and instituted in 2001. According to Darus et al. (2009), CASBEE is created given three significant ideas. First is the intention to appraise structures that correspond to their lifecycle. The second is distinguishing L (the environmental loading) of the building and Q (the quality of building performance) as the critical appraisal targets. The third is the introduction of the BEE to determine the final results of the environmental assessments of the building. BEE can be defined as the ratio of the 'Building environmental quality and performance' to the building ecological loadings' (Mao et al., 2009). The formula is depicted in Figure 2.1.

$$\mathrm{BEE} = \frac{Q:\text{Building environmental quality and performance}}{L:\text{Building environmental loadings}} = \frac{25\times(S_Q-1)}{25\times(5-S_{LR})} \quad (1)$$

**Figure 2. 1**:Building environmental efficiency formula (Darus et al., 2009; Mao et al., 2009).

CASBEE can be used for assessing private and public buildings used for residential and non-residential purposes. As a tool, there is the CASBEE-PD (for pre-design), CASBEE-NC (for new construction), CASBEE-EB (for existing buildings), and CASBEE-RN (for renovation) (Darus et al., 2009; Mao et al., 2009). According to Darus et al. (2009), the CASBEE tool does not consider economic measures (cost and profitability) or even social and aesthetic design parameters. The parameters are mainly focused on achieving environmentally sustainable objectives. Hence, the Q in Figure 2 is categorised into Q1 (indoor environment), Q2 (quality of

services), and Q3 (outdoor environment on-site). Similarly, L is categorised into L1 (energy), L2 (resources and materials), and L3 (off-site environment).

According to Darus et al. (2009), scoring criteria on a scale of 1 to 5 are set for each of the subcategories of Q and L for their assessment. Whereby an aggregated average of the scores for each assessment item concerning the ratio of floor areas for each item is calculated. “The results are presented in two forms firstly, the score sheet, which presents the scores of each of the Q and L subcategories, and secondly the assessment result sheet, which presents results for each field as radar charts, bar graphs, and numerical data for Q (environmental quality and performance of the building) and LR (the building’s load reduction)” (Darus et al., 2009:265). The BEE is additionally determined at this stage to produce the results of the overall evaluation of the environmental efficacy of the building into consideration. To determine BEE, the total scores for Q and LR are known as SQ, and SLR. This is calculated by applying the formula in Figure 8 (Darus et al., 2009).

According to Mao et al. (2009), CASBEE has been tested and found as an effective tool for the unique condition of Japan. Hence, building owners and developers are encouraged to get the CASBEE certification from local governments. Further, Mao et al. (2009) expresses that the GBTool has dramatically influenced the development of CASBEE because Japan is one of the ardent members of the Green Building Challenge process.

### 2.4.5 Hong Kong Building Environment Assessment Method (HK-BEAM)

This method of assessment was initiated in 1996 and adjusted to the environmental condition of Hong Kong from the BREEAM of the United Kingdom (Bunz et al., 2006). HK-BEAM aims to set good practice standards for environmental issues concerning the planning, design, construction, commissioning, management, operation and maintenance of buildings (Bunz et al., 2006; Darus et al., 2009). The HK-BEAM assessment is voluntary and covers many new and existing buildings, including residential, institutional, commercial, and industrial (Darus et al., 2009). An HK-BEAM evaluation ensures that the attainment of the predefined levels of performance is at least satisfactory. (Bunz et al., 2006; Darus et al., 2009). Darus et al. (2009)

mentioned that if the criteria, for instance, energy use, are unclear, HK-BEAM can lay out its performance criteria benchmark, subject to the data available and the consensus of the stakeholders. It is planned that the appraisal criteria be updated intermittently as new data is revealed and as legal requirements evolve (Darus et al., 2009).

Bunz et al. (2006) mentioned that "Credits" are granted where defined criteria regarding performance are fulfilled. The critical environmental aspects addressed is that of HK-BEAM Society 2003, such as Site aspects, Material aspects, Energy use, and Indoor environmental quality. For HK-BEAM, the general assessment grade granted to a building is resolved according to the percentage of applicable credits achieved by the structure (Bunz et al., 2006). Indoor environmental quality (IEQ) performance is further weighted in the overall rating to ascertain whether a minimum requirement of IEQ credits is met. Otherwise, the overall building performance rating will be downgraded (Bunz et al., 2006). The percentage grading system according to HK-BEAM Society 2003, includes Bronze (40 – 54% - satisfactory–above average), Silver (55-64% - good), Gold (65-74%-very good), and Platinum (75% and above - excellent) (Bunz et al., 2006).

### 2.4.6 Building and Construction Authority Green Mark (BCA-GM)

This assessment tool was initiated in 2005 to ensure that buildings in the construction industry of Singapore are more environmentally friendly. It is embraced and upheld by the National Environment Agency (Darus et al., 2009; Mao et al., 2009). According to Darus et al. (2009), five main criteria are used to assess the environmental performance of the building. They include "energy efficiency, water efficiency, Site/Project Development and Management (Building Management and Operation for existing buildings), Good Indoor Environmental Quality and Environmental Protection, and Innovation" (Darus et al., 2009:268).

For the assessment of new buildings, three evaluations are needed to guarantee continuous and appropriate maintenance of the Green Mark building. The criteria for New Buildings are sub-divided into Non-Residential and Residential Buildings (Mao et al., 2009). Structures are granted Platinum, GoldPLUS, Gold, or Certified rating based on the points scored (Darus et al., 2009).

Aside from actualising the minimum criteria in each evaluation scale, the project needs to meet every essential prerequisite and score at least 50% of the places in every bar, except for Innovation (Darus et al., 2009). According to Darus et al. (2009), Green Mark also accommodates the assessment of existing buildings under the criteria of the existing buildings except if they are going through a very significant refurbishment program.

### 2.4.7 High Environmental Quality (HQE) Method

According to Darus et al. (2009), this assessment method was initiated in France and launched in 1996 to enable developers and building owners to make construction choices in the direction of sustainable development at all phases. The HQE environmental assessments accommodate both new and rehabilitated buildings. To effectively implement this assessment method, an environmental management system is required (EMS) (Darus et al., 2009). Also, a part of HQE is managed based on ISO140001 concepts (Darus et al., 2009).

Darus et al. (2009) also stated that the execution of the HQE strategy requires the thought of various environmental issues, which must be considered. Areas that are polluted should be identified before building. Also, the best strategies to use for the erection of buildings should be identified considering accessibility. Other considerations include utilities, data on environmental implications of products and services, energy and water utilised during all stages of the building life cycle, waste and emissions produced and the broad cost implications of the building and its facilities (Darus et al., 2009).

### 2.4.8 Green Standard for Energy and Environmental Design (G-SEED)

This is a tool used in Korea for assessing the performance of green buildings concerning ecological friendliness and a healthy living environment (Yun, Cho, and Chae, 2018). G-SEED can assess existing buildings, green remodelling buildings, and new ones, including offices, schools, and residential buildings (KICT, 2016; Yun et al., 2018).

G-SEED was first launched in 2002 but was amended in 2016 and embraced assessments across the eight categories shown in Table 2.4, especially for new buildings. Notably, the most significant portion of the examination centres on the energy and environmental category (KICT, 2016).

Table 2. 4: G-SEED Rating System

| Categories | Average weightings | Prerequisites credits | No. of credits |
|---|---|---|---|
| Land use and transportation | 10% | - | 6 |
| Energy and environmental pollution | 30% | 1 | 6 |
| Materials and resources | 15% | 1 | 6 |
| Water management | 10% | 1 | 4 |
| Maintenance | 7% | 1 | 3 |
| Ecology | 10% | - | 3 |
| Indoor environment | 18% | 1 | 6 |
| Innovative design | 10% | - | 9 |

(Yun et al., 2018)

### 2.4.9 Green Star

This rating system was launched in 2002 by the Green Building Council of Australia (GBCA) to assess environmental issues regarding the design and construction of buildings in Australia. The target of making Green Star was to promote green building practices and operations while encouraging sustainable building development (Atanda and Öztürk, 2020; Green Star Australia, 2022a). There are nine credits for green the star assessment categories, including management, indoor environment quality (IEQ), energy, transport, water, materials, land use and ecology, emissions, and innovation (Green Star Australia, 2022b). This system of assessment has also been adopted by the green building council of countries like New Zealand (NZ) and South Africa (SA) (Medineckiene et al., 2015; Green Star NZ, 2022; Green Star SA, 2022).

Green Star is a champion among the most taken after resolute building assessment tools made to oblige the necessity for working in hot airs where cooling systems and solar shading are critical (Atanda and Öztürk, 2020). “Green Star comprises of four rating criteria which include space

use, spatial differentiation, conditional requirements and timing of certification" (Atanda and Öztürk, 2020:67). Accreditation is awarded based on the points scales such as 0 to 9 points (0 Star: assessed), 10 to 19 points (1 Star: minimum practice), 20 to 29 points (2 Star: average practice), 30 to 44 points (3 Star: good practice), 45 to 59 points (4 Star: best practice), 60 to 74 (5 Star: excellence), 75 to 100 points (6 Star: world leadership) (Atanda and Öztürk, 2020; Green Star Australia, 2022a; Green Star NZ, 2022; Green Star SA, 2022).

### 2.4.10 Sustainable Building Assessment Tool (SBAT)

This tool was developed by the South African Council for Scientific and Industrial Research (CSIR) to assist in setting out parameters for actualising a more sustainable building (Gibberd, 2002; Atanda and Öztürk, 2020). Hence, it involves 15 viewpoints arranged around the three significant sustainability constraints (environmental, economic, and social), as shown in Figure 2.2. The rating scale is out of 5 for each category, and 5 points criteria are attached to each of the 15 areas resulting in 75 indicators for assessments (Gibberd, 2002; Atanda and Öztürk, 2020).

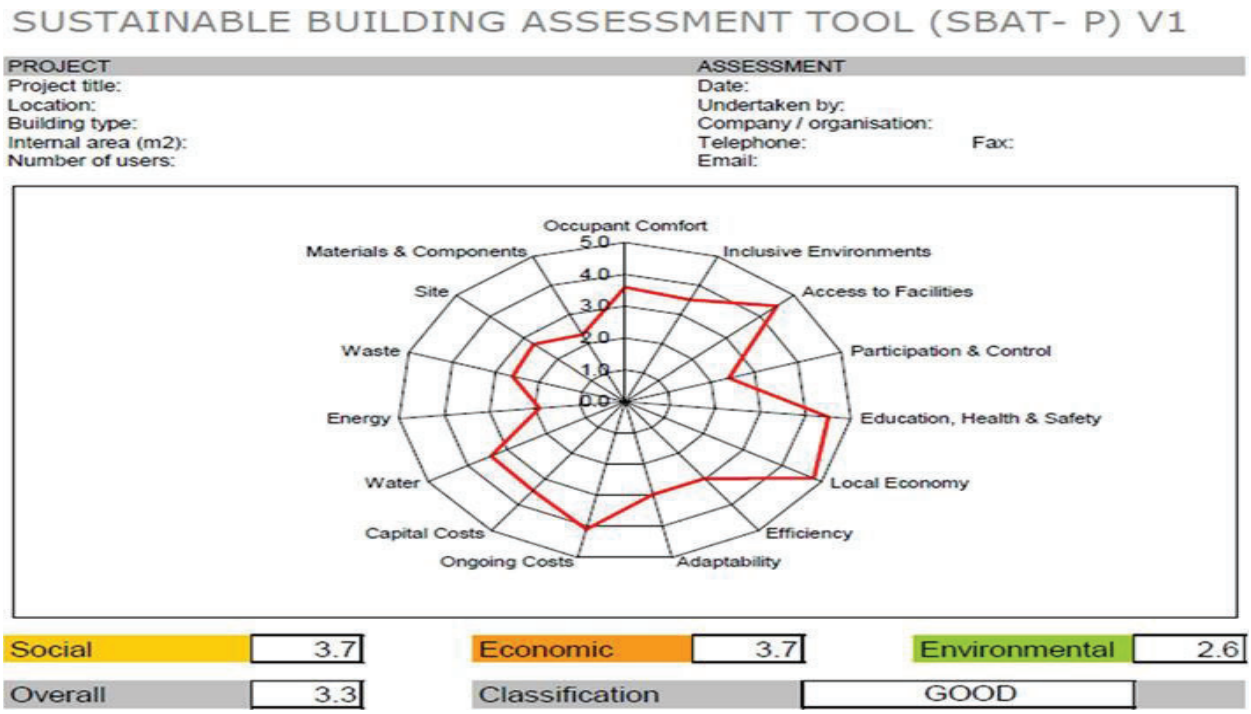


**Figure 2. 2:**SBAT result sample (Gibberd, 2002; Atanda and Öztürk, 2020)

### 2.4.11 Evaluation standard for green building (gb/t 50378-2006, China) (ESGB).

This tool was developed by several research institutes, including the China Academy of Building Research (CABR), Tsinghua University, etc. It has become a national standard (GB/T 50378-2006) in China (Mao et al., 2009). Notably, the labelling system of ESGB was launched in 2007 with the establishment of a rating system. The tool assesses all categories of buildings, including residential, commercial, offices, hotels, and the like. Incentives are given by the Ministry of Housing and Urban-Rural Development (MOHURD) to key participants (developers, designers, etc.) in the innovation of sustainable construction as a way of motivation and encouragement (Mao et al., 2009). "Differencing the other rating tools, the ESGB was constituted with six issues, and every issue contains three item types, including controlling items, common items, and priority items. The controlling items are the prerequisites for the applicants. The applicants will be ranked into three levels, depending on how many common items and priority items have been satisfied" (Mao et al., 2009:3).

### 2.4.12 Verde method

VERDE is an assessment tool for evaluating building environmental performance in Spain (Darus et al., 2009). It is created by the "Arquitectos, Urbanistas e Ingenieros Asociados, S.L.U.in the GBC Spain Consejo Superior de los Colegios de Arquitectos de Espana" (Darus et al., 2009:267). VERDE can assess new buildings such as residential, office, commercial, hotel, hospital, and educational buildings (Darus et al., 2009). The assessment criteria are similar to SBTool. Hence, the benchmarks are grouped into two fundamental categories: those that can be communicated numerically and those best depicted in text-based parameters. The rating scale ranged from 0 (minimum acceptable performance) to 5 (best practice) (Darus et al., 2009). The best practice rating is based on the performance obtained with the best available and affordable technology.

Table 2.5 presents various assessment tools discussed in this chapter with the countries that have used them.

**Table 2. 5**: Sustainable Building Construction Assessment Tools

| Tools | Countries | Strengths/Advantages | Weaknesses/Disadvantages | Citations |
|---|---|---|---|---|
| BREEAM | UK | -It is a well-established and popular environmental assessment instrument in the United Kingdom.<br>-It is a widely utilised method with global influence.<br>-Needs early participation, particularly during the design phase, which is advantageous to the project and its overall rating.<br>-It is more flexible in local and regional contexts.<br>- Robust indication of structural stability.<br>-Strong in assessing energy efficiency (lower energy use and carbon emissions) and thorough in analysing the environmental performance of the building.<br>-Includes all ISO economic aspect metrics.<br>-Can evaluate facilities beyond buildings.<br>-BREEAM outperforms other models in property management, health, and well-being issues.<br>-It can assess facilities other than buildings.<br>-A catalyst for market advancement since it stays current on best practices and regulatory developments. | -Complex computation technique that calls for specialised knowledge and training.<br>-Needs more capital expenditures to meet its objectives.<br>-Do not include private space while evaluating office buildings.<br>-Has an extensive technical manual. | BREEAM, 2011; Sev, 2011; Alyami et al., 2015; Atanda and Öztürk, 2020; Assefa et al., 2022; Doan et al., 2023; Ferreira et al., 2023 |
| LEED | Canada, USA, UK | -Worldwide recognition.<br>-Has a more straightforward calculation process than BREEAM.<br>-Allows greater design freedom, although additional paperwork may be needed for the certification procedure.<br>-Able to adjust to regional standards. | -Training is not necessary for certification, however an authorised professional (AP) can help collect evidence.<br>-Does not have a life cycle cost indicator assessment.<br>-Has no designated management category.<br>-Has limited UK ratings in buildings. | Zimmerman and Kibert, 2007; Darus et al., 2009; Mao et al., 2009; Alyami et al., 2015; Atanda and Öztürk, 2020; LEED, 2021; Assefa |

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| | | -Excellent at assessing energy performance (minimum and optimised energy) and environmental factors.<br><br>-Can assess facilities beyond buildings, and<br><br>-Pushes the market to enhance building sustainability and design. | -Lacks the academic rigor of BREEAM. | et al., 2022; Doan et al., 2023; Ferreira et al., 2023 |
| SBTool | Canada, USA, Germany, Poland, Spain, and China | -A general framework for sustainability ratings, enabling local organisations to to create unique grading schemes.<br><br>-Flexible and adaptable<br><br>-It adjusts weights based on context, considering site and location.<br><br>-Offers sustainability performance results that are both relative and absolute.<br><br>-It can manage structures with a broad scope and permits a more general description of structures with several occupants. | -Complex to implement<br><br>-Although authorised third parties can modify weights, there are still limitations regarding weighting adjustments.<br><br>-It takes a lot of resources to implement.<br><br>-The absence of an industry-wide agreement on a generic framework causes variances in its use.<br><br>-Creating localised metrics can be challenging. | Darus et al., 2009; Mao et al., 2009; Alyami et al., 2015; Larsson, 2007; Atanda and Öztürk, 2020; Cole, 2020 |
| CASBEE | Japan | -Thorough evaluation technique for assessing several facets of a building's environmental performance.<br><br>-Involves quantitative evaluation (energy consumption and water usage) and qualitative evaluation (design strategies and environmental management practices).<br><br>-Compared to LEED and BREEAM, CASBEE tools emphasise service quality more.<br><br>- Emphasises the local scenario | -Devoid external benchmarks, which may offer a more comprehensive comparative context.<br><br>-Does not include accessibility specifications needed to evaluate outdoor or private spaces.<br><br>-No certified baseline model making it difficult to monitor continuous progress.<br><br>- Accuracy in evaluating energy efficiency can be impacted by inadequate energy modelling. | Darus et al., 2009; Mao et al., 2009; Alyami et al., 2015; Atanda and Öztürk, 2020; Assefa et al., 2022 |

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|---|---|---|---|---|
| | | -Assessment includes private or outdoor areas in their assessment. | | |
| SBAT | South Africa | -Assesses environmental, social, and economic performance.<br><br>-Intended especially for usage in underdeveloped nations.<br><br>-A mechanism that assists the building design teams in making decisions.<br><br>-User-friendly and accessible to various stakeholders due to its ability to provide graphical reports.<br><br>-It can be applied to existing buildings, enabling them to be graded and benchmarked to standards.<br><br>-It aids in incorporating sustainable development ideas into the planning and design of buildings. | -It is dependent on users' subjective assessments and interpretations.<br><br>-Some facets of sustainability might not receive enough attention.<br><br>-Even though the tool is easy to use, some users may still find it challenging due to its intricacy.<br><br>- It needs data input, which for some projects could be scarce or challenging to collect.<br><br>- Its applicability to various building kinds and situations may differ. | Gibberd, 2017; Atanda and Öztürk, 2020; Cole, 2020 |
| BCA-GM | Singapore | -Aimed at tropical and sub-tropical regions.<br><br>-Verifies energy performance during building operations.<br><br>-Can assess facilities beyond buildings.<br><br>-Excellent in determining the building envelope's thermal performance.<br><br>-Requires face-to-face green building assessments.<br><br>-Certified buildings yield net positive energy and water savings throughout their lifecycle. | -Only be evaluated by domestic codes, regulations, and standards.<br><br>-Requires upfront investment cost to achieve certification.<br><br>-Intricate process and requires detailed documentation which can be difficult for some projects. | Bunz et al., 2006; Darus et al., 2009; Kim et al., 2022; Doan et al., 2023 |

**Table 2.5 (continued):** Sustainable Building Construction Assessment Tools

| Tools | Countries | Strengths/Advantages | Weaknesses/Disadvantages | Citations |
|---|---|---|---|---|
| HK-BEAM | Hong Kong, China. | -Comprehensive energy performance assessment, indoor environmental quality, site selection, and materials used.<br><br>-BEAM Plus has a specific category for "Management".<br><br>-Increased market values for certified buildings. | -Complex and needing expertise and resources. It could be difficult for smaller initiatives to comply.<br><br>-May not adequately address local context or unique challenges specific building types or locations face.<br><br>-A rise in construction cost when implemented. | Bunz et al., 2006; Darus et al., 2009; |
| HQE | France | -Only rating system that evaluates all outdoor environment-related ISO indicators.<br><br>-Considers not only environmental attributes but also social and economic factors. | -Complex implementation.<br><br>-Has no evaluation for a life cycle cost indicator.<br><br>-Need adaptation to local climates, regulations, and cultural preferences. An all-encompassing strategy might not work.<br><br>-Involves greater upfront costs and is resource-intensive. Nevertheless, the long-term advantages frequently offset these upfront costs. | Bidou, 2006; Bunz et al., 2006; Darus et al., 2009; Assefa et al., 2022 |
| G-SEED | South Korea | -Apart from sharing similarities with BREEAM and LEED, it has unique evaluation criteria for noise and safety.<br><br>-Has tailored its processes to fulfil local demands, considering factors peculiar to the Korean setting. | -It can be difficult to balance globalisation and localisation.<br><br>-Further study and improvement are required to increase its efficacy. | KICT, 2016; Yun, Cho, and Chae, 2018; Lee and Shepley, 2019. |
| Green Star | Australia, New | -Focus is on environmental indicators/performance. | -Complex procedure in certification.<br><br>-Each Green Star tool has unique weightings, | Medineckiene et al., 2015; |

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| | Zealand, South Africa | -Prioritises issues with greenhouse gas emissions when evaluating energy performance.<br><br>-Objective evaluation.<br><br>-Reduces resource consumption through the material category.<br><br>-Encourages well-being. | representing different environmental issues in distinct building sectors. This can make comparing different tools difficult.<br><br>-Private space is not incorporated in the assessment of office buildings.<br><br>-Weak in assessing social performance.<br><br>-Extra expenses may be needed for compliance, assessment, and documentation. | Green Star NZ, 2022; Green Star SA, 2022; Kim et al., 2022 |
| ESGB | China | -Comprehensive assessment of multiple environmental factors.<br><br>-Offers developers and builders incentives and guidelines.<br><br>-It is primarily focused on addressing the issue of construction waste.<br><br>-It makes use of a three-star rating system that enables performance-based distinction. | -Scores differ due to the large difference between two- and three-star ratings.<br><br>-Both time- and resource-consuming.<br><br>-Government regulations that are inconsistent and market constraints could prevent widespread adoption. | Mao et al., 2009; Zhang et al., 2019; Cui et al., 2021 |
| VERDE method | Spain | -Certifies a building's ecological values through a globally recognised assessment technique.<br><br>-Performed by a separate organisation that isn't connected to the designer or developer.<br><br>-Thorough assessment of diverse environmental factors.<br><br>-Gives the building's design phase more weight. | -At the moment, only office and residential buildings are certified.<br><br>-Certain data is needed for the certification procedure, which could be difficult for buildings already in place.<br><br>-Until the building experiences major modifications, the VERDE score is fixed once assigned.<br><br>-Its inability to record performance in real-time is due to its reliance on already-existing secondary data sources. | Darus et al., 2009; Braulio-Gonzalo, et al., 2022 |

**Table 2.5(continued):** Sustainable Building Construction Assessment Tools

| Tools | Countries | Strengths/Advantages | Weaknesses/Disadvantages | Citations |
|---|---|---|---|---|
| DGNB | Germany | -Holistic measure of the three pillars of sustainability.<br><br>-Consistently considers the entire life cycle of a project, unlike some other certification systems.<br><br>-A globally acknowledged standard for sustainability.<br><br>-Provides variants for newly constructed homes, pre-existing structures, renovations, and districts.<br><br>-It can be used as a planning, optimisation, or management tool and adjusts to different project phases. | -Complex due to its comprehensive nature.<br><br>-Navigating its many criteria and standards could take more time and skill.<br><br>-Resource-intensive. | Doan et al., 2023; Ferreira et al., 2023 |
| GOBAS | China | -Promotes energy efficiency, water conservation, and waste reduction.<br><br>-Encourages adoption beyond Olympic projects.<br><br>-Promotes innovation in green building technologies and materials. | -Complex and necessitates in-depth data gathering and examination.<br><br>-A smaller, non-Olympic project might be difficult to scale because of its unique requirements.<br><br>-Implementation can be costly.<br><br>-Subjectivity in certain criteria that causes assessments to be inconsistent. | Mao et al., 2009; Doan et al., 2017 |
| NABERS | Australia | -Simple and reliable in rating buildings based on energy, water, waste, and indoor environment.<br><br>-Provides cost-effective and independent validation of sustainability data. | -Ratings are valid for 1 year.<br><br>-Regular evaluation.<br><br>-Each building type (hotels, offices, etc.) has unique grading standards, making comparing challenging. | Mao et al., 2009; NABERS, 2024. |

| | | | | |
|---|---|---|---|---|
| Ecological footprint analysis | UK, EU | -Universal and flexible to adapt<br><br>-Measures ecological sustainability<br><br>- Based on the physical measurement of resource availability and consumption.<br><br>-Acknowledged both globally and locally.<br><br>-Able to assess accomplishments in relation to other initiatives and environmental constraints.<br><br>-Unambiguous message and easy to measure. | -Not a holistic measure of sustainability.<br><br>-EF does not discriminate between sustainable and unsustainable land use; instead, it considers the total amount of land used, ignoring the potential for recovery once the land's useful life has ended.<br><br>-No policy prescription.<br><br>-The dependability of results may be impacted by the difficulty of accurately gathering data for all components.<br><br>-The biocapacity assumption may not hold in practice. | Hurley et al., 2007; Wiedmann and Barrett, 2010; Castellani and Sala, 2012; Matuštík and Kočí, 2021. |
| High quality mark | UK, EU | -The system is among the few that takes carbon reduction and climate change into account.<br><br>-High results in not degrading the environment through building construction.<br><br>-The rating indicates high-quality homes, meeting more stringent standards than baseline regulatory requirements.<br><br>-Extensively used by buyers when choosing to buy or rent a new home.<br><br>-Overarching ratings in contrast to other BREEAM schemes<br><br>-Very reliable for new housing developments.<br><br>-Cost less to run. | - It focuses only on brand-new construction; it is not retrofitted.<br><br>-Strict scope; neither public nor commercial buildings are considered.<br><br>-It is mainly dependent on the home's location.<br><br>-Due to individual viewpoints, some subjectivity in the assessment criteria may cause variation. | Bre, 2020; Mazur et al., 2022 |

**Table 2.5 (continued):** Sustainable Building Construction Assessment Tools

| Tools | Countries | Strengths/Advantages | Weaknesses/Disadvantages | Citations |
|---|---|---|---|---|
| Green Calc | Netherland | -Comprehensive assessment and holistic approach.<br><br>-Adaptable.<br><br>-Open and unambiguous guidelines.<br><br>-Worldwide applicability. | -Complex and challenging to navigate.<br><br>-Resource-intensive and may require extra cost for changes or materials<br><br>-Subjectivity in some criteria leads to potential bias.<br><br>-Limited adoption compared to LEED or BREEAM. | Mao et al., 2009; Doan et al., 2017 |
| SBEM | UK | -Employed in the National Calculation Methodology (NCM) implementation process to show adherence to energy performance requirements.<br><br>-Mostly used for newly constructed non-domestic projects.<br><br>-Simple to implement.<br><br>-Calculation can be performed quickly, efficiently assessing multiple buildings or design options.<br><br>-Standardised, enabling uniform energy evaluations for various projects.<br><br>-Wide applicability to different kinds of commercial buildings. | -Unable to fully capture the nuances of a building's energy performance.<br><br>-Limited scope and neither water use nor occupant behaviour are addressed.<br><br>-Predicated on assumptions and generalisations.<br><br>-Simplification may result in inaccuracy in assessing complex buildings.<br><br>-Lack of methodological application in congruence with the different design stages of the building process.<br><br>-The tool's functionality is restricted mainly by the computation engine's incapacity to simulate intricate HVAC systems and tactics.<br><br>-May not be appropriate for specialised or residential buildings. | Raslan and Davies, 2010; Mahmoud et al., 2020 |
| Passivhaus | UK, EU, Spain | -Energy savings of over 90% | -Extremely expensive to implement. | Borrallo-Jiménez et al., |

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|---|---|---|---|---|
| | | -High air quality and occupant comfort<br><br>-Devoted to providing high-energy performance buildings, primarily for residential use.<br><br>-Applies to both newly constructed and pre-existing constructions.<br><br>-Prevents moisture accumulation and humidity. | -A major problem in Passivhaus projects is thermal bridging, which occurs when insulation layers shift and allow heat to escape.<br><br>-Technically challenging and needing specific maintenance knowledge.<br><br>-Involves strict adherence to standards which can be challenging. | 2022; Tobias, 2024 |

## 2.5 Benefits of Sustainable Building Construction

Sustainable building construction is of rising interest considering the depletion of world resources and the increasing populace. It has been forecasted that the world populace can arrive at 9 billion by 2050 (United Nations Environment Programme (UNEP), 2011). Applying sustainable principles in building construction is more beneficial than the conventional approach (Waidyasekara and Fernando, 2012; Dosumu and Aigbavboa, 2018).

There are environmental, social, and economic benefits to sustainable building construction. Environmental benefit deals with the safety of the ecosystem. It incorporates the decrease in carbon emissions which can affect the ozone layer (Vazquez, Rola, Martins, Freitas, and Rosa, 2011; Simpeh and Smallwood, 2018; Dosumu and Aigbavboa, 2021). It also includes decreases in the use of energy and water, decreases in generating waste, utilisation of waste in making construction materials, improved air and water quality, the reduction of exercises that will cause a loss in habitat, construction with more durable materials, and so on (Vazquez et al., 2011; Ametepey *et al*., 2015; Simpeh and Smallwood, 2018; Dosumu and Aigbavboa, 2021). According to Yudelson (2010), green structures can reduce energy and utilisation to around 30% to 50%. Madew (2006) added that energy and water usage could be diminished to about 60%. Similarly, the United States Green Building Council assessed that green buildings in North America could lessen energy utilisation by 30%, carbon emissions by 35%, and water

consumption by 30% to 50% (Commission for Environmental Cooperation, 2008; Dosumu and Aigbavboa, 2021).

Social-wise, sustainable building construction can improve occupants' well-being, satisfaction, and comfort in buildings (Rahim et al., 2014; Oluwunmi *et al*., 2019). It can improve the overall quality of life, work efficiency, and productivity of the occupants (Akadiri, Chinyio, and Olomolaiye, 2012; Waidyasekara and Fernando, 2012; Rahim et al., 2014; Oluwunmi *et al*., 2019). According to Ries, Bilec, Gokhan, and Needy, (2006), productivity can be enhanced by 25% remarkably when green structures are certified by the Leadership in Energy and Environmental Design (LEED) rating framework. Besides the improved health of employees and productivity, Hayles and Kooloos (2008) added that the sustainable construction of buildings can boost the organisation's image and provide a more pleasant working environment. Similarly, Simpeh and Smallwood (2018) added that sustainable building construction increases comforts, health, and aesthetics and allows for more job creation.

Economically, sustainable building construction can contribute to cost-effectiveness. Although sustainable buildings are perceived to have high initial costs in the short term, there is a high return on investment in the long run (O'Mara and Bates, 2012; Oguntona et al., 2019). The Royal Institute of Chartered Surveyors (2011) also recommends that underlying capital expense is not always high. Sinha, Gupta, and Kutnar (2014) affirmed that through sustainable construction, resources would be well managed and controlled, and there would be a reduced dependency and better growth/yield. Rahim et al. (2014) also asserted that sustainable construction allows for improved use of construction resources and operational savings. Oluwunmi et al. (2019) added that sustainable buildings have diminished operational and decreased utility costs. There is also around half to 90% of waste cost savings for green buildings (Commission for Environmental Cooperation, 2008). Other sources affirm that sustainable buildings are highly marketable (Milne, 2012; Du Toit, 2013; Altomonte et al., 2019) and attract reputable tenants who can afford them (Mattson-Teig, 2008; Du Toit, 2013; Oguntona et al., 2019).

## 2.6 Critical Hindrances to Sustainable Building Construction

There have been some obstacles to sustainable construction found in several studies. The barriers can be categorised under knowledge, economics, time and planning, technical, psychological disposition, cultural disposition, regulation/legislation, support and promotion, management/leadership, procurement, environment, and politics, as shown in Table 2.6. To start with, *Knowledge* includes skills and competency, which can be gained through education, awareness, and experience (Cetindamar, Wasti and Beyhan, 2012; Oxford English Dictionary (OED), 2023). Hence, the lack of adequate knowledge, education, training, competence, and expertise regarding sustainable construction among construction personnel are significant obstacles to building sustainably (Hakkinen and Belloni, 2011; Ahn et al., 2013; Ametepey et al., 2015; Saad, 2015; Aigbavboa et al., 2017; Durdyev et al., 2018a; Rock et al., 2019; Aghimien et al., 2019; Fathalizadeh et al., 2021; Marsh et al., 2021). Also, the lack of proper awareness, communication, and understanding of the benefits of building sustainably to the public/clients/stakeholders are crucial barriers (Zainul-Abidin, 2010; Hakkinen and Belloni, 2011; Ahn et al., 2013; Saad, 2015; Aigbavboa et al., 2017; Durdyev et al., 2018a; Rock et al., 2019; Aghimien et al., 2019). This aligns with Hang and Tan (2012), who suggest that there is limited research that highlights the benefits of sustainable construction practices in Singapore. There should also be appropriate communication on the strategies to follow as the lack is a significant hindrance, according to Hang and Tan (2012) in Singapore, Saad (2016) in South Africa, and Iqbal et al. (2021) in the United States.

*Financial and economic barriers* include cost premium/increased capital cost and higher final price, which keep investors from looking at sustainable buildings (Shi et al., 2013; Opoku and Ahmed, 2014; Karunasena et al., 2016; Aigbavboa et al., 2017; Tafazzoli, 2018; Ogungbile and Oke, 2019; Rock et al., 2019). Many are kept back because of fear of higher investment costs, perceived high cost, and misconception of construction cost overrun (Samari et al., 2013; Alsanad, 2015; Ametepey et al., 2015; Aigbavboa et al., 2017; Aghimien et al., 2019; Fathalizadeh et al., 2021; Marsh et al., 2021). According to Aigbavboa et al. (2017), it is a lazy man's view to perceive that sustainable buildings are costly without considering their long-term

benefits. A study in the United States by Ahn et al. (2013) on the subject discovered that there is a perception of more extended payback periods, which hinder sustainable building construction. Samari et al. (2013) also found that in Malaysia, there is a lack of credit resources to cover the upfront cost. In South Africa, Saad discovered that using expensive technologies can affect investment in sustainable buildings (Saad, 2016). Also, Saad (2016) found that builders and investors are not prioritising users' comfort but focus on maximising profit. This is also consistent with Durdyev et al. (2018a), a study in Cambodia on the subject, who affirmed that focusing on economic needs can deter the idea of building sustainably.

Another key barrier is of *time and planning.* According to Hakkinen and Belloni (2011), inadequate task and process phase scheduling negatively impacts sustainable building construction. Daniel et al. (2018) found that extensive pre-contract planning is a critical obstacle, while Shi et al. (2013) found that a longer time is required for completion.

An additional obstacle to implementing sustainable building construction is related to *technical* difficulties. Technical barriers can be associated with the lack of adequate methods and tools (Ametepey et al., 2015; Susanti et al., 2019), lack of green technology and techniques (Samari et al., 2013; Opoku et al., 2019), lack of innovation processes (Hakkinen and Belloni, 2011) and lack of effective enforcement (Saad, 2016; Ershadi et al., 2021).

Another key barrier is psychological disposition. Many scholars attest that there is a reluctance to shift from the conventional methods in construction practitioners (Sourani and Sohail, 2011; Ochieng et al., 2014; Alsanad, 2015; Daniel et al., 2018; Opoku et al., 2019; Aghimien et al., 2021). Others suggest that there is a lack of demand and interest for sustainable building/products from clients, stakeholders and project team members, especially in Finland (Hakkinen and Belloni, 2011), Singapore (Hwang and Tan, 2012), Malaysia (Samari et al., 2013), Ghana (Djokoto et al., 2014), Nigeria (Daniel et al.,2014; Osuizugbo et al., 2020; Aghimien et al., 2019) and South Africa (Saad, 2016; Aghimien et al., 2019; Marsh et al., 2021).

Similarly, the *cultural disposition* among construction practitioners can deter the implementation of sustainable building construction. Many scholars found cultural change resistance (Ochieng et

al., 2014; Ametepey et al., 2015; Iqbal et al., 2021; Toriola-Coker et al., 2021) and a lack of commitment to pursuing sustainability (Sourani and Sohail, 2011; Ametepey et al., 2015; Ershadi et al., 2021; Negash et al., 2021) as key barriers in this aspect. Also, this may be, among other things, a result of short-term benefit culture (Daniel et al., 2018) among construction practitioners and stakeholders.

There is also a lack of or insufficient legislation, regulations and policies to move sustainable construction implementation forward in many countries (Hakkinen and Belloni, 2011; Sourani and Sohail, 2011; Samari et al., 2013; Ochieng et al., 2014; Ametepey et al., 2015; Alsanad 2015; De Souza Dutra et al., 2017; Aghimien et al., 2018; Daniel et al., 2018; Susanti et al., 2019; Osuizugbo et al., 2020; Negash et al., 2021).

Similarly, support and promotion are on the downside regarding sustainable building construction in many countries by the government (Djokoto et al., 2014; Ametepey et al., 2015; Durdyev et al., 2018b). Besides, there is a lack of incentives, strategy, and mobilisation of resources to support sustainable construction and technological changes (Zhang et al.; 2012; Serpell et al., 2013; Samari et al., 2013; Alsanad, 2015; Luthral et al., 2015; Daniel et al., 2018; Fathalizadeh et al., 2021; Tafazzoli, 2018; Aigbavboa et al., 2019; Osuizugbo et al., 2020; Ershadi et al., 2021; Toriola-Coker et al., 2021). Additionally, there is a lack of top management support from the construction organisations to support sustainable construction (Iqbal et al., 2021) as well shortage of green suppliers in many developing countries (Gou et al., 2013; Shi et al., 2013).

Another critical challenge is that of leadership/management. Poor leadership and management of construction personnel to achieve project success in sustainable construction (Ametepey et al., 2015; Susanti et al., 2019; Karji et al., 2020). Besides, there is a lack of team integration among stakeholders (Saad, 2016; Ershadi et al., 2021) and inadequate collaboration (Ershadi et al., 2021, Iqbal et al., 2021) and insufficient integration and link-up in the industry (Sourani and Sohail, 2011). There are also critical challenges associated with the procurement of sustainable building projects. Hakkinen and Belloni (2011) mentioned that procurement/tendering problems

are among the key barriers to building sustainably in Finland. Also, Ershadi et al. (2021) found a lack of sustainable procurement management integration in many countries, including Australia. Furthermore, Toriola-Coker et al. (2021) found that there is less priority given to sustainability during the bidding stage of a construction project, especially in Nigeria. Notably, Organisation for Economic Co-operation and Development (OECD, 2015) suggests that procurement challenges are a global problem.

Other challenges include Environment and Politics. According to Ofori (2019) and Opoku et al. (2019), the difference in environmental conditions between developed and developing countries may hinder the adoption of sustainable practices. On the other hand, political interest may affect how things are done in the industry regarding sustainability (Ametepey et al., 2015).

**Table 2. 6**: Key barriers to sustainable building construction

| Barrier Category | Barrier | Source | Year | Country of Study |
|---|---|---|---|---|
| **Knowledge/Information** | Lack of knowledge and awareness | Hakkinen and Belloni | 2011 | Finland |
| | | Sourani and Sohail | 2011 | Chile |
| | | Ahn et al. | 2013 | United States |
| | | Samari et al. | 2013 | Malaysia |
| | | Alsanad | 2013 | Kuwait |
| | | Ochieng et al. | 2014 | Literature review |
| | | Ametepey et al. | 2015 | Ghana |
| | | Saad | 2015 | South Africa |
| | | Aigbavboa et al. | 2016 | South Africa |
| | | Aghimien et al. | 2017 | Nigeria |
| | | Durdyev et al. | 2018a | Cambodia |
| | | Ogungbile and Oke | 2019 | West African Countries |
| | | Opoku et al. | 2019 | Ghana |
| | | Rock et al. | 2019 | Australia |
| | | Aghimien et al. | 2019 | Nigeria and South Africa |
| | | Fathalizadeh et al. | 2021 | Iran |
| | | Marsh et al. | 2021 | South Africa |
| | Lack of education and training for construction professionals | Gou et al. | 2012 | Hong Kong |
| | | Samari et al. | 2013 | Malaysia |
| | | Ershadi et al. | 2021 | Australia |
| | | Toriola-Coker et al. | 2021 | Lagos, Nigeria |
| | Poor expertise and low level of sustainability among practitioners | Samari et al. | 2013 | Malaysia |
| | | Alsanad | 2015 | Kuwait |
| | | Daniel et al. | 2018 | Nigeria |

| | | | | |
|---|---|---|---|---|
| | | Tafazzoli | 2018 | United States |
| | Limited information that will allow practical implementation of practices | Gou et al.<br>Shi et al.<br>Saad | 2013<br>2013<br>2015 | Hong Kong<br>China<br>South Africa |
| | Limited professional knowledge/capabilities/designers | Ametepey et al.<br>Durdyev et al. | 2015<br>2018a | Ghana<br>Cambodia |
| | Poor communication on strategies | Hwang and Tan<br>Saad<br>Iqbal et al. | 2012<br>2016<br>2021 | Singapore<br>South Africa<br>United States |
| | Inadequate competence in sustainability | AlSanad | 2015 | Kuwait |
| | Limited understanding from clients/stakeholders on the benefits | Zainul-Abidin<br>Hakkinen and Belloni<br>Aigbavboa et al. | 2010<br>2011<br>2017 | Malaysia<br>Finland<br>South Africa |
| | Limited research highlighting the benefits of sustainable construction practices | Hwang and Tan | 2012 | Singapore |
| **Psychological dispositions** | Reluctance to shift from the conventional methods | Sourani and Sohail<br>Ochieng et al.<br>Alsanad<br>Daniel et al.<br>Opoku et al.<br>Aghimien et al. | 2011<br>2014<br>2015<br>2018<br>2019<br>2019 | United Kingdom<br>Literature Review<br>Kuwait<br>Nigeria<br>Ghana<br>Nigeria and South Africa |
| | Absence of demand for sustainable building/product | Hakkinen and Belloni<br>Hwang and Tan<br>Samari et al.<br>Djokoto et al.<br>Daniel et al.<br>Osuizugbo et al.<br>Marsh et al. | 2011<br>2012<br>2013<br>2014<br>2018<br>2020<br>2021 | Finland<br>Singapore<br>Malaysia<br>Ghana<br>Nigeria<br>Nigeria<br>South Africa |
| | Little interest among project team members | Hwang and Tan | 2012 | Singapore |
| | Lack of client's/stakeholders' interest | Hwang and Tan<br>Ochieng et al.<br>Saad<br>Osuizugbo et al.<br>Aghimien et al.<br>Marsh et al. | 2012<br>2014<br>2016<br>2020<br>2021<br>2021 | Singapore<br>Literature Review<br>South Africa<br>Nigeria<br>Nigeria and South Africa<br>South Africa |

**Table 2.6 (continued)**: Key barriers to sustainable building construction

| Barrier category | Barrier | Source | Year | Country of Study |
|---|---|---|---|---|
| **Financial/economic** | Financial/economic barriers | Ametepey et al. | 2015 | Ghana |
| | | Susanti et al | 2019 | Indonesia |
| | | Karji et al. | 2020 | United States |
| | Cost premium/Increased capital cost/Additional building cost/Higher final price | Hakkinen and Belloni | 2011 | Finland |
| | | Hwang and Tan | 2012 | Singapore |
| | | Samari et al. | 2013 | Malaysia |
| | | Ahn et al., | 2013 | United States |
| | | Shi et al. | 2013 | China |
| | | Opoku and Ahmed | 2014 | United Kingdom |
| | | Karunasena et al. | 2016 | Sri Lanka |
| | | Agbavboa et al. | 2017 | South Africa |
| | | Aghimien et al. | 2018 | Nigeria |
| | | Durdyev et al. | 2018a | Cambodia |
| | | Tafazzoli | 2018 | United States |
| | | Ogungbile and Oke | 2019 | West African countries |
| | | Rock et al. | 2019 | Australia |
| | High cost of sustainable options/implementing sustainable practices | Hwang and Tan | 2012 | Singapore |
| | | Alsanad | 2015 | Kuwait |
| | | Saad | 2016 | South Africa |
| | | Osuizugbo et al. | 2020 | Nigeria |
| | | Marsh et al. | 2021 | South Africa |
| | Fear of higher investment costs/perceived high cost/misconception of construction cost overrun. | Samari et al. | 2013 | Malaysia |
| | | Alsanad | 2015 | Kuwait |
| | | Ametepey et al. | 2015 | Ghana |
| | | Aigbavboa et al. | 2017 | South Africa |
| | | Aghimien et al. | 2019 | Nigeria and South Africa |
| | | Fathalizadeh et al. | 2021 | Iran |
| | | Marsh et al. | 2021 | South Africa |
| | Ignorance of lifecycle cost benefits | Toriola-Coker et al. | 2021 | Lagos, Nigeria |
| | Longer payback periods | Ahn et al. | 2013 | United States |
| | Absence of credit resources for upfront cost | Samari et al. | 2013 | Malaysia |
| | Use of expensive technologies | Saad | 2016 | South Africa |
| | Priority is given to economic needs | Durdyev et al. | 2018a | Cambodia |
| | Developers build to maximise profit only, not for users' comfort | Saad | 2016 | South Africa |
| **Time and Planning** | Inadequate scheduling of task and process phases | Hakkinen and Belloni | 2011 | Finland |
| | | Karji et al. | 2020 | United States |
| | Extensive pre-contract planning | Daniel et al. | 2018 | Nigeria |
| | Longer time required for completion | Shi et al. | 2013 | China |
| **Technical** | Technical barriers | Ametepey et al. | 2015 | Ghana |
| | | Susanti et al | 2019 | Indonesia |
| | Inadequate methods and tools | Hakkinen and Belloni | 2011 | Finland |
| | Absence of green technology and techniques | Samari et al. | 2013 | Malaysia |
| | | Opoku et al. | 2019 | Ghana |
| | Lack of innovation process | Hakkinen and Belloni | 2011 | Finland |
| | Inadequate enforcement | Saad | 2016 | South Africa |
| | | Ershadi et al. | 2021 | Australia |

**Table 2.6 (continued)**: Key barriers to sustainable building construction.

| Barrier Category | Barrier | Source | Year | Country of Study |
|---|---|---|---|---|
| **Support and promotion** | Non-existence of incentives/government support | Zhang et al. | 2012 | Hong Kong |
| | | Serpell et al. | 2013 | Chile |
| | | Samari et al. | 2013 | Malaysia |
| | | Alsanad | 2015 | Kuwait |
| | | Luthral et al. | 2015 | India |
| | | Tafazzoli | 2018 | United States |
| | | Osuizugbo et al. | 2020 | Nigeria |
| | | Ershadi et al. | 2021 | Australia |
| | | Toriola-Coker et al. | 2021 | Lagos, Nigeria |
| | Lack of promotion by government | Djokoto et al. | 2014 | Ghana |
| | | Ametepey et al. | 2015 | Ghana |
| | | Durdyev et al. | 2018b | Cambodia |
| | Absence of strategy to promote sustainable construction/green building | Samari et al. | 2013 | Malaysia |
| | | Daniel et al. | 2018 | Nigeria |
| | | Fathalizadeh et al. | 2021 | Iran |
| | Mobilisation of resources to support technological changes | Aigbavboa et al. | 2021 | South Africa |
| | Deficiency of top management support | Iqbal et al. | 2021 | United States |
| | Deficiency of green suppliers | Gou et al. | 2013 | Hong Kong |
| | | Shi et al. | 2013 | China |
| **Cultural dispositions** | Cultural change resistance | Ochieng et al. | 2014 | Literature Review |
| | | Ametepey et al. | 2015 | Ghana |
| | | Iqbal et al. | 2021 | United States |
| | | Toriola-Coker et al. | 2021 | Lagos, Nigeria |
| | Socio-cultural barriers | Ametepey et al. | 2015 | Ghana |
| | | Susanti et al. | 2019 | Indonesia |
| | Lack of consideration for sustainability in design and short-term benefit culture | Daniel et al. | 2018 | Nigeria |
| | Poor commitment | Sourani and Sohail | 2011 | United Kingdom |
| | | Ametepey et al. | 2015 | Ghana |
| | | Ershadi et al. | 2021 | Australia |
| | | Negash et al. | 2021 | Somaliland |
| **Regulation/legislation** | Deficiency/insufficient legislation/regulation and policies | Hakkinen and Belloni | 2011 | Finland |
| | | Sourani and Sohail | 2011 | United Kingdom |
| | | Samari et al. | 2013 | Malaysia |
| | | Ochieng et al. | 2014 | Literature Review |
| | | Ametepey et al. | 2015 | Ghana |
| | | Alsanad | 2015 | Kuwait |
| | | De Souza Dutra et al. | 2017 | Brazil |
| | | Aghimien et al. | 2018 | Nigeria |
| | | Daniel et al. | 2018 | Nigeria |
| | | Susanti et al. | 2019 | Indonesia |
| | | Osuizugbo et al. | 2020 | Nigeria |
| | | Negash et al. | 2021 | Somaliland |

**Table 2.6 (continued)**: Key barriers to sustainable building construction.

| Barrier Category | Barrier | Source | Year | Country of Study |
|---|---|---|---|---|
| **Management/Leadership** | Management/Leadership barriers | Ametepey et al.<br>Susanti et al.<br>Karji et al. | 2015<br>2019<br>2020 | Ghana<br>Indonesia<br>United States |
| | Absence of team integration among stakeholders | Saad<br>Ershadi et al. | 2016<br>2021 | South Africa<br>Australia |
| | Inadequate collaboration | Ershadi et al.<br>Iqbal et al. | 2021<br>2021 | Australia<br>United States |
| | Insufficient integration and link-up in the industry | Sourani and Sohail | 2011 | United Kingdom |
| **Procurement** | Tendering and procurement problems | Hakkinen and Belloni | 2011 | Finland |
| | Non-existence of sustainable procurement management integration | Ershadi et al. | 2021 | Australia |
| | Less priority is given to sustainability during the bidding stage | OECD<br>Toriola-Coker et al. | 2015<br>2021 | <br>Lagos, Nigeria |
| **Environment** | Environmental conditions difference between developed and developing countries | Ofori<br>Opoku et al. | 2019<br>2019 | Ghana<br>Ghana |
| **Politics** | Political barriers | Ametepey et al. | 2015 | Ghana |

## 2.7 Chapter Conclusion

This chapter provided an overview to elucidate sustainable building construction research. Hence, it discussed the concept of sustainability and the three critical aspects of sustainability such as environmental, economic and social. Similarly, it discussed building construction and its effect on the environment, economy, and social welfare. Besides, it presented a detailed discourse on the need to embed sustainable principles for the effective and successful construction and delivery of building projects. It also discussed the essence of sustainable building design and various sustainable building materials that can be used as an alternative to conventional methods. Furthermore, it differed in detail on the various acceptable assessment tools for evaluating the performance of buildings in terms of sustainability used by countries. Lastly, it discussed the benefits and barriers to sustainable building construction

# CHAPTER THREE

# THEORETICAL AND CONCEPTUAL PERSPECTIVES OF SUSTAINABLE BUILDING CONSTRUCTION RESEARCH

## 3.0 Introduction

This chapter provides an overview of sustainable building construction (SBC) and the theories and models associated with its research. It also presents the conceptual framework for the study. Chapter three discusses the various theories and models associated with sustainable building construction. Similarly, it depicts the study's conceptual framework, considering the factors influencing sustainable building construction. The identified gaps form the additional new construct.

## 3.1 Sustainable Building Construction Theory and Definition

According to Fazlic (2008), sustainability alludes to the theory of the actualisation and maintenance of the present and future needs of the people. GhaffarianHoseini (2012) also affirms that it accepts the interrelations of humans and the environment based upon the adjustment of genuine demands of humans, including social, cultural, environmental, and economical, and calls attention to the conservation of natural resources Sustainable buildings aim at the “required building performance with minimum adverse environmental impact while encouraging improvements in economic, social, and cultural circumstances” (Häkkinen et al., 2016:651). Similarly, DuPlessis defined “sustainable construction” as the “process applied to the complete construction cycle from the extraction and beneficiation of raw materials, through the planning, design, and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste. It is a holistic process aiming to restore and maintain harmony between the natural and built environments while creating settlements that affirm human dignity and encourage economic equity” (Du Plessis 2002:6). Hence, the term

“sustainable building construction” (SBC) can be defined as the construction of buildings in a sustainable and green way (Nelms et al., 2005; Tabassi et al., 2016).

"Green" and "sustainable" are terms that highlight ecological mindfulness and the protection of natural resources. "Green" is strictly focused on environmental health, while "Sustainable" is concerned with environmental health, economic vitality, and social benefits (WorldAtlas, 2021: online). In other words, Green is not just a colour, but a mindset focused on actualising environmental health. At the same time, sustainability involves green products, services and eco-friendly activities. Hence, green is a subset of sustainability. Gridal (2019:online) indicated, “Green building can be described as a sustainable building that only covers the environmental sustainability subject.” On the reverse, a sustainable building may be described as “a form of green building, but with a more stringent goal of indefinitely maintaining environmental footprints that are small enough that they will not impede future human activity and the functioning of ecosystems.” (CSR Report, 2017: online).

The development of a truly sustainable building requires complex measures to be applied during all the development stages in terms of aesthetics (shape of building and technologies), function (present and future adaptation), and construction (materials used) (Krizmane et al., 2016). Sustainable building is needed for better construction project delivery performance and positive societal contribution. Besides, “sustainable buildings contribute to meeting global goals in terms of climate change and human rights, as well as national and local goals of poverty reduction, job creation, economic growth, energy security, public health, and others.” (Krizmanea et al., 2016:98). Additionally, “Sustainable buildings optimise energy use, protect and conserve water, use environmentally preferable products, enhance indoor environmental quality, and optimise operational and maintenance practices” (Klotzl and Horman, 2007:322). The above reiterates the importance of sustainable building (which includes green building) and how green building is a subset of sustainable building, indicating that both are almost inseparable.

## 3.2 A Review of Sustainable Building Construction Theories

A theoretical framework can be characterised by a series of assumptions, ideologies, conceptions, and models that structure the premise to the topics, hence, building up the relationships between them (Maxwell, 2004; Creswell, 2009; Opoku, Ayarkwa, and Agyekum, 2017). Consequently, it can be depicted as a series of information that enables the comprehension of sustainable building construction from several viewpoints. Opoku et al. (2017) affirmed that there is a need to utilise theories in sustainable construction as a basis for an advanced study. Hence, existing views must be reviewed and evaluated for possible improvement to actualise a practical, sustainable building construction. The following broader theories underpin sustainable building construction research.

### 3.2.1 Resilience Theory

Walker and Salt (2006:1) defined resilience as the "ability of a system to absorb disturbance and retain its basic functions and structure". It also relates to sustainability concepts and the challenge of servicing the current system demands without eroding the potential to meet future needs (Walker and Salt, 2006). This aligns with Redman (2014), who affirms that sustainability science and resilience theory are complementary approaches. Redman (2014) describes this resilience theory as that which enables a system to adapt and respond to varying conditions and disturbances in ways that minimise losses to the system and its functions. The awareness of the resilience theory in sustainable development has existed for more than twenty years (Folke et al., 2002; Opoku et al., 2017). Although the resilience theory has a multidisciplinary concept (Redman, 2014; Laboy and Fannon, 2016; Opoku et al., 2017), some authors affirm that it is strongly connected to ecological disciplines (VanBreda, 2001; Redman, 2014). VanBreda (2001) pinpoints that this resilience theory deals with issues related to working environments, policies, individuals, communities, and families. Individual resilience is characterised by the skills, capacity, information, and experiences gathered over the long run as they try to overcome challenging situations and struggles (VanBreda, 2001; Opoku et al., 2017). Hence, the resilient theory is essential for this study as it demands that stakeholders and consultants possess the

skills, capacity, information, and experiences to bring about sustainability in the Built Environment. Besides, “we live in a time of growing population coupled with a declining resource base and great uncertainty about a range of environmental issues such as climate change” (Walker and Salt, 2006:2). Therefore, the enabling factors of resilience theory are critical for adaptions and improvements toward sustainable building construction and the actualisation of sustainable project delivery outcomes. Additionally, researchers such as Bruneau et al. (2003) and Tierney and Bruneau (2007) have categorised resilience into four domains in human systems. They are technical, organisational, social, and economic. “The technical domain involves the physical attributes and much of the design world, including the Built Environment of infrastructure, buildings, and designed landscapes. The organisational domain considers the governing institutions or managing structures that enact plans, policies, and regulatory frameworks to organise planning, mitigation, preparation, emergency response, and reorganisation of systems. The social domain considers the vulnerabilities and adaptive strengths of individuals and populations affected by a disturbance. The economic domain considers the capacity of local or regional economies to prepare and respond by innovating, rebuilding and reorganising (Laboy and Fannon, 2016:39). However, Laboy and Fannon (2016) argue that the resilience model is limited as it mainly focuses on the human beings and human environments. Hence, they suggest that resilience needs to be emphasised in ecology, the natural world, or the environment. Similarly, Achour, Pantzartzis, Pascale, and Price (2015) affirm that the planning of projects needs to take a further step by accommodating the “resilience” element to the set of sustainability aspects (society, environment, and economy). This will enable infrastructures to be environmentally, economically, socially viable and resilient enough to cope with disruptions (Achour et al., 2015). Resilience theory is, therefore, one of the theories that underpin the current study.

### 3.2.2 Social Cognitive Theory (SCT)

This theory originated from Albert Bandura as a social learning theory in 1960 and developed into Social Cognitive Theory (SCT) in 1986, and has been widely used in areas such as education, health, communication, and business (Bandura, 2000; Font, Garay, and Jones, 2016).

Notwithstanding, it has been receiving attention regarding sustainability in the Built Environment (Sampaio, Thomas, and Font, 2012a; Sampaio et al., 2012b; Font et al., 2016; Onuoha, Aliagha, and Rahman, 2018). SCT can be described as a psychological model of behaviour that clarifies the motivations, inspirations, assumptions, expectations, foresight, wants, and duty that could instantly direct a person's action (Iheanyichukwu, Aliagha, and Ufere, 2015; Onuoha, Aliagha, and Rahman, 2018). The heroes of this theory disclose that the ability to set up change is dictated by the common impact of individual tendencies and social variables, which to a great extent, shape one's inspirations, assumptions, motivations, and expectations (Bandura, 2002; Iheanyichukwu et al., 2015; Font et al., 2016). “People’s forethought and prediction could presume cognitive values and ethics with the implication of possible future events and as such establish goals to be either accomplished or circumvent and map out intervention strategies for attaining or evading such future events” (Iheanyichukwu et al., 2015:2891). Therefore, this implies that psychological factors can affect the implementation of sustainable practices that lead to sustainable building construction. A person’s mindsets, beliefs, expectations, and assumptions can either motivate or deter the adoption of sustainable practices. Hence, optimistic assumptions and dispositions will ensure commitment to erecting a sustainable building in the Built Environment. Diyana and Abidin (2013) also posit that motivation is subject to the point and advantages recognised through the thinking ahead measure, especially when the information on green building is an arising idea. Hence, Sustainable Building Construction (SBC) is a phenomenon that requires positive assumptions, expectations, motivations, and commitment to actualising sustainable outcomes.

### 3.2.3 Stakeholders Theory

There exists an assortment of definitions and understandings from the literature of what a stakeholder is. According to Friedman and Miles (2006), many definitions have been inappropriately used. A stakeholder’s definition can be categorised into analytical/descriptive and normative approaches (Friedman and Miles, 2006; Feige, Wallbaum, and Krank, 2011). Some notable definitions are from Freeman (1984) and Clarkson (1995). Freeman (1984) defined stakeholders analytically as any group or person who can influence or is influenced by

the accomplishment of the firm's goals. On the other hand, Clarkson had a normative approach to the definition as he defined stakeholders as "persons or groups that have, or claim, ownership, rights, or interests in a corporation and its activities, past, present, or future" (Clarkson 1995:106). Feige et al. (2011) posit that the aspects of the stakeholders' definition, which includes a group or individuals and that interest could take place in the "past, present or future", should be considered for the sustainable building sector. Nevertheless, they assert that these perspectives should not just be connected to a company or corporation but ought to be issue-centred (Feige et al., 2011). According to Feige et al. (2011), in the issue-centred concept, a pool of stakeholders serves as representatives in addressing the necessities and wishes of a lot more extensive arrangement of stakeholders. Thereby shortening the time spent on conversation and making decisions. Therefore, sustainable building construction is an appropriate illustration of a particular point of convergence or central issue: it's anything but theme applicable to single people and associations. However, it is significant worldwide. What's more, the point of successfully changing normal praxis can't be accomplished by a solitary organisation or firm (Feige et al., 2011).

### 3.2.4 Institutional theory

Institutional Theory (IT) gives a theoretical focal point that aids researchers in identifying and examining the influential factors that help the survival and legitimacy of organisational practices (Glover, Champion, Daniels, and Dainty, 2014). These factors include culture, social environment, regulatory and legal environment, tradition and history, and economic incentives (Lai, Wong, and Cheng, 2006; Baumol et al., 2009; Brunton et al.,2010; Glover et al., 2014). Institutional theory is a generally acknowledged hypothetical stance that accentuates rational myth, isomorphism, and legitimacy (Scott, 2008; Mensah, Ayarkwa, and Nani, 2018). There are three Isomorphic drivers of IT: mimetic, coercive, and normative (DiMaggio and Powell, 2000). These drivers can play massive roles in promoting sustainable building construction practices among companies and organisations in the construction industry.

Mimetic isomorphic drivers happen when companies copy the activities of successful rivals in the business, trying to duplicate the way to progress and thus legitimacy (Aerts et al., 2006; Sarkis et al., 2011). In other words, current practices can be improved by aligning themselves to the modus operandi of robust organisations. This is true as some studies support that the indigenous small-scale construction companies in developing countries can benefit from the organisations using joint ventures (Laryea, 2010; Zhu and Liu, 2010). This mimicking approach is also significant for the advancement of construction companies in many developed nations (Aerts et al., 2006; Glover et al., 2014). Coercive happens because of the influence of those who are in the position of authority. Mensah et al. (2018:7) indicate that Coercive isomorphic drivers are the governmental rules and regulations that pressurise organisations to practice sustainability voluntarily." This also aligns with Kraft and Furlong (2007), who stated that IT is a policy-making theory that accentuates government structures' formal and legal aspects. Coercive pressing factors, therefore, can be critical to driving sustainable building construction in the industry. On the other hand, "normative drivers deal with customers and market situations that drive an organisation to implement innovative practices. This constitutes the conformance to the rules and belief systems prevailing in an economic environment." (Mensah et al., 2018:7). Therefore, normative drivers are needed for building sustainably.

## 3.3 Conceptual Models of Sustainable Building Construction

Models are perspectives or conceptions scholars or theorists' lean-to or support (Omonyo, 2015; Tengan, 2018). Hence, understanding models is fundamental for generating knowledge on how sustainable building projects should be undertaken to achieve the desired outcome. The following models are most related to the present study.

### 3.3.1 Green Specification Model

Lam, Chan, Poon, Chau, and Chun (2010) postulated a conceptual model for implementing green specifications in Hong Kong. The constructs include green technology and techniques, reliability

and quality of specification, leadership and responsibility, stakeholder involvement, and guide and benchmarking systems.

Green technology and techniques were found to be the most critical factor. The study suggests that variables such as mitigation of environmental impacts, selection of materials based on low risk to the environment; selection of materials based on their renewability/recyclability, reduction of energy consumption, adoption of green practices or procedures, life cycle considerations and using available advanced green construction technology should be considered under the factor for the successful implementation of green specifications. Second, in terms of importance, is stakeholder involvement. However, various stakeholder groups may have distinct emphases requiring further investigation. Also, "whilst the procurement system being adopted for a construction project affects the contractual relationship between the stakeholders (such as the positions of specialist contractors), the specifications usually form part of the construction contracts (whether they are main contracts, sub-contracts or work packages), thus making it an important management tool to enhance the sustainability of construction resources" (Lam et al., 2010:659). Furthermore, the study affirmed that (with contribution from different stakeholders in setting up local material or information databases) "the success of green specifications relies not only on the specified contents but the effectiveness of the supply chain and monitoring mechanism for their sustainable adoption on an industry-wide basis" (Lam et al., 2010:659).

Lam et al. (2010)'s study mainly focused on specifications suggesting that the findings cannot be generalised to the entire sustainable building construction process. Hence, there is a need for a robust model. Besides, the findings were only analysed with exploratory factor analysis suggesting further methodical examination.

### 3.3.2 Edén-Rubino-Femenias's model

Eden et al. (2008) explored the mechanism for development toward more sustainable building in Sweden. Three conceptual pairs were used to discuss the factors that make sustainable building practices progress. They include governance and learning, exemplifying and legitimising, and symbol and performance. The explorative review points to increasing administration in

developing more sustainable buildings. Besides, the study affirmed that the transfer of results over organisation boundaries would need a process of experimentation in which the external and explicit evolution of knowledge will have to be internalised by new actors and tested in a new context. The study further affirmed that an implementation gap is more than a knowledge problem. There has frequently been a misjudgement of the impact of key individuals and rational choices on decision-making. This ignores the intricacy and unpredictability of the implementation process and neglects to give dependable clarifications regarding the connection between practice, performance and context (Fernie *et al.,* 2006, Rubino, 2007).

The study highlighted the essence of emerging tools for legitimising more sustainable building practices, including building material declarations, environmental programmes, environmental policies and life cycle costing. Similarly, the review uncovers a shift from solution fixed and closed concepts of sustainable building towards function, quantitative performance and systems thinking. Nevertheless, the study is limited because it is review based on a retrospective study, and the concepts are not exhaustive and have not been empirically investigated.

### 3.3.3 Windapo's Model

Windapo (2014) conceptualised four key green building drivers under economic and ecological/societal concerns in the Western Cape construction industry of South Africa. The drivers include stakeholder demands, financial issues, environmental sustainability, and social responsibility. Generally, the findings reveal that the main determinants under the mentioned conceptual factors include rising energy costs, the Green Star rating system, competitive advantages and legislation. Also, operation cost savings and marketing potential were among the significant benefits driving green building under financial issues. Besides, the study suggests that green buildings would be less attractive without a rating tool capable of conferring "greenness" on a building along with competitive advantage, corporate image, and product differentiation. Also, it was indicated that the financial benefits of green building are similarly linked to the standard rating tool.

The research was based on a descriptive case study with interviews and data analysed with thematic analysis. Although the study provided factual evidence on green building drivers, it was limited by its small sample size and the location-specific nature of the multi-case study approach. The author suggested a more detailed and robust study in the future.

### 3.3.4 Kalua's model

Kalua (2015) reviewed the literature on the economic sustainability of green building practices in the least developed countries. Hence, four key concepts were proposed for effective green building practices. They are public awareness, finance access, construction industry size, and capacity. The study suggests that public awareness of green buildings should be significantly raised. Second, there should be political willness to facilitate green building practices, especially by allowing public access to finance. Thirdly, the growth and development of the construction industry should be supported. Lastly, the capacity of the local industry should be enhanced to handle green building projects and produce green building materials.

Although Kalua's model has some significance in achieving green building practices, it seems to have mainly focused on economic aspects. Hence, the study is limited as it lagged in other elements such as environmental and social. This suggests that it may not be as effective in achieving sustainable building construction. Besides, the driving factors are not exhaustive. Furthermore, the study was based on a literature review and has not been empirically investigated, nor has the goodness of fit of the model been examined.

Kalua (2015) concludes that green building practices may not be economically sustainable in the least developed countries. Hence, this claim needs further investigation, especially empirically. Also, the model was not ascribed to any specific country.

### 3.3.5 Wong-Chan-Wadu's Model

Wong et al. (2016) conducted an empirical study to facilitate effective green procurement in construction projects in Hong Kong. They proposed ten constructs for actualising the desired

outcome. The constructs include green principles and techniques, efforts or initiatives by the industry and society, executive management's commitments and requirements, a mutual collaboration between stakeholders, the establishment of a reliable database, regulations and standards, green design incorporated with financial benefits, green policies and management systems of the organisation, life-cycle consideration and green construction technology, and supports from mid-level managers. Notably, mandatory environmental regulations by the government, client requirements in tendering, and government and non-governmental organisation requirements were the top three drivers of green procurement adoption from the study.

Wong et al. (2016) have studied some limitations. It focused only on procurement and not on overall sustainable building construction. Also, only factor analysis was used to interpret the conceptual constructs. The goodness of fit of the model was not determined, which suggests further methodological investigation such as the systematic approach of the structural equation model. Notably, the current study accommodates the use of the structural equation model for the determination of the significance and goodness of fit of the conceptual model as well as its validation.

The study recommends that the availability of green techniques is critical to implementing green procurement. Also, that models for various sorts of improvement should be established for private developers. Additionally, the study recommends using advanced construction IT like building information modelling, to stimulate the construction process and incorporate a green design approach, including waste reduction. The authors also proposed a larger sample for further study.

### 3.3.6 Determinants of sustainable building construction

Although there is a lack of studies that conceptualised, tested, and modelled the factors facilitating green and sustainable buildings, relevant determinants of sustainable building construction can be found in various pieces of literature. This section focuses on identifying the influencing determinants of sustainable building construction. It reviewed the literature related to

sustainable and green building. The reviewed studies helped the researcher propose a conceptual framework most relevant to sustainable building construction in South Africa. Sustainable building construction as a practice is concerned with ensuring elements and components of the system relate to or influence each other to facilitate the achievement of project targets and goals.

Eden, Rubina, and Femenias (2008) explored the mechanism for development toward more sustainable building in the west of Sweden. The study was based on a literature review, and three conceptual pairs of factors that can improve the progress of sustainable building practices were mentioned. The conceptual pairs included governance and learning, exemplifying and legitimising and symbol and performance. Similarly, Ayarkwa, Acheampong, Wiafe, and Boateng (2017) investigated the factors affecting the implementation of sustainable construction in Ghana (Architect's perspective). They found that client demand and requirements, stakeholder influence, cost efficiency, legislative and regulation, awareness and knowledge by top management impact sustainable construction. Another study in Ghana by Ametepey, Aigbavboa, and Ansah (2015) substantiated the findings of Ayarkwa et al. (2017) as they identified barriers such as lack of legislation, lack of professional knowledge, fear of higher investment cost, lack of government commitment, and cultural change resistance as significant impediments to sustainable construction in Ghana. They further categorised the findings into six components which included financial barriers, political barriers, management/ leadership barriers, technical barriers, socio-cultural barriers, and knowledge/ Awareness barriers. A similar study conducted in Nigeria by Nduka and Ogunsanmi (2015) on ‘stakeholders’ perception of factors determining the adoption of green building practices in construction projects in Nigeria’ identified a lack of awareness, expertise, and higher cost as a critical impediment. The authors, thereby, recommended the full establishment of the green building council of Nigeria for awareness creation and the introduction of guidelines, tools, and techniques that will drive future green building projects.

Liu, Low, and He (2012) investigated the driving and impeding factors for green practices in the Chinese building industry. The result showed that “countenance and incentives from the government” were the most significant driving force behind China's rapid expansion of the green

building industry. However, they mentioned significant barriers that included lack of application experience, high cost of design, and cost control in construction. This aligns with a study by Dahle and Neumeyer (2001). They identified government incentive support as well as the creation of environmental awareness as crucial factors for overcoming barriers to campus greening in London, UK. Similarly, Wang, Zang, and Pasquire (2018) investigated the factors that can enhance green building specifications adoption in China. The study summarised the variables into five components: green technology and techniques, awareness and attitude, policies and regulations, markets, and economics. Also, Wong, San-Chan, and Wadu (2016) identified "requirements, legislation, and standards; stakeholder involvement; corporate factors; market factors; feedback and building public confidence; and principles and techniques as factors enhancing the adoption of green procurement in Hongkong with regulations and standards by the government as the most significant. Further, Qian and Chan (2010) identified factors such as economic incentives and legislation for building energy efficiency (BEE) as key government measures to promote BEE in China.

A study in Gauteng Province of South Africa by Oguntona et al. (2019) on the benefits and drivers of green building implementation identified variables such as availability of more financing options, improved market for green products/materials, education and training on GB technologies, provision of economic incentives, and affordability of GB materials as key drivers. Another study by Windapo and Goulding (2015) in the Western Cape Province of South Africa proposed Corporate Factors (including image, vision, culture, policy, and social responsibility) as critical factors in implementing green building practices. Additionally, the authors found a high degree of unawareness of green building legislation/practices among construction company stakeholders. They also highlighted that primarily on-site staff are less motivated to adopt green practices than the management staff. Similarly, Windapo (2014) identified legislation, marketing benefits (from rising energy costs), the industry's green star rating systems, corporate factors and competitive advantage as notable green building drivers in the South African construction industry, especially in the Western Cape province. Generally, the results suggest that operational costs and stakeholders' demands can increase green building implementation. Also, the study

indicates that green buildings will always be needed where there is an industry rating system and an energy cost increase.

A study in Malawi by Kalua (2015) posits that factors such as the increase in public awareness regarding the need for green building, public access to construction finance, and enacting legislation to make green building compulsory are essential for economic sustainability of green building practices. Other factors such as construction industry development and growth and enhancement of local industry capacity to handle green building projects were mentioned.

The previously discussed findings aligned with several studies from the literature. For instance, education and training, including technical capacity, were mentioned by several authors for the effective implementation of green building practices and sustainable construction (Manoliadis et al., 2006; Arif et al., 2009b; DuBose, Bosch, and Pearce, 2007; Liu et al., 2012; Ahn et al., 2013; Niroumand et al., 2013; Khoshnava et al., 2014; Aktas and Ozorhon, 2015; Udawatta et al., 2015). "Knowledge and awareness creation" for the need for sustainable construction and green building was also mentioned by many authors (DuBose et al., 2007; WBCSD, 2008; Arif et al., 2009a, 2009b; Potbhare et al., 2009; Abidin, 2010; Hakkinen and Belloni, 2011; Ahn et al., 2013; Serpell et al., 2013; Abidin and Powmya, 2014; Khoshnava et al., 2014; Wang et al., 2014; Aktas and Ozorhon, 2015; Andelin et al., 2015; Udawatta et al., 2015; Murtagh et al., 2016). The regulatory environment, which comprises government requirements, legislations and standards, policies, and regulations regarding green building and sustainable construction, was also discussed by several studies (Manoliadis et al., 2006; DuBose et al., 2007; Du Plessis, 2007; WBCSD, 2008; Arif et al., 2009a, 2009b; Qi et al., 2010; Hakkinen and Belloni, 2011; Arif et al., 2012; Boyle and McGuirk, 2012; Ahn et al., 2013; Gou, Lau and Prasad, 2013; Niroumand et al., 2013; Serpell et al., 2013; Abidin and Powmya, 2014; Khoshnava et al., 2014; Low, Gao and Tay, 2014a; Wang et al., 2014; Wong and Abe, 2014; Zhai, Reed, and Mills, 2014; Zhang, 2014; Aktas and Ozorhon, 2015; Andelin et al., 2015; Udawatta et al., 2015; Murtagh et al., 2016; Wong, Chan, and Wadu, 2016; Oguntona et al., 2019; Yas and Jaafer, 2020). Incentive schemes, especially from the government, also received lots of attention and were mentioned by several studies as vital for promoting green and sustainable construction (Manoliadis et al., 2006;

DuBose et al., 2007; Richardson and Lynes, 2007; Sayce et al., 2007; Arif et al. 2009a, 2009b; Qi et al., 2010; Liu et al., 2012; Ahn et al., 2013; Gou et al., 2013; Abidin and Powmya, 2014; Khoshnava et al., 2014; Mulligan et al., 2014; Tan, 2014; Aktas and Ozorhon, 2015; Udawatta et al., 2015; Brotman, 2016; Oguntona et al., 2019; Yas and Jaafer, 2020; Chen et al., 2022).

Corporate factors, including image, vision, culture, and policy proposed by Windapo and Goulding (2015) as essential for green building implementation within organisations, were also mentioned by several authors (Arif et al., 2009a; Potbhare et al., 2009; Bond, 2010; Bond, 2011a; Bond, 2011b; Arif et al., 2012; Boyle and McGuirk, 2012; Gou et al., 2013; Serpell et al., 2013; Abidin and Powmya, 2014; Low et al., 2014a; Low, Gao, and See 2014b; Mulligan et al., 2014; Wong and Abe, 2014; Zhang, 2014; Aktas and Ozorhon, 2015; Andelin et al., 2015; Brotman 2016; Yas and Jaafer, 2020). The need to enforce sustainable principles, tools, and techniques, including the use of sustainable materials as suggested by Nduka and Ogunsanmi (2015) and Wong et al. (2016), was also mentioned by some authors (Dahle and Neumayer, 2001; Lam et al., 2009; Lam et al., 2010; Hakkinen and Belloni, 2011; Ametepey et al., 2015; Wang et al., 2018). Additionally, the adoption of green rating systems/sustainable building assessment tools is found essential for facilitating sustainable building construction (Richardson and Lynes, 2007; Lam et al., 2009; Liu et al., 2012; Nduka and Ogunsanmi, 2015; Wong et al., 2016; Darko et al., 2017; Onuoha et al., 2018; Assylbekov et al., 2021). Lam et al. (2009) assert that there should be proven green specifications model clauses, references for green performance assessments, and advanced green technology for construction purposes to enable companies to adopt green procurement toward achieving sustainable construction. Marketing factors such as benefits, demands and the like were suggested by Wong et al. (2016) were also acknowledged by many authors as essential for the adoption of green and sustainable construction by companies (Chan, Qian, and Lam, 2009; Potbhare et al., 2009; Bond, 2010; Boyle and McGuirk, 2012; Love et al., 2012; Abidin and Powmya, 2014; Low et al., 2014a; Mulligan et al., 2014; Wang et al., 2014; Windapo, 2014; Zhang, 2014; Zhai et al., 2014; Andelin et al., 2015; Wang et al., 2018; Darko et al., 2017; Oguntona et al., 2019; Yas and Jaafer, 2020).

Other notable factors for bringing about sustainable construction which can be relevant in the building sector include leadership, communication and collaboration, cost efficiency, feedback and building public confidence, personal commitment, self-identity, attitude and traditions, moral or social conscience, construction industry development, and tendering and contractual requirements (Richardson and Lynes, 2007; Lam et al., 2010; Wang et al., 2014; Kalua, 2015; Tabassi et al., 2016; Ayarkwa et al., 2017; Darko et al., 2017; Murkeji, 2017).

Murkeji (2017) mentioned transcendent leadership (TL) as a key to Sustainable Construction Project Management in China and India. He affirms that "the literature endorses the TL process as a way to stimulate practitioners' masterly facilitation of expert internal and external stakeholders, for greater collaboration, proactive planning and decision- making, innovative performance, motivation, morality, and consciousness not only for the reduction of project failures but also to deliver triple bottom line sustainability in profitability, people, and protection of the environment." (Murkeji, 2017:439). Also, Tabassi et al. (2016) posit that project managers' leadership competencies and transformational leadership qualities are essential drivers for sustainable construction. Lam et al. (2010) further assert that business leaders who act as green specification champions can use good leadership and responsibility in the decision-making process to achieve common objectives like diminishing pollution because of construction activities and reducing energy consumption. Similarly, Richardson and Lynes (2007) mentioned internal leadership among stakeholders with decision-making power as critical ingredients for successful green building projects.

Richardson and Lynes (2007) also mentioned "communication between professional designers" as a critical ingredient for successful green building projects. Wang et al. (2014) also posit that communication strategies such as television programs, education, and training programs are essential for building green. Personal commitment, self-identity, attitude, traditions, and moral or social conscience, which can relate to psychological/behavioural dispositions (Murtagh et al., 2016), were identified as individual-level drivers for green-building by Darko et al. (2017). Darko et al. (2017:44) mentioned that "individual-level drivers are relatively intrinsic and

describe what internally drives people to want to move towards sustainability goals or try GB practices on their projects."

Similarly, a study by Wong et al. (2016) recommended using advanced construction IT like building information modelling, to stimulate the construction process and incorporate a green design approach, including waste reduction. This aligns with Lam et al. (2010), who proposed using advanced green technology to implement green specifications successfully. Also, Hakkinen and Belloni (2011) suggested that BIM and BIM-based tools may play a significant part in the sustainability management of buildings. Conversely, some authors mentioned contractual-related elements such as performance base standards (Ahn et al., 2013; Darko et al., 2017) and reliability and quality of specifications (Lam et al., 2009/2010) as necessary in facilitating the adoption of green and sustainable building. As Ayarkwa et al. (2017) indicated, tendering and contractual requirements can cause barriers to sustainable construction if not adequately addressed.

Planning-related elements such as strategic planning, concept planning and project programming were also identified as determinants for successful sustainable building construction (Dosumu and Aigbavboa, 2018; Shittu, 2021). Furthermore, supporting the growth of the construction industry was found to be critical for the adoption of green building practices as well as improving the economic sustainability in developing countries (Kalua, 2015). Table 3.1 presents the summary of the factors (termed sustainable building construction determinants), the number of occurrences of the elements from the reviewed studies, and their rankings.

**Table 3. 1**:Determinants of sustainable builiding construction

| **Determinants** | **References** | **Rank** |
|---|---|---|
| Legislation,standards, policies, and regulations | 1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29,30, 32, 33, 34, 35, 36, 37, 42, 43, 44, 46, 47, 52, 57 | 1st |
| Knowledge (education, technical capacity, training, competence, awareness creation, information | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 29, 33, 36, 40, 42, 42, 45, 47, 49, 52, 55, 56 | 2nd |
| Incentives schemes and government support | 1, 2, 3, 4, 5, 7, 8, 10, 16, 17, 18, 20, 22, 25, 28, 30, 35, 36, 37, 38, 39, 40, 41, 42, | 3rd |

| | | |
|---|---|---|
| | 47, 49, 52, 55, 56, 57 | |
| Corporate image, vision, culture, policy, ethical and social responsibility | 3, 8, 16. 17, 18, 20, 24, 25, 26, 27, 28, 31, 33, 35, 36, 38, 39, 40, 44, 46, 47, 52, 56 | 4th |
| Market Factors (e.g. demand, benefits, affordability etc.) | 12, 17, 20, 21, 26, 27, 28, 29, 31, 32, 33, 39, 42, 43, 44, 46, 49, 52, 53, 54, 55, 56 | 5th |
| Economic benefits (Cost efficiency/reduced life cycle cost | 8, 12, 13, 34, 35, 36, 45, 46, 47, 48, 49, 52, 56 | 6th |
| Sustainable Principles and green techniques (including the use of SB materials) | 1, 8, 9, 12, 21, 23, 35, 45, 48, 52, | 7th |
| Clients/stakeholders' demands and requirements | 15, 20, 27, 32, 36, 44, 47, 52, 55 | 8th |
| Personal/owners commitment | 3, 10, 13, 15, 19, 32, 49, 52 | 9th |
| Green building rating systems/sustainable building assessment tools | 8, 9, 35, 40, 41, 49, 52 | 9th |
| Stakeholder Involvement/influence and their mutual collaboration | 22, 29, 35, 36, 48, 52, 57 | 11th |
| Top management support and commitment | 3, 10, 13, 15, 35, 52, 56 | 11th |
| Leadership, management and responsibility | 41, 43, 48, 50, 51 | 13th |
| Competitive advantage/awards | 26, 35, 36 47, 52 | 13th |
| Moral obligation or social conscience to protect the environment | 6, 19, 20, 36, 52 | 13th |
| Communica-tion and collaboration | 3, 10, 21, 41, | 16th |
| Attitude and traditions | 5, 21, 34, 52 | 16th |
| Advanced technologies/tools | 23, 35, 48 | 18th |
| Self-identity | 19, 52 | 19th |
| Performance-based standards and contracts | 1, 52 | 19th |
| Strategic planning, concept planning, and project programming | 29, 47 | 19th |
| Reliability and quality of specifications | 48 | 22nd |
| Access to finance (public access) | 14 | 22nd |
| Construction industry development | 14 | 22nd |

**Table 7 References:** **1**=Ahn et al. (2013); **2**=Manoliadis et al. (2006); **3**=Aktas and Ozorhon (2015); **4**=Khoshnava et al. (2014); **5**=Udawatta et al. (2015); **6**=Niroumand et al. (2013); **7**=Arif et al. (2009b); **8**=Liu et al. (2012); **9**=Nduka and Ogunsanmi (2015); **10**=Ametepey et al. (2015); **11**=Edén et al., 2008; **12**=Wang et al. (2018); **13**=WBCSD(2008); **14**=Kalua (2015); **15**=Abidin (2010); **16**=Serpell et al. (2013); **17**=Abidin and Powmya (2014);

**18**=Andelin et al. (2015); **19**=Murtagh et al. (2016); **20**=Potbhare et al. (2009); **21**=Wang et al. (2014); **22**=DuBose et al. (2007); **23**=Hakkinen and Belloni (2011); **24**=Du Plessis (2007); **25**=Gou et al. (2013); **26**=Low et al. (2014a); **27**=Windapo (2014); **28**=Zhang (2014); **29**=Dosumu and Aigbavboa (2018); **30**=Qi et al. (2010); **31**=Boyle and McGuirk (2012); **32**= Aiyetan (2014); **33**= Arif et al. (2009a); **34**= Dadzoe et al. (2021); **35**=Wong et al. (2016); **36**=Ayarkwa et al. (2017); **37**=Qian and Chan (2010); **38**=Brotman (2016); **39**=Mulligan et al. (2014); **40**=Assylbekov et al. (2021); **41**=Richardson and Lynes (2007); **42**=Hwang and Tan (2012); **43**=Illeperuma and Abeynayake (2022); **44**=Bond (2010); **45**=Doan et al. (2021); **46**=Agyekum et al. (2021); **47**=Shittu (2021); **48**=Lam et al. (2009/2010); **49**=Onuoha et al. (2018); **50**=Tabassi et al. (2016); **51**=Mukerji (2017); **52**=Darko et al. (2017); **53**=Love et al. (2012); **54**=Chan et al. (2009); **55**=Oguntona et al. (2019); **56**=Yas and Jaafer (2020); **57**=Chen et al. (2022).

### 3.3.7 Selected factors and justification

Table 7 reveals that the top four ranked SBC determinants in descending order are: "government requirements, legislations, and standards, policies, and regulations", which are renamed as Regulatory Environment; Knowledge (education, technical capacity, and training, knowledge and awareness creation, information); Incentive Schemes; and Corporate factors (image, vision, culture, policy, social responsibility). However, three of these factors are chosen. The chosen factors are regulatory environment, corporate factors, and knowledge. They are selected because they seem foundational to achieving sustainable building construction and can cover most overlapping variables. For instance, Windapo (2014) suggests that the financial drivers of green building are linked to the (regulatory environment associated with the) provision of a standard rating tool. Table 3.2 provides insight on how the determinants were compressed to form the independent latent variables of the proposed model. Additionally, three factors that seem critical but have not been studied or thoroughly studied for their degree of impact on SBC are the adoption of modern building techniques; choice of project delivery strategy (relating to the contractual, specification and tendering requirements); and the use of project management techniques.

Advanced technologies/techniques also refered to as modern builidng techniques will ensure the eradication or mitigation of shortcomings such as lack of innovation processes, lack of effective enforcement etc. (Hakkinen and Belloni, 2011; Saad, 2016; Ershadi et al., 2021). Similarly, the

choice of project delivery strategy will enlighten on the best suitable contractual system for sustainable building construction for both public and private projects in South Africa. In so doing, problems relating to contracts, specification, procurement, tendering and the like, will be tackled (Lam et al., 2010; Hakkinen and Belloni, 2011; Darko et al., 2017; Ershadi et al., 2021; Toriola-et al., 2021). Furthermore, the use of project management techniques will ensure the mitigation or aversion of inadequate scheduling of task and process phases, extensive pre-contract planning, and time and cost overrun, which are among the barriers to sustainable construction (Hakkinen and Belloni, 2011; Shi et al., 2013; Daniel et al., 2018; Karji et al., 2020). According to Halliday (2008), good project management is a crucial overarching aspect in delivering sustainable projects in the short and long term. Hence, project management techniques are vital in achieving sustainable building construction. Besides, project management techniques (PMTs) will help achieve proper monitoring and control of sustainable building projects. Similarly, PMTs will help adequate management of critical success factors such as stakeholders, time, cost and quality (Low, Gao and Tay, 2014).

Therefore, these factors (advanced techniques, project delivery strategies, and project management techniques) together with the (other three) previously selected, made up the six sustainable building construction determining factors for the conceptual model of the current study. Consequently, the elements (determinants) are named/renamed in this study as regulatory environment, knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques.

**Table 3. 2**:Naming of the proposed latent independent variables from the identified determinants

| **Independent Variables** | **Compressed Determinants** |
|---|---|
| Regulatory Environment | Legislation, standards, policies, and regulations |
| | Green building rating systems/sustainable building assessment tools |
| | Sustainable principles and green techniques (including the use of SB materials) |
| Knowledge Sharing | Education, technical capacity, training, competence, awareness creation, information |
| Corporate Dispositions | Corporate image, vision, culture, policy, ethical and social responsibility |
| | Moral obligation or social conscience to protect the |

| | |
|---|---|
| | environment |
| | Leadership, management and responsibility |
| | Market Factors (e.g. demand, benefits, affordability etc.) |
| | Economic benefits (Cost efficiency/reduced life cycle cost |
| | Competitive advantage/awards |
| | Clients/stakeholders' demands and requirements |
| | Stakeholder Involvement/influence and their mutual collaboration |
| | Top management support and commitment |
| | Incentives schemes and government support |
| | Attitude and traditions |
| Project Delivery Strategy | Performance-based standards and contracts |
| | Reliability and quality of specifications |
| Project Management Techniques | Strategic planning, concept planning, and project programming |
| | Communication and collaboration |
| Modern Building Techniques | Advanced technologies/tools |

### 3.3.8 Proposed sustainable building construction conceptual framework

According to Swaen (2015), a conceptual framework delineates what one hopes to discover through the research. It characterises the important factors for the investigation and guides out how they may relate to one another (Swaen, 2015). It depicts the relationship between the independent and dependent variables that make up the research (Ogolla and Moronge, 2016). Consequently, the proposed independent variables to determine effective implementation of sustainable building construction (SBC) for project delivery success in the South African construction industry include regulatory environment, knowledge sharing, corporate disposition, choice of project delivery strategy, project management techniques, and the adoption of modern building techniques. As previously stated, Table 3.2 provides insight on how the determinants were compressed to form the independent latent variables/gaps of the study. Also, it was proposed that SBC implementation is a critical intervening variable for actualising an integrated SBC project delivery. Therefore, the researcher aims to establish and confirm these proposed conceptual frameworks and develop these into a model. Figure 3.1 presents the proposed conceptual framework for the current study.

The following hypotheses relate to the objectives concerning the relationships between the constructs in the proposed integrated sustainable building construction (ISBC) model. The broad hypotheses and the proposed specific hypotheses to be tested are as follows:

H1: SBC-determinants influence SBC implementation:

H11: Regulatory environment influences SBC implementation,

H12: Knowledge sharing influences SBC implementation,

H13: Corporate disposition influences SBC implementation,

H14: Project delivery strategies influence SBC implementation,

HI5: Project management techniques influence SBC implementation, and

H16: Modern building techniques influence SBC implementation.

H2: SBC implementation influences project delivery outcomes.

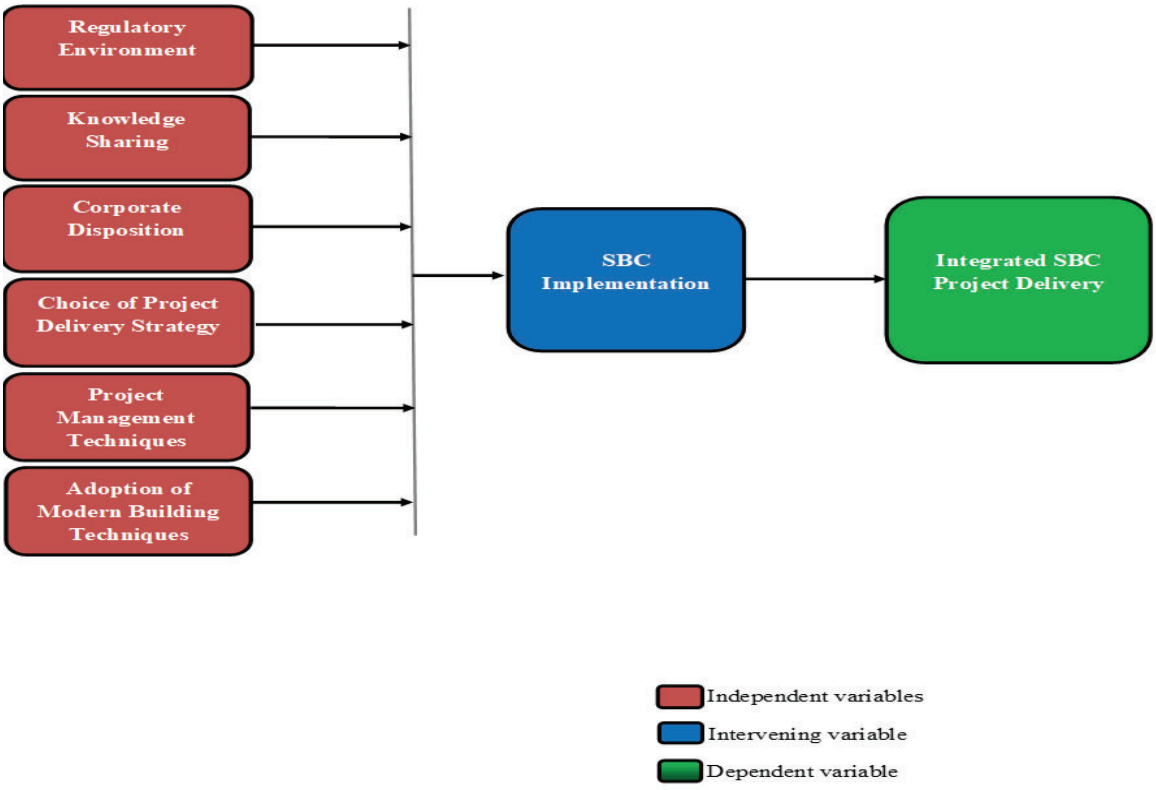


**Figure 3. 1:**The proposed conceptual sustainable building construction model for the study.

## 3.4 A Rationale of the Theories Adopted for this Study

There has not been a consensus on a "one fits all" theory on achieving sustainability in the building sector. However, some theories contain key variables to facilitate effective sustainable building construction (SBC). Besides, the sustainable development theory discussed in chapter 2, the study adopts resilience theory and institutional theory in conceptualising the SBC model for South Africa. Although the discussed theories in this chapter link with sustainable building construction, resilience and Institution theories were found as most notable and can make up for some overlaps with the other theories. The Resilience theory strongly connects to ecological discipline (VanBreda, 2001; Redman, 2014). Also, VanBreda (2001) indicates that the resilience theory deals with issues related to working environments, policies, individuals, communities, and families. Individual resilience is characterised by the skills, capacity, information, and experiences gathered over the long run as they try to overcome challenging situations and struggles (VanBreda, 2001; Opoku et al., 2017). Hence, the resilience theory is essential for this study as it demands that stakeholders and consultants possess the skills, capacity, information, and experiences to bring about sustainability in the Built Environment. Similarly, the institutional theory is characterised by the influential factors that help the survival and legitimacy of organisation practices, such as culture, social environment, regulatory and legal environment, tradition and history, and economic incentives (Lai et al., 2006; Baumol et al., 2009; Brunton et al., 2010; Glover et al., 2014).

Furthermore, this study stands on the shoulders of key studies such as Eden et al. (2008), Lam et al. (2010), and Windapo (2014). Consequently, the combined theories and conceptual models underpin the proposed variables for the successful actualisation of sustainable building construction, especially in South Africa. The six proposed independent variables include regulatory environment, knowledge sharing, corporate disposition, choice of project delivery strategy, project management techniques, and adoption of modern building techniques.

## 3.5 Chapter Conclusion

This chapter reviewed existing theories regarding sustainable building construction (SBC). The reviewed theories included resilience, socio-cognitive, stakeholder, and institutional theory. Factors that can facilitate the implementation of SBC were discussed. Additionally, the proposed conceptual model for the study was presented in relation to the specific objectives and hypotheses of the study. The exogenic variables comprising the SBC model are knowledge sharing, regulatory environment, corporate disposition, choice of project delivery strategy, the use of project management techniques, and modern building techniques. The conceptual framework for the study was strongly underpinned by the resilience theory and institutional theory and studies such as Eden et al. (2008), Lam et al. (2010), and Windapo (2014). The study posits that sustainable building construction will be effectively implemented when there is: adequate knowledge sharing on the concept; an adequate established regulatory environment; proper corporate disposition; innovation from newer advanced technologies; adequate project delivery strategy; and adequate use of project management techniques.

The next chapter discusses in detail the identified gaps from the theoretical framework used as part of the conceptual framework, including choice of project delivery strategy, the use of project management techniques, and the modern building techniques. Chapter four indicates that bridging the gaps can effectively improve SBC in a developing country such as South Africa.

# CHAPTER FOUR

# GAPS IN SUSTAINABLE BUILDING CONSTRUCTION RESEARCH

## 4.0 Introduction

This chapter discusses the identified gaps from chapter three about sustainable building construction research towards successful project delivery. The gaps include project delivery strategies, project management techniques, and adopting modern building techniques. These factors are part of the six constructs that form the conceptual framework of the current study. They might have been referenced in previous studies but have yet to be assessed as comprehensive constructs. The discussion aims to elucidate the efficacy of these factors in achieving sustainable building construction project delivery success.

## 4.1 Gap One: Understanding Sustainable Building Construction Project Delivery Strategies

### 4.1.1 Project delivery

Project delivery is an all-inclusive process required to execute and finish a building facility or other type of project from the inception stage to handover (Design-Build Institute of America (DBIA), 2018). Project delivery stages of construction works are the stages that aid the workflow (arrangement of related activities) to achieving an end-of-stage deliverable to be developed and culminates in gates (control points) which can be utilised to guarantee that the proposed works remain within the agreed mandates, lines up with the reason for which it was considered, and can progress successfully from one stage to the next (Watermeyer, 2012). The construction work delivery needs to be managed and controlled logically, methodically, and auditable (Watermeyer, 2012).

There are critical decisions to make. These include choosing a suitable project delivery method, the right procurement strategy, and the contract format for the construction project (DBIA,

2018). The beginning stage in fostering any delivery management system is to identify the information that needs to be developed and accepted by the client at a particular point in the delivery process to advance a project (Watermeyer, 2012). Project delivery methods and procurement strategies are levers for re-engineering the construction project (Oke, Aigbavboa, and Tong, 2018). Therefore, project delivery methods and procurement strategies are linked to the performance of building projects. Many studies have suggested that the project's performance largely depends on the project delivery method chosen (Gad et al., 2015; Mehany et al., 2017; Hashem et al., 2018). Performance is assessed based on time, cost, quality, satisfaction, sustainability and so on.. (Oke et al., 2018). Choosing a suitable delivery method and procurement strategy begins with a comprehensive understanding of available choices. Clients must also understand the consequences of each choice because "the delivery method establishes when parties become engaged; it impacts the choices of contractual relationships, and it influences ownership and the impact of changes and modification of project costs." (DBIA, 2018:2). This also aligns with (Oke et al., 2018), who affirm that delivery systems are the focal point as they decide the tendering and contractual procedures throughout the project stages.

Additionally, some factors must be considered to make an informed decision. They can be categorised under external and internal factors (Luu, Ng, and Chen, 2005; Ratnasabapathy, Rameezdeen, and Gamage, 2006; Ghadamsi and Braimah, 2012). External factors include economics, politics, finance, legal, natural disasters, technology, etc. At the same time, internal factors include project characteristics, client characteristics, and requirements (Ghadamsi and Braimah, 2012). Client requirements involve time, cost, and quality-related factors (Ratnasabapathy et al., 2006; Ghadamsi and Braimah, 2012). Also, DBIA (2018:2) asserts that "Project considerations have fundamental impacts on the delivery method selected. These considerations include a realistic budget, a schedule that includes a reasonable performance period, a responsive and quality design process, a risk assessment with the allocation of risks to the appropriate parties and a recognition of the level of expertise within the owner's organisation." Hence, there should be a sound, systematic procedure essential for choosing the best delivery method to meet the needs of a particular type of work (Ali, Zakaria, and Che-Ani, 2011; Ghadamsi and Braimah, 2012).

### 4.1.2 Project delivery method and procurement method

Some scholars have used these terms interchangeably to mean the same thing (Mathonsi and Thwala, 2012; Olanike, Baba, and Ahmad, 2020). However, it is vital to understand that procurement is a subset of a project delivery method, especially in this study. A project delivery method or system defines the roles and relationships of the project stakeholders and the timing of engagement of each entity during the various phases of the project (El Asmar, Hanna, and Loh, 2013; El Asmar et al., 2016; Abkarian, El Asmar, and Underwood, 2017; Sullivan et al., 2017). This also aligns with Gad et al. (2015). They defined a project delivery method as the process adopted by various stakeholders to execute and complete the project. It outlines the roles, responsibilities, and relationships between the multiple participants in a project and the sequence in which the project must be completed (Gad et al., 2015). This sequence alludes to the project stages, and the relationships include contractual relationships between the owner and other parties involved in the building's design, documentation, and construction (Jackson, 2010; Alarcón and Mesa, 2014; Hanks, 2015).

Franz and Leicht's definition of project delivery systems is another one that provides the most comprehensive explanation. They concluded that a project delivery system is characterised by allocating responsibilities, involvement timing, procurement practice in assigning bids, contractor selection criteria, and payment provisions (Franz and Leicht, 2016). As a result, it is essential to comprehend the payment provisions and procurement policies intertwined with delivery systems (Raouf and Al-Ghamdi, 2019).

Generally, procurement alludes to purchasing goods, services, or construction from a third party at the ideal price, in a suitable quantity, at the right time and place (Martins, 2009; Office of Procurement Ombudsman, 2012; Ruparathna and Hewage, 2015). Chopra and Meindl (2007) defined procurement as a system of acquiring an organisation’s raw materials, components, services or other resources by an organisation, to execute its operations. Therefore, construction procurement obtains services and supplies for efficient and timely delivery of the end product (Choudhury and Sanampudi, 2008). It is the purchase of construction-related services to erect a

new building and may include all related site works or modification, renovation, maintenance, expansion, or demolition (Scottish Government, 2011; Ruparathna and Hewage, 2015). It also involves identifying, selecting, and commissioning the necessary inputs for the construction project (Department of Business Innovation and Skills, 2012). Traditionally, procurement focuses on cost, quality and delivery (Tiwari, Wei, and Nor, 2019). However, sustainability entails considering other factors, such as the environment and society. Hence, sustainable procurement is a plus as it also considers environmental factors and other like it in decisions of supply chain management (Zailani et al., 2012; Yook, Choi, and Suresh, 2017; Tiwari et al., 2019). According to Min and Galle (2001:1222), sustainable procurement is an "environmentally-conscious purchasing practice that reduces sources of waste and promotes recycling and reclamation of purchased material without adversely affecting performance requirement of such materials."

### 4.1.3 Various types of project delivery methods

Due to the fragmented architecture, engineering, and construction (AEC) industry, project participants may have distinct priorities throughout the process (Gunhan, 2019). These priorities call for suitable delivery methods to best meet the needs of the various parties involved and the project objectives. Hence, there is a need for improvement from the conventional delivery method (Robichaud and Anantatmula 2011). Besides, sustainable building projects are complex; they require extensive collaboration and expertise (Gunhan, 2019). However, there has yet to be an established method for sustainable building projects (Hashem et al., 2018; Gunhan, 2019). The following subsections discuss the available project delivery methods, highlighting their pros and cons.

#### *4.1.3.1 Design-bid-build (DBB)*

This is popularly known as the traditional project delivery system used since the late twentieth century (Shrestha et al., 2012; Gad et al., 2015). In this method, the owner contracts separately with the designer or the design team who prepares the design document after the owner solicits a fixed price bid from the builder to perform the work (Hashem et al., 2018). One builder is chosen

(usually the lowest bidder) and agrees with the owner to construct a facility following the plans and specifications (Korkmaz et al., 2010; Gunhan, 2019). Additionally, this method thrives in situations where: there is an existence of a full tender document for price certainty; a bill of quantities can be used for valuing variations; the client desires competitive tendering; the scope of work is clear and well-defined to facilitate the detailed design (Ghadamsi and Braimah, 2012). However, in this method, any modifications requested by the owner will result in a chain of change orders because the designer and constructors are engaged separately (Hashem et al., 2018). Hence, the DBB method creates silos among project participants; for instance, the builder has no input during the design stage (Robichaud and Anantatmula, 2011; Gunhan, 2019). According to Perkins (2009), there is frequently a lack of knowledge sharing between the designer and contractors, with each working toward their own objectives rather than in a collaborative setting. Similarly, DBIA (2018) affirmed that in this method, the project's effectiveness and constructability might be compromised if construction input is not incorporated into the design. Due to its nature, it is possible to make crucial design choices that impact the kinds of materials used and the means and methods of construction without giving them enough thought from a construction perspective. This is because the designer and the contractor have no contractual relationship, and during the design phase, there is no opportunity for collaboration (DBIA, 2018). This also aligns with Mante et al. (2012), who affirmed that the DBB's inherent negative characteristics include a lack of communication, increased price competition, and fragmentation. However, new methods to the traditional construction delivery systems emerged in the late 1970s due to several factors, including the growing size of projects, the high cost of short-term financing, more sophisticated owners, runaway inflation, and other factors (Hashem et al., 2018). Hence, alternative project delivery methods were developed in response to the drawbacks and are currently utilised extensively in numerous construction projects (Hashem et al., 2018). According to Cantirino and Fodor (1999), some new approaches are variations of the conventional method, while others are adaptations of traditional ways to contemporary circumstances.

#### *4.1.3.2 Design and build (DB)*

In contrast to design-bid-build (DBB), this delivery method is a single agreement between an owner and a single entity to execute a design-build contract for both design and construction. Hence, this system provides the client with a single contracting point (Olanike et al., 2020). However, the entity may outsource all or part of the design and construction to other companies (Korkmaz et al., 2010). Unlike DBB, the client is committed to the design and construction costs much earlier (Reichstein et al., 2013; Olanike et al., 2020), whereas the constructor oversees all project-related duties (Akiner and Akiner, 2018). Similarly, Korkmaz et al.'s findings indicate that DB can integrate key project participants (designers, speciality designers, contractors, and subcontractors) at a medium to high level early in the design process (Korkmaz et al., 2010; Gunhan, 2019). Also, there is an increase in collaboration between the designers and constructors since the design and construction are performed simultaneously by a single entity (Hashem et al., 2018). Ghadamsi and Braimah (2012) indicate that this method is generally regarded as appropriate when the client is unfamiliar with the construction process and the project is technically complex. Also, it is used when there are few variations, and the client wants a single point of responsibility (Ghadamsi and Braimah, 2012; DBIA, 2018). Furthermore, the owner wants work to begin quickly on the site and prioritises time, quality, cost, or value for money, among other things (Ghadamsi and Braimah, 2012). Although this method has long existed, just like DBB, dissatisfaction with DBB led to much attention being paid to it in the late 1980s and early 1990s (Perkins, 2009; Hashem et al., 2018).

#### *4.1.3.3 Develop and construct*

This method is very similar to the design and builds, as the contractor is responsible for the project's design and construction. The difference is that, under this approach, the client's design consultants create concept sketches or plans and hand them off to the contractor, who then develops them and creates detailed working drawings (Ogunsanya, 2018; Olanike et al., 2020). Based on what was developed and produced, the contractor will construct the project and complete it (Mathonsi and Thwala, 2012; Olanike et al., 2020).

#### *4.1.3.4 Construction management at risk (CMR)*

CMR is also known as the construction manager/general contractor method. It is an alternative to the conventional project delivery method (Feuer, Glick, and Clevenger, 2015; Hashem et al., 2018). In this method, the owner employs the general contractor early in the design stage of the construction project to provide preconstruction and construction services to the owner (Farnsworth et al., 2016; Feuer et al., 2015; Hashem et al., 2018). Hence, this method can integrate key project participants early in the design process (Korkmaz et al., 2010). This also agrees with Akiner and Akiner (2018). They state that this system is comparable to design and build in that it treats the phases of project planning, design, and construction as a single, integrated task.

In this method, the general contractor can advise the design team on costs and scheduling and complete tasks like ordering materials and coordinating subcontractors in advance (Jackson, 2010; American Institute of Architects (AIA), 2011; Hanks, 2015). According to Feuer et al. (2015), due to increased costs, extended schedules, and delays in traditional project delivery methods, this method, which was first implemented in the early 1960s, started receiving significant attention, especially in the 1970s. DBIA (2018) also states that project delivery is typically quicker in this method than in traditional design-bid-build. However, the lack of a direct contractual relationship between the contractor and designer is a primary drawback (DBIA, 2018). Therefore, this places the owner between those entities in resolving project issues. Additionally, there is a possibility of conflicts regarding construction quality, the completeness of the design, and impacts on schedule and budget, which may lead to adversarial relationships (DBIA, 2018).

#### *4.1.3.5 Management contracting*

Here, a contractor is hired and paid to manage, procure, and supervise a project's construction instead of building it. The selection of the main contractor is either by negotiation or competition (Olanike et al., 2020). However, the actual/physical construction work is done by a series of package contractors, specialist contractors, or subcontractors (Rashid et al., 2006; Ogunsanya,

2018). Hence, the management contractor is employed as a construction consultant to be part of the client's team and to provide the required management expertise (Oladirin, Olatunji, and Hamza, 2013). The primary distinction between this method and construction management is that the specialist contractors or subcontractors are not only bound by a contract with the management contractor but also with the client in the latter scenario (Rashid et al., 2006; Ogunsanya, 2018). According to Ogunsanya (2018), a benefit of this method is the early involvement of the management contractor in the project. Also, the management contractor can appoint trusted subcontractors they have worked with previously rather than risk an unknown new contractor (Oyegoke, 2001). However, a drawback that can result in disagreements and conflicts is the lack of a single point of responsibility for the project's design and construction phases (Ogunsanya, 2018).

#### *4.1.3.6 Turnkey*

This is an American term for "all in" or package contracts (Olanike et al., 2020). It can also be referred to as package deals. In this method, a contractor is given the job of taking care of everything that needs to be done for the project's construction, completion, commissioning, and handover. In other words, the contractor is responsible for everything from preparing the project brief, obtaining approval, designing, financing, building, furnishing, and decorating to commissioning and handing over a finished, cleaned, and ready-for-use project (Rashid et al., 2006; Olanike et al., 2020). The term "turnkey" refers to the client receiving a key and entering the finished project by turning the key in the door, and everything is up to complete operating standards (Ashworth, Hogg and Higgs, 2013; Ogunsanya, 2018).

#### *4.1.3.7 Design-build-maintain (DBM)*

This is a form of project delivery method usually for large-scale infrastructure projects. There are a variety of contracts associated with this method. However, a common denominate is that the single contract is delegated to the private sector for the responsibility of designing, building, and maintaining the asset for the duration of the contract (Koppinen and Lahdenperä, 2004). Contract may be obtained through bidding based on the output specification provided by the client. In this

method, private financing may also be provided in the contract. As a result, DBM substitutes the acquisition of a flow of services derived from an asset for the acquisition of an asset. Consequently, these projects typically exhibit high-risk transfer. However, clients usually consult external advisers on legal and financial issues, contract management and performance monitoring (Koppinen and Lahdenperä, 2004). The model of this method also allows for the reorientation of the public and private parties for mutual interest in the asset's whole-life performance in terms of supply quality and availability. Unlike the traditional method, DBM allows construction companies to be interested in the asset's long-term performance (Koppinen and Lahdenperä, 2004). Hence, there is a motivation to estimate the total cost of building and maintaining the asset, to finish construction as soon as possible, and to guarantee high quality.

The different methods for providing DBM services include Design-Build-Operate and Maintain, Design-Build-Finance-Operate, Build-Own-Operate-Transfer, Build-Operate-Transfer, Build-Transfer-Operate, and Build-Own-Operate, leasing models, and concession (Smith, 2003; Koppinen and Lahdenperä, 2004). They are briefly discussed as follows.

*Design-Build-Operate and Maintain (DBOM)*: This is the simplest form of DBM in which a lump-sum design and build contract is used together with an operation and maintenance contract to provide infrastructure assets. The concession period typically lasts approximately ten years (Koppinen and Lahdenperä, 2004). The DBOM method considers a project's life cycle and integrates operations and maintenance functions with design and construction functions (Horman et al., 2006; Gunhan, 2019).

*Design-Build-Finance-Operate (DBFO):* This arrangement is based on DBOM but involves greater risk transfer and private financing (Koppinen, and Lahdenperä, 2004). The client pays the service provider using the predetermined payment method while maintaining the title to the land. The concession time frame is usually fifteen to thirty years (Horman et al., 2006; Gunhan, 2019).

*Build-Own-Operate-Transfer*: The project company is exposed to greater end-user risk as it gets paid based on usage, usually through user fees. A project company is a company responsible as the first-tier supplier for organising the delivery of the DBM project to the client. In this method,

"the private organisation designs, finances, builds, maintains and operates the facility during the contract period, and ownership of the facility transfers for a period to the private sector" (Koppinen and Lahdenperä, 2004:37). The concession period is usually twenty to forty years (Koppinen, and Lahdenperä, 2004).

*Build-Operate-Transfer*: A build-operate-transfer (BOT) contract is one in which a government usually concedes to a private company to finance, build, and operate a project for twenty to thirty years in the hope of making money. The project is returned to the public entity initially granted the concession after that time (Hayes and Kelly, 2022).

*Build-Transfer-Operate (BTO)*: This model is very similar to Build-Operate-Transfer. However, the public sector lends the completed asset to the private sector after it has been handed over to them by the private sector. In this, the project company is relieved of the responsibility of furnishing the high-cost insurance required by the project during the facility's operation (Koppinen and Lahdenperä, 2004). Law Insider dictionary defined BTO as a "Build-Transfer-Operate contract to build a facility; after the completion of the constructed facility, the investor shall transfer such facility to the Implementing Government Agency and shall have the right to operate such a facility for a fixed term commercially" (Law insider: online)

*Build-Own-Operate (BOO)*: This is like the Build-Own-Operate-Transfer model, only that the private sector owns the facility, and ownership is not transferred to the public sector (Koppinen and Lahdenperä, 2004). Hence, it may be considered partial privatisation.

*Leasing Models*: This DBM model warrants that "the client may pay for the work, after which the private organisation operates the facility for the contract period and gets paid through a lease" (Koppinen and Lahdenperä, 2004:39). A combination of private and public funding is used in leasing models. The private sector may acquire partial ownership of the asset. The lease typically lasts about ten years (Koppinen and Lahdenperä, 2004). With this model, the private sector builds or rehabilitates the structure.

*Concession*: With this arrangement, the promoter is solely responsible for the project. The finance-build-own-operate-transfer method is another name for this method (Smith, 2003). With

the introduction of PFIs in the early 1990s and PPPs in the late 1999s, the strategy began to be applied in the United Kingdom. One organisation—the promoter—has exclusive control over all project-related duties, roles, and obligations (Ogunsanya, 2018). On the other hand, the champion is a multi-purpose joint venture explicitly created to carry out the project. A joint venture is typically a group of companies tasked with finding funding and creating a revenue stream big enough to pay off the debt, run the facility, and earn a profit for the client, who is typically a governmental body (Ogunsanya, 2018).

#### *4.1.3.8 Integrated Project Delivery (IPD)*

This newer delivery method mainly focuses on the collaboration of all parties (Aknar, 2016). The American Institute of Architects (AIA) defined it as the project delivery method that "integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimise the project results, increase value to the owner, reduce waste, and maximise efficiency through all phases of design, fabrication, and construction." (AIA 2007). In other words, this project delivery method aims to enhance collaboration among key stakeholders by sharing all risks and rewards through a mutual contract (Garcia et al., 2016; Aknar, 2016; Gunhan, 2019). As a result, the parties are crucial to the processes. According to Aknar (2016), IPD is the only system tailored to a project teamwork approach. This is so that the project team can accomplish the project's goals by collaborating, exchanging, and sharing knowledge. AIA (2007) mentioned nine critical principles for implementing IPD. They include mutual respect and trust, mutual benefit and reward, collaborative innovation and decision-making, early involvement of key participants, early goal definition, intensified planning, open communication, appropriate technology, and organisation and leadership. Therefore, the application of IPD is anchored on these nine principles (Kent and Bercerik-Gerber, 2010; Aknar, 2016).

The "Mutual Respect and Trust" principle primarily emphasises cooperation between the owner, the design team, the construction companies, and the like. It is a vital principle for enhancing project efficiency, teamwork, and collaboration (Kent and Bercerik-Gerber, 2010).

The “Mutual Benefit and Reward” principle ensures that all team members profit from IPD (Kent and Bercerik-Gerber, 2010). The “Collaborative Innovation and Decision-Making” principle ensures that the project team or participants examine important decisions and unanimously select the best one (Aknar, 2016). Therefore, this initiates the early involvement of key stakeholders to enable the adoption of the best options and practices that will improve performance efficiency towards attaining project success and client satisfaction (Aknar, 2016). The early involvement of key stakeholders will also enable the implementation of the “Early Goal Definition” principle. The early goal definition principle ensures that the project's stages and goals are clearly stated early and receive unanimous consent from all participants (Aknar, 2016).

The “Intensified Planning” principle focuses on adequate planning and scheduling activities to mitigate time overruns, construction waste and so on. The “open communication” principle guides the team members or project parties in ensuring honest, respectful, and open communication of the responsibilities of the participants, including the risks and rewards. It also encourages harmony and despises all forms of segregation (Aknar, 2016). The “Appropriate Technology” principle allows new technologies, such as innovative software or tools, to speed up the design process and increase project functionality. Generally, deploying relevant technologies improves the effectiveness of both traditional delivery methods and IPD projects (Hanks, 2015; Aknar, 2016). Finally, the “Organisation and Leadership” principle allows for sound leadership and management in the organisation for project efficiency (Aknar, 2016).

### 4.1.4 Procurement Strategies

This refers to the strategies used in purchasing construction work and objects. It is a subset of a project delivery method/system. According to Murdoch and Hughes (2008), procurement is a combination of different methods for purchasing construction objects and includes such variables as a source of funding, partner selection method, price basis, amount of subcontracting and the like. It consists of the methods to use for bidding (DBIA, 2018). Some key procurement strategies are discussed in the following subsections.

#### *4.1.4.1 Price-based procurement*

The cost is the primary consideration when choosing the project teams in this method. The owner asks many contractors to submit bids for the project to achieve the lowest economical price and the best construction contractor skills. This strategy includes two-step sealed bidding and low bid selection (Hashem et al., 2018). This strategy, nevertheless, has its detractors. For instance, many have confirmed that choosing the lowest bidder leads to change orders, cost increases, and schedule delays—all of which are signs that the project would be subject to claims and disputes (El Wardani et al. 2006; Pesämaa et al. 2009; Hashem et al. 2018).

#### *4.1.4.2 Best value-based procurement*

According to El Wardani et al. (2006) and Alleman et al. (2017), this strategy strives to hire the project team that provides the best value in terms of cost and technical expertise. It chooses the most advantageous offer under the condition that the contractor submitting the request for proposal (RFP) has been cleared for prequalification (Gransberg and Shane 2015). There are two ways this strategy could be set up. It is either a one-step request format for a proposal or a two-step format with a request for qualification (for shortlisting) before a request for a proposal. Negotiations between the owner and the qualified project participants/contractors may begin when the owner receives these proposals (Hashem et al., 2018). The decision is then made based on the pricing and other considerations, which are weighted based on the project's size, nature, owner organisation, and other factors (El Wardani et al., 2006; American Society of Civil Engineers (ASCE), 2012; Raouf and Al-Ghamdi, 2019). According to El Wardani et al. (2006), schedule growth is relatively modest because this procurement process incorporates qualitative and quantitative selection criteria. However, research by Alleman et al. (2017) suggested that this style of procurement may occasionally have a disadvantage due to increased award growth.

#### *4.1.4.3 Qualification-based procurement*

Cost is not the primary selection criterion in this procurement approach. Therefore, only a request for a qualification response is needed, which is then examined and awarded to the contractor with the highest level of qualification (Hashem et al., 2018; Raouf and Al-Ghamdi,

2019). Past performance, technical credentials, financial stability, project innovation, and relationships built through previous projects are the main factors that are mostly considered (Alleman et al. 2017; El Wardani et al. 2006). The main benefit of this procurement strategy is that it emphasises innovation and other qualitative factors compared to cost. However, El Wardani et al. (2006) indicates that some projects employing this approach were delivered slightly behind schedule and with an increased expense.

#### *4.1.4.4 Sole-source selection*

In this approach, without any competition, a sole source is chosen based on pre-existing connections, historical performance, technical expertise, or unique qualities required by the nature of the project or in emergencies like natural catastrophes (El Wardani et al. 2006; ASCE 2012; Raouf and Al-Ghamdi, 2019). This type of procurement can be advantageous in safeguarding, for instance, the government interests and ensuring that the best possible service is provided. It can also be beneficial in terms of cost reduction and prevent waste by avoiding unnecessary competition (Perry, 2023). Furthermore, chosen a sole source can simplify the procurement process. Arguably, it balances efficiency, quality, and cost-effectiveness (Raouf and Al-Ghamdi, 2019; Perry, 2023).

#### *4.1.4.5 Two-stage open book*

Under this procurement strategy, the client invites potential team members for a single project or from a framework to submit bids for a project based on an outline brief and cost (Ogunsanya, 2018; Designing Buildings, 2022). In the first stage, bids are picked based on the contractors' and consultant teams' capacity, capability, stability, experience, the strength of their supply chain, and fee (profit plus company overhead). In the second stage, the successful contractor and consultant team is then given the go-ahead to develop a proposal based on an open book cost that satisfies the client's specified objectives and cost benchmark. This strategy is distinct from Price-Based/Cost Led Procurement in that it enables faster mobilisation, lowers industry bidding costs, and gives clients a chance to work with a single integrated team earlier to test design, cost, and risk issues before beginning on-site after awarding at the end of the second stage (Ogunsanya,

2018). Early contractors/subcontractors' interaction sits at the core of this strategy (Designing Buildings, 2022)**.** This procurement strategy has also been identified as one of the advanced or newer methodologies in building (Ogunsanya, 2018).

#### *4.1.4.6 Targeted procurement (TP)*

This is an innovative government procurement intervention strategy designed and used in the construction industry to promote the participation of targeted enterprises and targeted labour in government infrastructure contracts (Ofori, 2009; Adediran and Windapo, 2017). This is usually done to achieve the state entities' "contractor development goals," which are included as a relevant criterion for contract award, along with other functional criteria (e.g., price and quality). Small and medium-sized enterprises in the construction industry typically benefit from this strategy (Ofori, 2009).

#### *4.1.4.7 Public-private-partnerships*

This strategy is generally understood as cooperative arrangements between the public and private sectors to deliver specific services. Campbell (2001) defined it as the private sector's design, construction, financing, maintenance, or operation of public infrastructure or a public facility under a long-term contract. In this partnership, profit and risk may be shared equally or unequally. National Treasury (2015) defined this strategy as a contract between a public-sector agency or municipality and a private party in which the latter accepts significant financial, operational, and technical risks in the project's design, financing, construction, and operation. According to Hodge and Greve (2010), there are five forms of PPP. They include institutional cooperation for joint production and risk sharing, public policy networks, long-term infrastructure contracts, civil society and community development, urban revitalisation, and downtown economic development (Hodge and Greve, 2010; Ogunsanya, 2018). The project delivery methods which are mainly used for PPP include design-build-operate-transfer (DBOT), design-build-finance and operate (DBFO), Build-own-operate-transfer (BOOT), Build-operate-transfer (BOT), leases, and concession (Ogunsanya, 2018).

### 4.1.5 Contract formats

This refers to the different ways a client might agree with the project participants that will specify how the job completed will be paid for (Puddicombe, 2009; Tajul and Sutrisna, 2010; Hashem et al., 2018). Therefore, contracts are subsets of procurement strategies. The construction sector offers several contract forms, each with advantages and disadvantages of its own. As a result, it's crucial to choose contracts depending on the owner's needs and particular project types. Traditional lump-sum or fixed-price contracts, cost-plus or cost-reimbursable contracts, guaranteed maximum price (GMP) contracts, unit price, and target price contracts are some of the most often utilised contractual methods (Chan et al. 2011; DBIA, 2018; Hashem et al., 2018).

#### *4.1.5.1 Lump-sum and fixed-price contracts*

This kind of agreement emphasises the final product to decide the amount paid for the work performed (Puddicombe, 2009; Hashem et al., 2018). The project's overall cost is estimated during the bidding process. It works best when the project scope is well-defined (Ibbs et al., 2003). In other words, the project is clearly specified regarding the drawings, requirements, and cost, presumably reducing the likelihood of a change of orders (Hashem et al., 2018). This method's popularity can be attributed to its ease of use and capacity to pass risks to subsequent parties (Hashem et al., 2018). However, some of the notable drawbacks of this strategy include an increase in change orders, claims, and disputes, as well as a lack of quality and collaboration (Chan et al., 2011; Ghassemi and Becerik-Gerber, 2011; Hashem et al., 2018). Although there is similarity between Lum-sum and Fixed-price contract, there is a technical difference. Risks, such as cost overruns, are shared between the contractor and clients in fixed-price contracts, unlike lump-sum contracts where the contractor bears the entire risk (Hashem et al., 2018; Bartholomew, 2022).

#### *4.1.5.2 Cost-reimbursable or cost-plus contracts*

Here, the contractor receives payment for both the agreed-upon price and the actual cost of the work (Puddicombe, 2009; Hashem et al., 2018). The owner is responsible for all project

expenses, including a fixed or variable fee, to satisfy specific cost and duration requirements (Raouf and Al-Ghamdi, 2019). This type of contract comes in various forms, including cost-plus fixed fees, cost-plus-percentage fees, and cost-plus incentive fees. This contracting format offers a more significant partnership between the owner and the contractor than lump-sum contracting because the owner has greater control over the contractor's books (project records) and subsequently on the project (Hashem et al., 2018). Also, incorporating project changes is more manageable with cost-reimbursable payment provisions, which lower the contractor's contingency at the bidding time (Ibbs et al., 2003; Raouf and Al-Ghamdi, 2019).

Furthermore, some scholars proposed a cost-reimbursable arrangement for green building projects to save money (Reed and Gordon 2000; Robichaud and Anantatmula 2011). It was indicated that a cost reimbursable or cost-plus contract would save time and money and deliver a high-quality product if an owner's representative is actively involved. However, the antecedent assumes that there is little to no risk for the contractor, resulting in no contingency on submitting a higher estimate upfront as a contingency compromise (Robichaud and Anantatmula, 2011; Raouf and Al-Ghamdi, 2019). The owner may be vulnerable in this type of contract because of the massive gap in the risk sharing of the project.

#### *4.1.5.3 Guaranteed maximum price (GMP) contracts*

Here, the contractor sets a limit cost within which the project must be finished. The contractor is held liable and takes on the financial risk and burden of completing the project if the project's cost exceeds the GMP (Hashem et al., 2018). The cost savings, however, could be split between the owner and the contractor by a mutually agreed-upon ratio if the project is completed within the GMP (Puddicombe, 2009; Chan et al., 2010, 2011; Hashem et al., 2018). Some notable advantages of this contract form include decreased risks and claims, incentives for better performance, and integration of interests in building projects (Chan et al., 2010; Hashem et al., 2018). Some scholars view GMP as a hybrid of a cost-plus and lump sum contract (Chan et al., 2011; Hashem et al., 2018).

#### *4.1.5.4 Unit price contracts*

Here, the contractor submits a price per unit for each work item during the estimating process (Hashem et al., 2018). In the end, each item's entire quantity of work is multiplied by its corresponding unit price, and the total for each item is summed to calculate the overall project cost. The projected unit price includes the overhead and profit (Ibbs et al., 2003; Hashem et al., 2018).

#### *4.1.5.5 Target Price Contracts (TCC)*

This is mainly used with integrated project delivery (IPD) methods and is similar to GMP. According to Hashem et al. (2018), the cost necessary to execute the project is best estimated using this contracting method. The initial target cost will be adjusted if any specification revisions are reached through mutual agreement between the parties. Any cost savings once the project is finished will be split between the owner and the contractor, much like a GMP contract. Target price contracts differ from GMP in that cost overruns that occur in the project are shared between the project stakeholders (Chan et al. 2010, 2011). In this contract strategy, there is improved quality and fewer claim and dispute incidents, and an increase in collaboration between the owners and the other project participants (Chan et al., 2010, 2011; Hashem et al., 2018)

Having briefly discussed the predominant contract formats, the choice of contracts should be strategically tied to the project delivery method chosen, the procurement strategy, the level of collaboration necessary, and the type of project being produced, considering their benefits and drawbacks (Puddicombe 2009; Hashem et al., 2018).

### 4.1.6 Project performance and the impact of delivery strategies

#### *4.1.6.1 Project performance/success metrics*

Any project's overall execution is invariably a compilation of how well its goals are displayed (Mensah, 2007). This indicates that performance efficiency and effectiveness are essential for achieving project execution objectives. Hence, project success is related to project performance.

Performance is the level of attainment of an endeavour or effort; it relates to the predetermined goals or aims that make up the project parameters (Chitkara, 2005; Ogunsanya, 2018). The project management body of knowledge traditionally affirmed that time, cost, and quality are the three main constraints of project performance (PMI, 2021). From a project management point of view, success is determined by how well a project meets or exceeds the needs and expectations of its stakeholders (Ogunsanya, 2018). In other words, construction project success is typically determined by whether it is delivered on time, within budget, by quality specifications, and to the client's satisfaction (Emere, Musonda and Okoro, 2019). Besides, performance is understood to be the fulfilment of a duty in a way that absolves the performer of all obligations arising from the contract (Ogunsanya, 2018). Hence, the triangular constraints (time, cost, and quality), predominantly used over the years, needed to be revised (Ogunsanya, 2018; Tengan, 2018).

Some scholars have argued that it is crucial to include health and safety aspects of the project in performance evaluation because the construction industry is the most dangerous due to its high rate of fatalities (Billy, Cameron and Duff, 2006; Ngacho and Das, 2014; Jimoh, Oyewobi, and Aliu, 2015). Hence, safety performance was added to their studies. Similarly, Du et al. (2016) added occupational health, safety, and environment to the triangular constraint. Some scholars have also added other measures to broaden the performance objectives. For example, Ogunsanya (2018), in his study on sustainable procurement, along with the time, cost, and quality, included risk, stakeholders' satisfaction, rapid infrastructure development and economic development as performance criteria. Similarly, Eriksson and Westerberg (2009), in their study on the "effect of procurement on construction project performance", used measures such as time performance, economic performance, quality, environmental performance, work environment, and innovation.

Additionally, sustainability has been used as a performance criterion (Korkmaz et al., 2010; Oke et al., 2018; Tengan, 2018). For instance, Tengan (2018) used project sustainability, time, cost, project conformity, health and safety performance, client satisfaction, environmental, contractor performance, end-user satisfaction, value for money, fit for purpose, and successful project closure as project performance measures. The study evaluated the impact of effective monitoring on the outcome of construction project delivery. Similarly, Korkmaz et al. (2010), in the quest to

assess the influence of project delivery methods on achieving sustainable high-performance buildings, used schedule; cost; level of high performance and sustainability, quality, construction safety, and the owner's post-occupancy evaluation as performance criteria. Furthermore, Olanipekun et al. (2018) used delivery performance measures which included traditional metrics (cost, time, and quality) and sustainability metrics (indoor environmental quality, sustainability rating, and energy efficiency levels). The study investigated how motivation and owner commitment relate to green building delivery performance (Olanipekun et al., 2018).

#### *4.1.6.2 Impact of delivery strategies on construction project performance*

There have been varying results on the impact of project delivery and procurement systems on construction project performance (Gad et al., 2015; Mehany et al., 2017; Hashem et al., 2018). Many suggest that the choice project delivery strategy can impact the performance measures' attainment (Nkado, Laryea, Leiringer, Hughes, 2010; Oke et al., 2018). Also, Jimoh, Oyewobi, and Aliu (2015), in their study on the impact of procurement methods and project types on construction project performance, established a relationship between procurement methods and performance. Several scholars affirm that alternative contracting methods have faster project delivery than traditional design-bid-build (DBB) method (Septelka and Goldblatt 2005; AECOM 2006; Hale et al. 2009; Carpenter and Bausman 2016; Antoine, Alleman, and Molenaar, 2019). For example, in the design and build (DB) method, the overlap between the design and construction phase delivers a shorter schedule benefit (Less schedule growth and faster delivery time) compared to DBB (Perkins, 2009; Shrestha et al., 2011; Minchin et al., 2013; Chen et al., 2016; Hashem et al., 2018; Antoine et al., 2019).

Similarly, DB and construction manager/general contractor (CM/GC) were affirmed to have less cost growth than DBB (Warne, 2005; Shrestha et al., 2007; Hale et al., 2009). Additionally, some scholars claim that using alternate contracting methods rather than DBB results in cost certainty being known earlier (Shrestha et al., 2007; Gransberg and Shane, 2010; Touran et al., 2011; Antoine et al., 2019). In contrast, Rashid et al. (2006) suggest that DBB has a better price certainty at a much earlier project stage. Additionally, because the design and all associated working drawings are thoroughly produced and documented before tendering, the client receives

firmer and more affordable pricing (Rashid et al., 2006). Besides, they suggested that using DBB eliminates any ambiguity or uncertainty in the design or building process, frequently leading to excessive cost inflation by the contractors.

Moreover, when a bill of quantities is employed, the bidding process tends to be more equitable, which lowers the project cost. However, Akiner and Akiner (2018) state that in DBB, the project owner may contribute to the rising cost by asking for modifications and adding new components to the construction product. Besides, the project owner responsible for the construction project cost may face increased costs because of outside variables like high inflation, which will raise the cost of materials (Lopez and Love, 2012). Also, some researchers believe that only the turnkey approach can ensure that the project budget will stay the same in the eyes of the project owner and the client (Arditi and Ongkasuwan, 2009; Chang, 2009; Akiner and Akiner, 2018). Furthermore, Arditi and Ongkasuwan (2009) suggest that the turnkey system is the only one where the client does not need to take time into account because the builder will only invite purchase orders when the project is finished or is in its final phases.

Rashid et al. (2006) also affirm that DBB has a high degree of quality certainty and applicable standards compared to DB but not to CM. This indicates that the traditional method of project delivery is still held in high regard by some scholars. However, many have criticised the approach's lack of project integration and intensity (Carpenter and Bausman, 2016; Chen et al., 2016; Hashem et al., 2018; Antoine et al., 2019). Mollaoglu-Korkmaz et al. (2013) assert that if the contractor is informally involved, then DBB has a relative potential to provide satisfactory levels of integration for attaining sustainability goals.

Kantola and Saari (2016) explored the most effective delivery system for nearly-zero-energy building (nZEB) projects that use low energy, primarily generated from renewable sources. The authors declined the usage of DBB and indicated that because nZEB projects have a multiparty contracting system, an integrated project delivery (IPD) system with a competitive procedure on negotiations or a competitive dialogue procurement technique would work well (Kantola and Saari, 2016).

Considering the brief discourse on the impact of project delivery strategies on project performance, one may suggest that different systems are used for various projects in alignment with the achievement of the predetermined goals and performance criteria. In other words, there may not be a "one-size-fits-all" system that will meet all the available performance measures. Therefore, the more important criteria for the project owner or client should be used to determine the project delivery system (Akiner and Akiner, 2018).

## 4.2 Gap Two: Understanding Sustainable Building Construction Project Management Techniques

### 4.2.1 Essence of project management and its techniques

Many organisations, including the construction industry, have identified project management as essential to enhancing project performance and delivering products and services effectively and efficiently. The Project Management Institute (PMI) defines project management as applying skills, knowledge, techniques, and tools to a project activity to meet the project requirement. The project objectives were mainly the triangular constraints of time, cost, and quality (specifications) until the arrival of sustainable projects, which invited other dimensions like environmental and community (Ashleigh, Ujiako, Chipulu, and Wang, 2011; Abdelkhalik and Azmy, 2022). The sustainable success dimensions can be summarised as the triple P (planet, people and profits). Systematic procedures and practices are critical to achieving the threefold P objectives and the triangular constraints. Hence, project management techniques (PMTs) are significant factors in achieving project deliverables (Emere et al., 2019; Emere, 2020). PMTs "are systematic procedures or practices project managers use to produce specific project management deliverables" (Patanakul et al., 2010; Emere et al., 2019).

Additionally, Horine (2013) affirms that a project could only succeed by applying management practices such as techniques and skills. As organisations continue to move toward project-based management to get more done with fewer resources, the need for project management and its techniques becomes increasingly essential (Patah, 2010; Horine, 2013). Likewise, the fact that

each client needs to have value for the money invested in projects makes project management fundamental as it lessens money-related misfortunes by annihilating poor undertaking speculations at a very early stage in their life cycles (Patah, 2010). Consequently, project management methodologies and their techniques are being implemented in the construction industry to deliver projects successfully.

### 4.2.2 Project management methodology and techniques

Researchers have characterised project management methodology in several ways, most of which are similar. Project management methodology is a set of methods, techniques, procedures, rules, templates, and best practices used on a project (PMI, 2021). Additionally, Introna and Whitley (1997) defined project management methodology as a structured set of techniques for solving a specific problem. Different researchers agreed with the two definitions as they accept that project management methodology is a set of principles, guidelines, and approaches with structured techniques for solving a specific problem or achieving defined project objectives (Gane, 2001; Charvat, 2003; Spundak, 2014). Considering the given definitions, PMTs are subsets of project management methodologies.

Several project management methodologies have emerged. Arguably, the project management body of knowledge (PMBoK) (also known as the project management book framework) is the most utilised (Campbell, 2009; Macek, 2010; Ghanim, Munassar, and Dahlan, 2013). PMBoK is a collection of generally accepted project management techniques that can easily be integrated into other methodologies (Software Engineering (SE) Project, 2004). Additionally, project management purists assert that PMBoK is a set of agreed-upon standards and conventions for managing projects rather than a methodology (Campbell, 2009). This suggests that what PMBoK is to project management is what a dictionary is to a book. In other words, as the dictionary collects the agreed-upon vocabulary used to write books, so also PMBoK contains the agreed-upon tools and techniques, standards and guidelines essential for effective project management (Campbell, 2009; Ghanim et al., 2013; Spundak, 2014).

Other project management methodologies found which can be used for managing projects include Agile (Chin, 2004; Williams, 2005; Spundak, 2014; Rasnacis and Berzisa, 2016); PRINCE² (White and Fortune, 2002; Pincemaille, 2008); Waterfall (Abdelkhalik and Azmy, 2022); Structural Systems Analysis and Design Methodology (SSADM) (White and Fortune, 2002; SE Project, 2004); The European Risk Management method (RISKMAN) (White and Fortune, 2002; Taylor et al., 2006); Artech (Artech Information System, 2003); International Organisation for Standardisation (ISO) (Macek, 2010; Rehacek, 2014) and the RIBA Pan of Work (Chapman, 2001; White and Fortune, 2002) to mention but a few.

However, not all methodologies will be suitable for construction projects. Abdelkhalik and Azmy (2022) discovered that PMBoK, Agile, and Prince² are among the predominant methodologies used for green building projects. This indicates that project management methodologies and their defined techniques depend on the project type, size, technology, and schedule. Hence, manipulating and configuring things to suit one's project environment is vital for maximum results (Rehacek, 2014). This means that PMTs can be picked from various methodologies customised and tailored according to the given project to achieve the project deliverables.

### 4.2.3 Project management and sustainability

Project management and sustainability are two subjects that have received significant attention in the last decades. However, they are seldom incorporated into one study or a framework, even though project management could positively influence the integration of sustainability dimensions into projects (Bocchini, Frangopol, Ummenhofer, and Zinke, 2014; Abdelkhalik and Azmy, 2022). There is a paucity of existing studies relating to the role of project management in sustainable building construction success (Marcelino-Sádaba, González-Jaen, and Pérez-Ezcurdia, 2015). Besides, reputable methodologies like PMBoK, ISO and Prince² did not consider sustainability and environmental issues (Brones, De Carvalho, and De Senzi Zancul, 2014; Abdelkhalik and Azmy, 2022). Similarly, Abdelkhalik and Azmy (2022) affirm that many studies are concentrated on sustainable and environmental management instead of project management and its essential role in sustainable and green architecture.

Project management and its techniques are essential for effectively managing the construction of sustainable and green buildings from inception to the operation phase. Besides, sustainable assessment/rating systems are designed to evaluate structures considering the planning, design, construction, and operation stages (RSMeans, 2011). Wu and Low (2010) also affirm that some credits in the rating systems, such as LEED2.2, Green Globes, and BCA Green Mark 3.0, are related to project management. This makes project management contributions enormous.

A few frameworks have been developed that have not remedied the issues surrounding project management and sustainability integration nor applied significantly. For instance, Marcelino-Sadaba et al. (2015) developed a framework comprising products, processes, organisations, and managers to enable project managers to tackle sustainability projects. Another is the reference guide to sustainability in project management developed by the international organisation of green project management (GPM). The methodology is known as PRISM (Project Integrating Sustainable Methods). It is based on a series of standards incorporated in ISO 21500:2012 (Green Project Management, 2013). The application of this methodology is scarce, and a paucity of studies address it (Abdelkhalik and Azmy, 2022). Similarly, Mustapha, Manan, and Wan Alwi (2017) aimed to create a sustainable green management system with an integrated approach toward organisational sustainability. The framework was relevant for collecting, monitoring, analysing, and managing information and resources to enhance the profitability and efficiency of an organisation (Mustapha et al., 2017; Abdelkhalik and Azmy, 2022).

Several studies have concurred that the contribution of project managers is essential in integrating project management and sustainable building construction for the actualisation of project success and meeting the deliverables (Hwang and Ng, 2013; Abdelkhalik and Azmy, 2022). For instance, Hwang and Ng (2013) averred that the cost, risks, and long period required for planning and designing green buildings demand adequate project management knowledge, skills and techniques to mitigate the challenges. Some fundamental knowledge areas were mentioned. They include “schedule management and planning, stakeholder management, communication management, cost management, and human resources management” (Abdelkhalik and Azmy, 2022:6). Some critical skills mentioned included analytical, decision-

making, team working, delegation, and problem-solving skills (Hwang and Ng, 2013; Abdelkhalik and Azmy, 2022). It is noteworthy that project management techniques are part and parcel of these knowledge management areas and skills and are used in achieving their objectives (Emere et al., 2019; PMI, 2021).

### 4.2.4 Project management techniques for achieving the targeted deliverables and objectives.

Project management techniques (PMTs) have been found it essential in meeting deliverables for the actualisation of project success (Emere et al., 2019). There is a plethora of techniques that can be used and some of which are discussed in this section. For instance, *Work Breakdown Structure* (WBS) is critical in subdividing project expectations and tasks into smaller and manageable chunks (Bresner and Hobbs, 2008; Burke, 2013; Michael, Deepak and Tong, 2014). As per Burke (2013), this technique aids in defining the scope of work, is time-related, enhances production efficiency, and is a reference for similar work. Similarly, the *Critical Path Method* (CPM*)* is a vital time management technique for determining all project activities' start and finish dates (White and Fortune, 2002; Burke, 2013; PMI, 2021). This technique identifies the sequential activities that form the critical pathways. A developed network diagram and calculation are required to produce a logical project timeline used as the project plan framework (Burke, 2013). CPM can be used with WBS in representing work activities for effective time management (PMI, 2012). Additionally, Deliverable Breakdown Structure (DBS) is used to identify the project deliverables, including project management deliverables and their interrelation (Bresner and Hobbs, 2012; PM², 2016). DBS usually precedes the WBS as it recognises deliverables used in creating WBS.

The *Program Evaluation and Review Technique* (PERT) calculates the expected completion time for a task by considering the optimistic time, pessimistic time, and realistic time (Kerzner and Kerzner, 2017; Emere et al., 2019; PMI, 2021). Similarly, the Milestone Analysis technique (Golini et al., 2012; Stojcetovic et al., 2013; Michael et al., 2014) adds significant value to project scheduling. According to Verzuh (2008), “Milestones are like dashboard reviews of a

project. The number of activities planned at the beginning of the project with their timelines is reviewed for their status. It also allows for checking the project's health" When used with other time management techniques such as PERT and CPM, it can assist in accurately determining the project's progress and in knowing if it is on schedule (Verzuh, 2008).

The *PESTEL Analysis* technique is crucial to understand how the environment might impact a project or an objective. PESTEL is an acronym for "Political, Economic, Social, Technological, Environmental, and Legal factors". It helps identify the external factors that can impact an organisation and their project objectives, planning and execution (PM², 2016). As the name implies, this technique can be critical for achieving sustainable goals.

Earned Value Management (EVM) assists in the planning and controlling projects in comparable units for precise tracking (Burke, 2013). It is also a vital technique for cost management (Bresner and Hobbs, 2006; Emere et al., 2019). Similarly, *Analogous* and *Parametric Estimating* are used for cost management (Patanakul et al., 2010; Bresner and Hobbs, 2012; Chou and Yang, 2012). With analogous estimating, the cost can be assessed using similar projects (PMI, 2021), while parametric uses unit rate to determine the price (PM², 2016).

For quality management, two techniques were found critical. They are quality benchmarking and quality review/audit (Patanakul et al., 2010; Chou and Yang, 2012; PMI, 2021). With quality benchmarking, organisations can evaluate various aspects of their large-scale work tasks and processes with best practices of the company's processes, usually within a peer group defined for comparison (Chen, 2002). The information enables the organisation to develop plans to make improvements or adapt specific best practices to enhance some aspects of performance (Emere et al., 2019). However, quality review allows for inspection and ensures that the target objectives are met according to requirements (PMI, 2021).

Some techniques were mentioned to address procurement and ensure efficient resource management. They include the *Make or Buy Analysis* and *Bidder Conference* (Bresner and Hobbs, 2012; Chou and Yang, 2012; Ferreira et al., 2013; PM², 2016; PMI, 2021). Through *Make or Buy analysis,* organisations can reach an informed decision on what to outsource and what not to outsource (Chou and Yang, 2012; PM², 2016; PMI, 2021). This technique is vital

considering the scarce resources and needs for sustainability. Hence, managers and project sponsors frequently face difficulty deciding what to make or buy (PM², 2016). Factors such as cost comparison, technology, supplier-related information and support systems and the like., are considered in the decision-making (PM², 2016). Similarly, the *Bidder conference* helps suppliers make inquiries, gather information for bid preparation, and ensure that all bidders have access to the same information (Chou and Yang, 2012; PM², 2016).

Another technique is that of *Lesson learned* essential for improving project performance. This technique identifies development/improvement areas within a project to help similar projects avoid certain pitfalls in the future (PM², 2016). It helps capture the lessons learned from managing risks, quality issues, outsourcing or contractor issues, and change requests (White and Fortune, 2002; Bresner and Hobbs, 2012; Ferreira et al., 2013).

The *change control* technique ensures that all changes essential to a product or system can be systematically addressed. Additionally, it ensures that unnecessary interruptions are avoided, and resources are used efficiently (Ferreira et al., 2013; PM², 2016).

For risk management, *SWOT analysis* and the *Delphi technique* were identified (White and Fortune, 2002; Patanakul et al., 2010; Cetindamar et al., 2012; PMI, 2021). The former can examine the strength, weaknesses, opportunities, and threats to project criteria and deliverables for effective contingency planning (PM² Guide). In contrast, the latter estimates the likelihood and outcome of future events. A group of experts exchanges views, and each independently gives estimates and assumptions to a facilitator who reviews the data and issues a summary report (PMI, 2021).

*Brainstorming* and *meeting* were identified as primary exploratory techniques that aid in achieving project outcomes (Agumba, 2006; Stojcetovic et al., 2013; Michael et al., 2014). Through brainstorming, relevant ideas for the planning and execution of the project can be generated. The project manager should conduct a requirement gathering and a brainstorming exercise that includes the client and shareholders (Bezzi, 2011). On the one hand, a *meeting* is essential in conveying information and raising ideas to ensure that the project's progress is tracked and controlled (Agumba, 2006). A typical example of a *meeting* is a status meeting.

Furthermore, *stakeholder management/analysis* and *conflict management* were acknowledged as human resource management techniques essential in achieving project objectives (Patanakul et al., 2010; Chou and Yang, 2012; PMI, 2021). These two techniques ensure systematic handling of the issues and interests concerning man-management to prevent detriments to the project outcomes (Emere et al., 2019).

Although the discussed techniques are not exhaustive, they have been generally accepted, among others, by several authors and the project management puritans as reliable in improving project performance irrespective of the chosen methodology (Milosevic, 2003; SE Project, 2004; Campbell, 2009; Ghanim et al., 2013; Spundak, 2014). They are also the most cited project management techniques (Emere et al., 2019).

### 4.2.5 Use of Project management techniques in developing countries and South Africa

The use of project management techniques in the construction industries of developing countries is critical, if high performance and project success rates are to be achieved (Abbasi and Al-Mharmah, 2000, Yimam, 2015). Unfortunately, the essence of these techniques needs to be addressed, and their usage is still in the developing phase (Abbasi and Al-Mharmah, 2000; Emere, 2020). It was highlighted that project managers' familiarity with the existing project management techniques is average, while only about 28% of these techniques are used by project managers (White and Fortune, 2002; Patanakul et al., 2010; Emere, 2020). Abbasi and Al-Mharmah (2000) who studied project management practices in Jordan. Results showed that only 21.9% applied the Project Evaluation and Review Technique, while 28.1% and 34.4% used the work breakdown structure and critical path method. Generally, the results showed a very scanty or no use of the essential and most cited techniques discussed in 4.3.4.

Similarly, on the African continent, it was revealed that inadequate implementation of project management practices, including project management techniques, is partly the reason for project inefficiency, project delays, failure to achieve budget and scheduled expectations, as well as poor quality performance on construction projects (Ali, 2010; Yimam, 2015). These project delivery

shortcomings are predominant, especially in African nations such as Ghana, Nigeria, Ethiopia, Zimbabwe including South Africa (Idoko, 2008; Ahsan and Gunawan, 2010; Ika and Hodgson, 2010; Rwelamila and Purushottam, 2012; Egwuonu, 2015). Most construction companies in developing countries need more experience and organisational structure to adequately apply project management methodologies and their required techniques, which has hindered their performance efficiency (Enshassi et al., 2009; Kissi and Ansah, 2013). Sukhoo et al. (2004) added that project management problems arise from a shortage of skilled staff, difficult economic and social conditions, weak political institutions, and deeply rooted cultural and religious beliefs which affect developing disciplines like project management. This suggests the need for sustainability and project management integration in construction.

In South Africa, some authors affirmed that some construction companies, especially many from small and medium enterprises, take shortcuts in their project undertaking, neglecting the essence of project management techniques in improving project performance (Gillam, 2004; Agumba, 2006; Moiwa, 2013). Additionally, in the quest to secure contracts, the builders make unrealistic delivery promises without adequately analysing the demands and cost implications of the project (Gillam, 2004; Agumba, 2006; Emere et al., 2019). These shortcomings, therefore, result in the inability to start or complete the project on time and often, quality is compromised to make an acceptable profit. Emere (2020) found that many professionals, especially in SMEs, are still neutral on the efficacy of project management techniques. Additionally, a study by Olatunji (2010) aimed to determine the causes of delays in project delivery in South Africa. Findings revealed that the major factors include lack of adequate planning, lack of management style, lack of quality management during design and construction, incompetency, lack of constructability reviews of designs, and so on. Notably, the study affirmed that using project management techniques is one of the essential ways to mitigate the shortcomings and delays in project delivery (Olatunji, 2010). The essence of project management techniques in meeting project objectives and deliverables must be considered. They are vital for achieving project success which is a by-product of project performance efficiency and effectiveness (Patah, 2010; Kerzner, 2010). Hence, they will be relevant for ensuring sustainable building construction, particularly in developing countries, like South Africa. The current study considered project management

techniques as one of the critical factors for achieving sustainable building construction and project success.

### 4.2.6 Factors impacting the adoption of project management techniques.

Various factors that can influence the use of project management techniques discovered in literature can be grouped under knowledge, economic consideration, organisational culture, situational consideration and psychology (Talukder, 2012; Kissi and Ansah, 2013; Filistilis and Chalatsis, 2014; Sephoso, 2015; Emere, 2020). Firstly, *knowledge* incorporates the skills and capabilities acquired through education and experience (Cetindamar et al., 2012; OED, 2023). Cetindamar et al. (2012) affirm that educational background can impact the relationship between using techniques and performance. This suggests that the higher the degree of training of the project manager on the required project management skills, the better they can provide practical solutions to solve problems in the organisation (Agumba, 2006; Kissi and Ansah, 2013; Egwuonwu, 2015). Therefore, knowing which techniques to use in any project circumstance is crucial for successfully implementing project management techniques and actualising better project performance. This aligns with Filistilis and Chalatsis (2014), who posit that competency with project management activities will impact the adoption of project management practices, including project management techniques.

Additionally, Cetindamar et al. (2012) asserts that experience affects the relationship between using techniques and performance. Hence, project managers are encouraged to pursue the necessary project management skills and knowledge to be competent in dealing with the project management activities of their organisations. Besides, to deliver a successful project, the project manager and his team must clearly understand their priorities for efficient management (Kissi and Ansah, 2013). With adequate project management knowledge, they can use the proper techniques to plan, schedule, control, and execute their construction projects effectively for optimum performance.

*Economic consideration* is the second key factor that can impact the adoption of project management techniques (PMTs). The availability of finance is significant in the execution of

construction projects. Agumba (2006) and Michael et al. (2014) affirm that an organisation's financial capacity will tremendously impact project management success and the usage of PMTs. For example, an excellent financial ability to run a project would enable the appointment of competent personnel to adopt project management processes and techniques to attain project objectives. On the other hand, financial incapacity is why some contractors employ unqualified workers (to save money), which contributes to poor project performance (Van Wyk, 2003; Thwala and Mvubu, 2008), and this disposition can affect the application of PMTs. This aligns with Gillam (2004) and Agumba (2006). They affirm that some companies cut corners (not using PMTs in achieving their project deliverables) and compromise in their project execution due to a lack of funds to employ competent persons to handle the project management processes (Gillam, 2004; Agumba, 2006). They make improbable delivery promises to secure a contract without considering the implications (Agumba, 2006; Moiwa, 2013). Therefore, the financial capability will improve the relationship between using PMTs and performance. In contrast, lack of funds is a deterrent to this relationship.

Thirdly, there is the *organisational culture* which includes policies, approaches and actions, and the project management culture. Talukder (2012) posits that organisation culture can positively or negatively impact the adoption of project management techniques. For instance, good project management culture and approaches will favour the utilisation of essential PMTs to meet the project deliverables, unlike a bad one. Additionally, good support from the top management will provide a conducive environment for implementing innovative approaches and techniques to improve project performance (Talukder, 2012; Cetindamar et al., 2012; Kissi and Ansah, 2013). In contrast, inadequate organisational approaches, such as a lack of adequate supply of information from the professional team and the introduction of activities not included in the performance contract, can result in roadblocks to the free progression of the project tasks and activities (Sephoso, 2015). Similarly, developing a culture of learning and a clear project manager's career path for all project management roles enhances the adoption of project management techniques, unlike when these elements are not in place (Cooke-Davies, Crawford and Lechler, 2009; Shi, 2011).

Fourthly, *psychological dispositions* such as preconceived beliefs about PMTs can impact their use. A moral conviction that project execution ought to do with PMTs would be ideal, unlike such ideas that PMTs are time and resource-consuming to use, creating resistance to change and innovation (Talukder, 2012; Kissi, Ahadzie and Badu, 2014). Additionally, a tepid demeanour towards change can discourage implementing new techniques and practices (Loo, 2002; Kissi et al., 2014). Even so, resistance is reduced when there is proper awareness of the benefits of innovative changes for project performance enhancement (Talukder, 2012; Sephoso, 2015).

Fifthly, *situational considerations* can impact the choice of techniques to suit the project's phase, size, type and strategy (Milosevic, 2003; Milosevic and Iewwongcharoen, 2004; Patanakul et al., 2010). Milosevic and Iewwongcharoen (2004) affirm that project life cycle phases impact the choice of techniques. Some techniques may be used more at a particular project phase than others. Subsequently, the utilisation of project management techniques (PMTs) in various project life cycles is a consequence of the unique targets and deliverables at each phase (Crawford, Hobbs, and Turner, 2002; Patanakul et al., 2010; Shenhar, 2010). This aligns with Agumba (2006), who categorised PMTs according to project phases. Likewise, Milosevic (2003), including Milosevic and Iewwongcharoen (2004), posit that project size impacts the selection of PMTs. Hence, the uncertainty and complexity of a project will demand the correct type of techniques to achieve efficiency and effectiveness in the execution (Milosevic and Iewwongcharoen, 2004; Cetindamar et al., 2012). In other words, simple projects require simple techniques, while complex projects require specialised techniques. This statement aligns with Golini et al. (2015), who grouped the use of PMTs based on clusters of project complexity. Project types influence the utilisation of PMTs (Crawford et al., 2002; Milosevic and Iewwongcharoen, 2004). The utilisation of PMTs fluctuates depending upon the undertaking, as some projects may be more administrative, routine, unique and technical aspects compared to others (Crawford et al., 2002). Additionally, Milosevic and Iewwongcharoen (2004) propose that PMTs can be selected based on strategic focus. They suggest that construction projects will generally forfeit time rather than cost, while engineering consulting projects will forfeit cost to fulfil the time constraint. Hence, the predominant PMTs used can vary from one focus to another (Milosevic and Iewwongcharoen, 2004). For example, a schedule-driven project will use the

necessary time and scheduling techniques. In contrast, a cost-driven project will use the techniques relevant to mitigating cost overruns (Milosevic and Iewwongcharoen, 2004). Table 4.1 presents the factors discussed in this section.

**Table 4. 1:** Factors that can impact project management techniques adoption

| Factors | Key points | Sources |
|---|---|---|
| Knowledge | Education/Skill/Competence | Agumba (2006); Cetindamar et al. (2012); Kissi and Ansah (2013); Filistilis and Chalatsis (2014); Egwuonwu (2015) |
| Economic consideration | Availability of funds for the project operation | Agumba (2006); Michael et al. (2014) |
| Organisational culture | Organisation policies, approaches and actions | Iyer and Jha (2005); Cetindamar et al. (2012); Talukder (2012); Kissi and Ansah (2013); Sephoso (2015) |
| | Project management culture | Talukder (2012) |
| | Top management support | Talukder (2012); Cetindamar et al. (2012); Kissi and Ansah (2012) |
| Psychological disposition | Resistance/lukewarm attitudes to change | Loo (2002); Talukder (2006); Kissi and Ansah (2013); Kissi et al. (2014) |
| | Preconceived beliefs | Agumba (2006); Talukder (2012); Kissi et al. (2014) |
| Situational consideration | Project phase | Crawford et al. (2002); Milosevic and Iewwongcharoen (2004); Agumba (2006); Shenhar and Dvir (2010) |
| | Project size | Milosevic (2003); Milosevic and Iewwongcharoen (2004); Cetindamar et al. (2012); Golini et al (2014) |
| | Project type | Crawford et al. (2002); Milosevic (2003); Milosevic and Iewwongcharoen (2004); Agumba (2006) |
| | Strategic focus | Milosevic and Iewwongcharoen (2004); Patanakul et al. (2010) |

### 4.2.7 Impact of project management techniques on project performance

In the search for ways to remain in front of the pack in the present aggressive and cluttered worldwide economy, project management has become the remedy for many companies to deliver business results consistently (Ali, 2010; PM1, 2021). Project management helps create a strategic

value chain that gives organisations an edge over their competitors, particularly in high-risk sectors and markets. Having the capacity to deliver projects on time and within budget are good indicators that a company will get the next job or whether its new product will hit the market (PMI, 2021). Subsequently, project management techniques (PMTs) are advantageous for improving project performance (Murphy and Ledwith, 2007; Ko, 2011).

Several scholars also endorsed that proper PMTs application will positively influence project success (Wideman,1991; Milosevic, 2003; Murphy and Ledwith, 2007; Moiwa, 2013; Emere et al., 2019). PMTs can enhance the project's scope definition with a results orientation, streamline allocations and resource usage, reduce cost and time with higher profit margins, and improve risk handling and control (Wideman, 1991; Emere, 2020). Moreover, Kerzner and Kerzner (2017) affirmed that good project management practice, such as using techniques, enables accomplishments to be measured against plans, and issues can be identified early enough for mitigation. In other words, effective project management practice can stop pointless spending, decrease risks and enhance achievement appraisal (Kerzner and Kerzner, 2017). Getting the most out of the scarce accessible resources is principal. Even the money spent on proper planning cannot be compared to the detriment of poor management (Burke, 2013). Further, Abbasi and Al-Mharmah (2000) contend that the benefits of effective adoption of PMTs are known-work progress, better work organisation, defined goals and objectives, good management of human resources, better communication, better time utilisation, and better quality. The benefits show that there should be more focus on the PMTs' adoption as they are crucial in project execution.

Similarly, a study by Joslin and Muller (2016) on the "impact of project methodologies on project success" indicates that PMTs have a bearing on project outcomes such as time, cost, scope, quality and client satisfaction. Time is one of the fundamental models for task accomplishment. Actualising time objectives involves effective planning, scheduling and controlling project procedures. Hence, using time-related techniques such as the critical path method, program evaluation and review technique, work breakdown structure, milestone analysis and so on will improve time performance. Time-related techniques will help reveal the

parameters required to finish the project and plan the specific activities within the predefined time (Bresner and Hobbs, 2012; Patanakul et al., 2010; PMI, 2021).

Equally, meeting a project's cost objective is indispensable. The cost of a project requires an organised methodology. The accuracy of the project estimate is relative to the accuracy of planning and control (Burke, 2013). Burke (2013) further asserts that the project manager's challenge is "to know how to use the portfolio of special project management techniques to predict what will happen in the future". The inability to control cost effectively may lead to cost overruns, time delays and quality problems. Therefore, using cost-related PMTs like earned value management, analogous estimating and parametric estimating will be relevant for meeting project cost objectives (Bresner and Hobbs, 2006; Patanakul et al., 2010; Bresner and Hobbs, 2012; Burke, 2013; PM², 2016).

PMTs are also linked to project scope management. Techniques like work breakdown structure and deliverable breakdown structure can assist in defining the scope of work, identifying the project deliverables and subdividing the scope of work into manageable chunks that can be allocated to appropriate individuals and tracked with time (Burke, 2013; PM², 2016). Burke (2013) asserts that effective scope management is one of the critical factors determining project success. This is because the inappropriate interpretation of the client's requirements will produce a misleading definition of the scope of work. This can lead to rework and additional effort that might affect the project time, cost and quality (Burke, 2013). Subsequently, the project manager is expected to appropriately define the scope of work for effective planning and control.

Furthermore, the quality of deliverables achieved on a project reveals whether the performance is poor or not (Emere, 2020). Good quality means compliance with defined standards. Therefore, project managers should be concerned with achieving the required quality standards to meet the organisation and client expectations (Lester, 2007). Literature suggests that PMTs such as quality benchmarking, quality review, and lessons learned inter-alia could aid in improving the quality performance of a project (Patanakul et al.,2010; Chou and Yang, 2012; Ferreira et al., 2013; Emere, 2020; PMI, 2021).

Views from the literature have shown the benefits of using PMTs in improving project performance and achieving project success. Hence, the current study incorporates project management techniques as one of the critical factors for actualising sustainable building construction and project success.

### 4.2.8 Interventions to enhance the use of project management techniques.

Interventions can be seen as improvement initiatives. It entails bringing innovative changes to an organisation's modus operandi (Badilescu-Buga, 2013). It can also mean an improvement in a service or product. Literature has identified key improvement initiatives that favour project performance and management techniques (PMTs). A study conducted in Norway by Andersen and Vangaasar (2009) suggests that implementing project management methodologies and creating internal project management schools (for training) are the two fundamental improvement efforts.

Generally, project management training is recommended by several scholars as one of the vital areas for the improvement of project management practices (Loo, 2002; Greenhalgh et al., 2004; Thomas and Mullaly, 2008; Andersen and Vangaasar, 2009; Carayon, 2010). According to Carayon (2010), adequately coordinated training specific to the adopted methodology and the new working methods should be instituted. For Loo (2002), more emphasis should be laid on project management training, particularly planning techniques. Besides, Greenhalgh et al. (2004) states that a knowledgeable person should conduct training. Additionally, Andersen and Vaagaasar (2009) suggest that internal schools should be created in an organisation solely for project management training.

Some scholars also suggest that to improve project management practices, there should be an establishment of standardised/customised project management processes (Milosevic and Patanakul, 2005: Thomas and Mullay, 2008; Andersen and Vaagaasar, 2009). Various scholars agree that before implementing project management methodologies and techniques, project management processes should be standardised and tailored for their accommodation (Thomas and Mullaly, 2007; Milosevic and Patanakul, 2005; Andersen and Vaagaasar, 2009). In other

words, provisions should be made for the accommodation of the methods, tools, and techniques early enough, especially during the planning phase (Sephoso, 2015). Moreover, the project management processes should be benchmarked with industry standards (Barber, 2004).

Another improvement initiative is by standardising/customising PMTs were necessary for future reference (Milosevic and Patanakul, 2005: Thomas and Mullay, 2008; Shi, 2011). According to Thomas and Mullaly (2008), the techniques will detail how the processes should be conducted, what tools to use to carry forward those processes, and any other techniques that would make the processes successful. Subsequently, PMTs should be tailored and customised to suit the project context for effectiveness.

Similarly, there should be proper project management competencies within an organisation, especially by the project manager, for the successful adoption of the appropriate project management methodology and subsequent use of PMTs (Thomas and Mullaly, 2008; Andersen and Vaagaasar, 2009; Shi, 2011). Also, the employees to enforce the project management initiatives should be competent to guide the rest of the staff who do not possess these skills (Thomas and Mullaly, 2008; Sephoso, 2015). Besides, organisations should also be aware of the competencies of the team members for proper placement of their roles within a project team (Sephoso, 2015). Moreover, Thomas and Mengel (2008) suggest that project managers should be prepared to diagnose situations and adopt and adapt appropriate techniques for meeting objectives.

Additionally, a good learning culture within an organisation must be addressed as it is a catalyst for accommodating any innovation (Shi, 2011; Sephoso, 2015). Shi (2011) states that an organisation should develop a learning culture to ensure that its employees embrace the project management way of doing things and familiarise themselves with better ways of getting things done. For Greenhalgh et al. (2004), not only a learning culture is required but also a leadership culture that is proactive enough to encourage the sharing of project management knowledge between knowledge holders and adapters. With these two combinations, employees in the organisation are prone to adopting the project management methodology (Greenhalgh et al., 2004).

Furthermore, developing a basic understanding of organisational project management practices among all stakeholders is a crucial improvement initiative (Thomas and Mullaly, 2008; Shi, 2011). All stakeholders involved in the project should know the value of project management, not project managers alone. According to Fernandes, Warda, and Araujo (2013), developing a basic understanding of the institutionalised project management processes, tools and techniques, its purposes, and its benefits must involve all staff in project activities. This is important to improve project management practices and create a project management culture. These basic understandings may be actualised among the organisation's stakeholders by customising project management documentation (Fernandes et al., 2013). Finally, awareness of perceived and actual project management benefits should be created among all the organisation's staff, from top management to the lowest employee (Zhai, Xin and Chen, 2009; Fernandes et al., 2013; Sephoso, 2015). In addition, employees with good project management expertise should feel free to share their knowledge with other employees (Greenhalgh et al., 2004).

## 4.3 Gap Three: Understanding Sustainable Building Construction Modern Building Techniques

Modern Building Techniques (MBT) refer to the newer and advanced methodologies that will facilitate sustainable building construction practices (Hussin, Rahman, and Memon, 2013; Li, Fang, and Wu, 2020; Kineber et al., 2022). The following subsections discuss the essence of the use of MBT and the various types most relevant to SBC project delivery.

### 4.3.1 The essence of using modern building techniques.

The need for project performance improvement is a major reason for using modern building methodologies (Mollaoglu-Korkmaz et al., 2013; Olawumi, Chan, Wong and Chan, 2018). The construction industry in the world's developing countries, especially in Africa, still suffers tremendous challenges in their project performance (Ameh and Daniel, 2013; Emere et al., 2019). Prevalent challenges in developing countries include budgetary issues, poor planning and scheduling, imperfect project design, ineffective communication and information sharing,

inability to coordinate and evaluate processes properly, poor quality of work, the collapse of buildings, fatalities and injuries, lack of requisite skills among personnel and poor stakeholder collaboration (Ahsan and Gunawan, 2010; Ali, 2010; Oyewobi and Ogusemi, 2010; Yimam, 2011). These challenges result in project costs and time overruns, poor quality in project delivery, health and safety deficiency, client dissatisfaction with the project outcome and so on. (Ahsan and Gunawan, 2010; Ali, 2010; Oyewobi and Ogusemi, 2010; Yimam, 2011; Ameh and Daniel, 2013; Rwelamila and Purushottam, 2012; Egwuonu, 2015; Emere, 2020).

Conversely, the industry, especially in developing countries, including South Africa, still needs to catch up in embracing innovative approaches that will improve project performance and enhance productivity (Muhammad, Ahmed and Yakasai, 2017; Gurung, 2020). Hussin, Rahman, and Memon (2013) suggest that using advanced methods like Building Information Management Modeling, Lean techniques, Value Engineering (VE), Industrialised Building System (IBS), Sustainable Supply Chain Management (SSCM) etc., can improve sustainable construction project performance. Additionally, Srai and Lorentz (2019) suggest that advanced techniques including big data analytics can improve sustainable construction. However, more needs to be explored on the efficacy of these building techniques on sustainable building construction, especially empirically and quantitatively. Consequently, the current study seeks to fill this gap in the South African construction industry.

### 4.3.2 Modern Building Techniques

#### *4.3.2.1 Building information management (BIM)*

The process of designing, constructing and operating a building while utilising electronic object-oriented information, (i.e building information models) is known as building information management, or BIM (BAMB, 2020). Building information management is recognised as a value-maintaining and creating process during the whole life cycle of a building and its components (UK BIM Task Group, 2013; BAMB, 2020). This is supported by the collection, creation, and sharing of virtual geometric models and the intelligent structured data it enables (UK BIM Task Group, 2013). BIM software should not be confused with building information

management (BIM). BIM software is a set of digital tools used to set up a BIM process and create BIM models (BAMB, 2020). Building Information Management (BIM) models, which incorporate 3D design, analysis, cost estimating, and construction scheduling, are revolutionising how buildings are built and constructed (McArthur, 2015). They can also facilitate multi-disciplinary coordination (McArthur, 2015).

Building Information Management (BIM) has been perceived and defined in various ways by many authors (Sacks et al., 2010; Eastman, Teicholz, Sacks and Liston, 2011; Arayici and Coates, 2012; Azhar, Khalfan and Maqsood, 2012; Succar, 2013; Karen, 2014; Chartered Institute of Builders (CIOB), 2016; Fadason, Danladi and Akut, 2018; Hamma-Adama and Kouider, 2019). In contextual summary, BIM is a process characterised by various software tools for designing, planning, scheduling and managing a construction project from inception to closure. This aligns with Azhar et al. (2012), who described BIM as "an improved process and tool, which contains a set of virtual aspects, concepts, and systems of a facility within one environment". Similarly, Gilkinson, Raju, Kiviniemi, and Chapman (2015:81) describe BIM as "a process of generating the building data, developing a building model with those data and maintaining the model and data throughout its life cycle". They continued to describe it comprehensibly as "a method representing a design as definable objects (be it a solid component or void space) with the provision of all relevant geometry, relations, and attributes (that form a coordinated digital data set to include computable information necessary) to design, build, operate and ultimately decommission a project" (Gikinson et al., 2015:81). Hence, to implement BIM two aspects should be considered. First, is the "use of 3D technology (software) to model and analyse the building model using software tools such as Revit, ArchiCAD, and others, while the other is the process/conceptualisation which enables other knowledge domains such as cost, schedule, project management, safety, sustainability parameters to be embedded in BIM software to provide a one-source central hub of information for project stakeholders" (Olawumi et al., 2018:3).

BIM tools form part of the BIM database and gear the model to work at its total capacity and produce its expectations, thereby aiding the project team in achieving their BIM and project

objectives throughout the project lifecycle (Kekana, Aigbavboa and Thwala, 2015). Consequently, BIM tools can be defined as "systematically designed software that incorporates all aspects of engineering and construction processes virtually to enable efficient planning, design, construction, and management of buildings and infrastructure" (Muhammad et al., 2017:3). It is crucial to understand that no one BIM software does all the functions needed in executing construction projects from inception to closure. Hence, various BIM tools can be helpful for the architectural, engineering and construction (AEC) processes, each having its unique functions while collaborating with other software to achieve the desired project objectives. It is noteworthy that different classes of BIM tools exist, for example, design creating tools, analysis tools, scheduling and construction management tools, quantity take-off tools, Shop drawings and fabrication tools, as well as file sharing and collaboration tools (Yahaya and Muhammad, 2016; Muhammad et al., 2017) all of which when used adequately can result to efficiency and effectiveness of project performance and the actualisation of project success. This aligns with Latiffi et al. (2013), who affirms that BIM is a set of digital tools essential for effectively managing construction projects.

BIM models bring innovation to the traditional approach and change how structures are planned, assembled, and maintained: lessening expenses, sparing time and so on. (Bui, Merschbrock and Munkvold, 2016; Gurung, 2020). Consequently, the use of BIM and its tools has been identified as a major approach to tackling the pursuit of completing construction projects within the predicted time, cost and quality, which has become slippery over the years (Gleason, 2013; Adeyemi, Darcelle, Matthew and Sithembisile, 2016; Bashir, 2018; Ndhlela, 2018); identified for meeting safety objectives (Kymmell, 2008; Sulankivi, Kähkönen, Mäkelä, and Kiviniemi, 2010; Ganah and John, 2017), sustainable project performance (Bynum, Issa and Olbina, 2013; Mollaoglu-Korkmaz et al., 2013) and the enhancement of capability and productivity within the Built Environment (Azhar, 2011; Muhammad, Ahmed and Yakasai, 2017). Additionally, "the use of BIM has yielded several benefits such as effective communication and information sharing, increased design transparency, better decision support, rapid design visualisation and better collaboration among stakeholders" (Muhammad et al., 2017:2). Furthermore, Bynum et al. (2013) posit that BIM models have made it possible to reduce overall project contingencies and

costs by raising project quality, delivering precise quantity take-offs, and improving scheduling. Therefore, all these benefits culminate in attaining the project's desired goal, achieving maximum performance and, in turn, project success.

Developed countries such as the USA, the UK, and some Nordic countries have embraced BIM technology in the architectural, engineering and construction sector (Ullah, Lill and Witt, 2019). In the USA, BIM adoption recorded up to 71% (Kassem, Succar and Dawood, 2013; Hamma-Adama et al., 2017) and showed an adoption rate of 7.33% per year compared to 49% adoption in 2009 (Hill, 2010; Hamma-Adama et al., 2017). In the UK, the awareness and usage of BIM were recorded at 69% in 2019, while those who were aware but were not using was about 29%, and only 2% were neither aware nor using BIM in their construction projects (Statistics UK, 2019). It was also revealed, according to the NBS International BIM report, that the use of BIM in 2016 was about 67%, 78% and 46% for Canada, Denmark, and Japan, respectively, with expected future usage of 85%, 93% and 88% by 2021 (Anifowose, Babarinde and Olanrewaju, 2018). According to Eadie et al. (2013) and Ullah, Lill and Witt (2019), the use of BIM has enabled developed countries to deliver their project on the stipulated time, within the required budget, enhanced productivity, as well as increase the overall quality of the project.

Conversely, developing countries' construction industry has yet to fully embrace BIM adoption (Muhammad et al., 2017; Gurung, 2020). In Nigeria, awareness and knowledge of BIM technology are very scarce (Onungwa, Uduma-Olugu and Igwe, 2017; Hamma-Adama, Kouider and Salman, 2018), and this is mainly connected to a lack of education on the BIM concept and lack of trained staff on the use of BIM tools (Abubakar, Ibrahim and Bala, 2013; Onungwa et al., 2017; Hamma-Adama et al., 2018). Although there is about 40% awareness in Kwara State by Anifowose, Babarinde and Olanrewaju (2018), BIM tools still need to be improved. South Africa was found to be at least five years ahead of Nigeria in BIM adoption and the top-ranked BIM user in Africa (Hamma-Adama et al., 2017). In South Africa, Shakantu and Froise (2014) found that 58% were aware of BIM usage, but its adoption is averaging on 20%. Hence, this indicates that the use of BIM has yet to be appreciated in the developing countries of Africa fully.

Considering the brief discourse on the essence of BIM, the current study identifies BIM as one of the variables that will contribute to sustainable building construction for successful project delivery in South Africa.

#### *4.3.2.2 Lean techniques*

Lean construction is a modern approach to managing construction (Goit, 2016). Together, the goal, tenets, and methods of lean construction serve as the framework for a fresh approach to project delivery. Lean construction lays the groundwork for an operations-based project delivery system, in contrast to conventional project management methods in the construction industry (Goit, 2016). According to Lukowski (2010), lean construction is the practical application of lean thinking, or lean manufacturing principles, to the building environment. Lean thinking offers a method for clearly defining value, minimising unnecessary interference to boost productivity, doing more with fewer resources to align goods with user needs better, and reducing waste while generating value (Carvajal-Arango et al., 2012; Li, Fang and Wu, 2020). Yahya and Mohamad (2011) defined lean construction as aiming to manage and optimise the construction process to profitability and deliver what the customer requires, hence, eliminating waste from the construction flow by applying the appropriate principles, resources, and measures to deliver things correctly the first time. Wasteful actions include not meeting a client's specific needs, taking longer than necessary to complete a task, and leaving inventory unused (Goit, 2016). Lean principles include value specification, value stream identification, flow, pull and perfection (Womack and Jones, 2003; Li et al., 2020).

Moreover, essential elements of lean construction include concurrent design and construction, project control implementation across the project's life cycle from conception to delivery, and a clear set of delivery-process objectives focused on maximising performance for the client at the project level (Aziz and Hafez, 2013). In other words, Lean systems aim to design, produce, and deliver goods and services that meet or exceed customer expectations in terms of cost, quality, time, performance and continuous improvement (Ogunbiyi, Goulding, and Oladapo, 2014). When the concepts are correctly put into practice, projects can experience significant increases in efficiency, quality, and safety (Aziz and Hafez, 2013; Ogunbiyi et al., 2014).

Therefore, lean construction has been identified as one of the strategies for improving sustainable construction (Ogunbiyi et al., 2014). According to Ogunbiyi et al. (2014), the health and safety practice through lean construction can contribute to sustainable construction by improving workers' social life and lessening the direct and indirect cost of accidents. Additionally, eliminating material waste through lean construction has been pinpointed as one of the most efficient and cost-effective strategies for encouraging sustainable practices on building sites (Ogunbiyi et al., 2014). Like this, lean construction concepts emphasise efficient, waste-free, safe material flow, storage, and handling to reduce cost, energy use, and resource consumption and offer value for clients and end users (Nahmens and Ikuma, 2009). Consequently, lean construction is a factor for sustainable construction.

Unfortunately, more needs to be investigated the impact of lean technology on sustainable construction (Nahmens and Ikuma, 2009; Koranda et al., 2012; Ogunbiyi et al., 2014). Hence, the present study considered lean techniques as part of modern building techniques to contribute to sustainable construction.

#### *4.3.2.3 Value Engineering*

Value Engineering, also referred to as value management, has been linked to improving sustainable construction (Mahadik, 2015; Wao, Ries, Flood, and Kibert, 2016; Gunarathne et al., 2022; Kineber et al., 2022). Heralova (2016) defined VE as a technique for problem-solving, eliminating unnecessary expenses, enhancing quality, and reducing life cycle costs. Wao (2015) affirms that VE helps achieve better quality and performance standards. According to Mahadik (2015), value engineering may boost the value created by sustainable construction. Combining value engineering with sustainable building is a strategy that can overcome sustainable construction challenges (Mahadik, 2015).

As the name implies, value engineering/management, which focuses on overall value, seeks to identify, maximise, achieving value for money without necessarily reducing the function and aesthetics of the item (Potts and Ankrah, 2013; Gunarathne et al., 2022). Hence, its philosophy of

efficient use of materials and resources is strongly related to sustainable construction (Al-Yami, and Price, 2006; El-Alfy, 2010).

According to Rachwan, Abotaleb, and Elgazouli (2016), value engineering not only improves quality and cost savings but also positively affects the environment and global green building. According to the article, value engineering integrated with sustainable construction resulted in a 40% cost reduction for the item and a 55% increase in thermal insulation (Rachwan et al., 2016). This aligns with Wao et al. (2016), who recommended value engineering as a potential tool for improving sustainability outcomes due to its focus on performance, quality improvements and cost saving.

However, barriers such as a lack of adequate information on value engineering, time constraints, a lack of direction on sustainability standards, a lack of understanding and awareness of sustainability, and conflicting perceptions toward sustainability have affected the integration of sustainability with value engineering (Abidin and Pasquire 2007; Gunarathne et al., 2022). Nevertheless, a structured value engineering job plan, functional analysis systems techniques and the Delphi method for inventive thinking have been suggested to mitigate some challenges associated with value engineering integration in sustainable construction (Wao et al., 2016; Yu et al., 2018; Gunarathne et al., 2022).

Having discovered value engineering as a variable that can improve sustainable construction, the present study includes it as part of the essential modern building techniques for actualising sustainable building construction in South Africa.

#### *4.3.2.4 Industrialised Building System (IBS)*

This innovative approach to building construction has been affirmed to improve sustainability and green construction (Kamar et al., 2010; Hussin et al., 2013; Shamsuddin, Zakaria, and Mohamed, 2013). An industrialised building system (IBS) can be defined as a construction technique in which components are made in a controlled setting, whether on or off-site, transported, placed, and put together with little further site work (Abdullah et al., 2009; Kamar, lshawi, and Hamid, 2009). It can also be defined as the complete integration of all subsystems

and components into an overall process while adopting industrialised production, transportation, and assembly processes (Uttam et al., 2008; Zabihi, Habib, and Mirsaeedie, 2013). This method makes building construction more efficient, less labour-oriented, quick and meets quality requirements (Shamsuddin et al., 2013). Similarly, Nawi, Lee, and Nor (2011) described IBS as a construction process that used methods, items, or building systems that involved prefabricated parts and on-site installation.

IBS has many benefits across the three primary sustainability parameters (environment, social and economy). For instance, an environmental benefit of IBS is the ability to move construction processes from the site to a much better-controlled factory environment (Gorgolewski, 2005; Yunus and Yang, 2011). In this, the local communities will not be disturbed by the intense activities, air pollution, noise, traffic chaos and the like unlike the conventional building approach (Yunus and Yang, 2011). This aligns with (Yunus and Yang, 2011), who assert that IBS has the potential to promote sustainable deliverables. The authors state that this can be achieved by its ability to control the manufacturing environment better, reduce waste, use energy-efficient building materials, and stabilise work conditions (Yunus and Yang, 2011).

According to Bari et al. (2012), standardising product sizes in a controlled setting aids in reducing waste on factory and construction sites. Additionally, Jaillon et al. (2019) posits that the ability of IBS to minimise waste can be a catalyst for a decrease in natural resource consumption and sustainable construction (Jaillon et al., 2009). Besides, Jaillon et al. (2009) indicated that an IBS deployment typically results in a 52% reduction in waste. Furthermore, IBS can adapt modern and smart building energy systems (mechanical, electrical, fire safety, etc.) that are renowned for their outstanding environmental performance (Jaillon and Poon, 2009; Saleh and Alalouch, 2020). Hence, IBS is regarded as the future of the construction industry (Zhang, Skitmore, and Peng, 2014),

Social-wise, prefabrication in the building industry will significantly impact the labour market (Saleh and Alalouch, 2020). For instance, Automation investments will reduce reliance on low-skilled workers and international labour (El-Abid and Ghazalia, 2015). As prefabrication creates

safer and cleaner building sites, it can also encourage healthier working environments (Saleh and Alalouch, 2020). Additionally, regulating the levels of moisture and volatile organic compounds in an industrial environment, it enhances the health of the building's occupants (Saleh and Alalouch, 2020). Ghaffarianhoseini et al. (2018) further suggest that controlling the quality of a building's components will reduce the likelihood that its residents may experience chronic health problems. Moreover, IBS can help mitigate traffic disruptions in urban areas, reduce on-site construction activities and reduce disturbances associated with construction (Ghaffarianhoseini et al., 2018; Saleh and Alalouch, 2020).

IBS can simultaneously facilitate good collaboration between the participants, who can be located anywhere in the world (Yunus and Yang, 2011). According to Richard (2006), multinational corporations can maintain continuous production by utilising the same techniques, know-how, and experiences, potentially lowering associated costs (Yunus and Yang, 2011). Even though some may believe that the first essential investment is quite significant, once the break-even point is reached, the advantages of industrialisation will grow dramatically with the volume of units produced (Tam et al. 2007; Chen et al. 2010; Yunus and Yang, 2011). According to Jaillon and Poon (2009), implementing IBS methods in a project might result in a 16% overall labour cost reduction and a 15% reduction in overall construction time. Scholars have affirmed that IBS has proved to be a success wherever it has been used. Not only was it effective at hastening housing project construction, but it also raised the standard and affordability of the projects where the IBS was used (Mydin et al., 2014).

Considering the views from the literature, the discussed industrialised building system has been incorporated in this study as one of the variables to facilitate sustainable building construction in the South African construction industry.

#### *4.3.2.5 Sustainable supply chain management (SSCM)*

Sustainable supply chain management is another variable identified to improve sustainable construction (Hussin et al., 2013) and is consequently relevant in the building sector. To understand sustainable supply chain management, it is vital first to understand supply chain and

supply chain management. According to Misra, Khan, and Singh (2010), a supply chain is a network of suppliers, factories, distribution hubs, warehouses, and retailers that allows for the acquisition, transformation, production, and delivery of raw materials to the client. They further state that the supply chain comprises all the processes involved in moving and transforming items from the raw material stage to the final consumer, including the information flows related to those processes (Misra et al., 2010). On the other side, supply chain management (SCM) involves integrating all these activities/processes through strengthened supply chain relationships/linkages to gain a sustainable competitive advantage (Vollmann et al., 2005; Misra et al., 2010).

Consequently, Carter and Rogers (2008), defined sustainable supply chain management (SSCM) as the "strategic, transparent integration and achievement of an organisation's environmental, social, and economic goals in the systemic coordination of key inter-organisational business processes for improving the long-term economic performance of the specific company and its supply chains" (Carte and Rogers, 2008:368). It was also defined as "the creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organisational business systems designed to efficiently and effectively manage the material, information, and capital flow associated with the procurement, production, and distribution of products or services to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organisation over the short and long-term." (Ahi and Searcy, 2013:339). The definitions suggest that sustainable supply chain management is a plus to the management of the supply chain. Therefore, considering the economic, social and environmental parameters of sustainability, organisations that make up the supply chain and their managers will make decisions that promote the integration and coordination of SSCM practices throughout the supply chain (Green, Zelbst, Meacham and Bhadauria, 2012).

#### *4.3.2.6 Big data analytics*

This is the process of analysing massive and diverse data sets to find hidden patterns, undiscovered correlations, market trends, customer preferences, and other valuable information

that can help organisations make better business decisions (TechTarget, 2012; Abell et al., 2017; Ren et al., 2019), increase sustainability, and move society toward the circular economy (Soroka et al., 2017; Ren et al., 2019). According to Chou, Ngo, Chong, and Gibson (2016), the true value of big data is obtained through big data analytics, a group of advanced technologies used to handle vast amounts of data. A component of big data analytics called "predictive analytics" allows customers to see trends and provides methods for getting value out of massive data (Chou et al., 2016). Besides, due to its potential to give useful patterns and knowledge to raise business intelligence, explore future markets, and promote operational efficiency, applications of big data analytics have drawn interest from both industry and academia (Zhong et al., 2016; Lamba and Singh, 2017; Ren et al., 2019). Hence, the construction industry would have benefited.

According to Veras, Suresh, and Renukappa (2018), although the relationship between big data and sustainability is still developing, there are already several applications that can be mentioned for the environment, health, and construction, including monitoring biodiversity loss, identifying pollution hotspots, finding endangered species, and managing smart energy for cost or investment saving purposes. Big data analytics, therefore, has been linked to improving sustaining construction (Srai and Lorentz, 2019) and is relevant to the current study.

## 4.4 Chapter Conclusion

This chapter discussed in detail the gaps identified from the literature review which are among the critical factors relevant to improving sustainable building construction (SBC). The discussed gaps included project delivery strategies, project management techniques, and modern building techniques. These gaps represent three new constructs conceptualised and are included in the current framework of the study.

Project delivery strategies included various delivery methods and procurement methods, and contract formats relevant to the current study. Project management techniques included the techniques relevant to scope management, integration management, procurement management, time management, cost management, quality management, risk management, stakeholder

management, and so on. The modern building techniques discussed, included lean technology, building information management, value engineering, sustainable supply chain management, industrialised building systems, big data analysis and the like.

The next chapter will review sustainable building construction in developing countries, Nigeria and Ghana.

# CHAPTER FIVE

# SUSTAINABLE BUILDING CONSTRUCTION IN DEVELOPING COUNTRIES: AFRICAN EXPERIENCE

## 5. 0 Introduction

This chapter discusses sustainable building construction (SBC) in developing nations, particularly Africa, such as Nigeria and Ghana who have written extensively on the need for SBC. It presents an overview of each nation's construction industry, the state of sustainable building construction, regulations and policies instituted, and challenges. Furthermore, it concludes with the lessons learnt.

## 5.1 Nigeria

### 5.1.1 Nigerian construction industry overview

Nigeria's economy greatly benefits from the construction sector. It provides roughly 5% of the GDP, accounts for one-third of all fixed capital investments made in Nigeria and employs about 8% of the workforce (Dada and Akpadiaha, 2012; Akadiri, 2015). Unfortunately, despite Nigeria being the most populous country in Africa, the contribution of buildings to its growth has yet to produce the intended results (Akadiri, 2015; Davies and Davies, 2017). This results from unsuccessful projects and poor performance (Davies and Davies, 2017). The industry has been maligned by building collapses, ongoing delays, abandonment, cost overruns etc. (Nwachukuwu et al., 2010; Windapo and Rotimi, 2012).

On the other hand, the industry is familiar with project management. Project activities have been made easier using trading and new project management tools and techniques (Olateju et al., 2011; Ogunde et al., 2017). However, the usage has not been maximised, resulting from a lack of project management skills among many project participants (Egwuonu, 2015; Emere, 2020). Hence, the industry's transition from the standard traditional procurement system

to the project management delivery system has not produced the desired outcome (Ogunde et al., 2017). Public and private building construction projects virtually never meet deadlines or requirements for cost, quality, and materials (Akadiri, 2015), indicating a need for a more efficient and holistic method of building.

Similar problems are being faced by urban residents and the government in Nigeria due to the necessity and significance of housing to accommodate the country's rapidly growing urban population (Taiwo and Adeboye, 2013). To address the housing needs of the rapidly expanding population, the government and the private sector are searching locally for alternate sources of building materials due to the high cost of conventional building materials in Nigeria (Taiwo and Adeboye, 2013). Furthermore, the operations of the Nigerian construction sector harm the environment and natural resources, indicating the necessity of sustainable building construction (Umar, Lembi and Emechebe, 2021).

### 5.1.2 Sustainable building construction in Nigeria

Otegbulu (2011) criticises the Nigerian designers' and contractors' failure to consider environmental concerns, sustainability, and green design when designing new buildings or remodelling old ones. For instance, when the energy from the main grid fails, or electricity generators experience operational issues, the entire working environment becomes uncomfortable in some buildings in Lagos that lack natural ventilation and illumination (Otegbulu, 2011; Nduka and Sotunbo, 2014). Otegbulu’s findings also revealed that institutional, residential, and commercial buildings have deficiencies in user satisfaction, functional space layout, and service type (Otegbulu, 2011; Nduka and Sotunbo, 2014).

#### *5.1.2.1 Building performance assessment tool*

Nigeria must adapt performance standards, methods, codes, and regulatory tools to reduce, prevent, and improve the Built Environment (Adegbile, 2013; Nduka and Sotunbo, 2014). The Federal Government passed laws to protect the environment in Nigeria (Nwokoro and Onukwube, 2011). Laws, including the Environmental Impact Assessment Act of 1992 (EIA Act), the National Policy on Environment (NPE) of 1989, and the Federal Environmental

Protection Agency Act of 1988 (FEPA) (Nwokoro and Onukwube, 2011; Nduka and Ogunsanmi, 2015; Amasuomo, Atanda, and Baird, 2017). In order to advance toward the sustainable building, Nigeria also formed the Green Building Council of Nigeria (GBCN), which is at the level of potential membership with the World Green Building Council (Shaba and Noir, 2014; Amasuomo et al., 2017). However, the council has not yet produced a nationwide green/sustainable building assessment rating tool for office, retail, multi-unit residential, public, and educational building developments in Nigeria, (Amasuomo, Atanda and Baird, 2017).

According to reports, the Green Building Council of South Africa (GBCSA) is open to allowing GBCN to use the Green Star SA rating system until it can create, establish, and run its rating system (Shaba and Noir, 2014; Nduka and Sotunbo, 2014; Nduka and Ogunsanmi, 2015). However, only LEED-certified structures have been identified in Nigeria (Amasuomo et al., 2017). This is consistent with a study by Adegbile (213) that contends LEED is Nigeria's best foreign building performance assessment technique. The results showed that LEED, which scored the best with 80 out of 100 points, assists customers in determining environmental performance because of its solid foundation, significant investments, and proven benefits. Few LEED-certified buildings in Nigeria are enlisted in Amasuomo et al. (2017). They include, " the Heritage Place in Ikoyi, Lagos for (LEED BD+C Core and Shell v3-LEED 2009); The NOX building in Abuja a Gold rated building for (LEED BD+ C: New Construction v3-LEED 2009); P&G Nigeria MDO Warehouse rated Silver building for (LEED BD+ C: New Construction v3-LEED 2009); RFA HSClassroom North in Abuja for (LEED BD+C: School v3 – LEED 2009); RFA HS- Classroom South in Abuja for (LEED BD+C: School v3 – LEED 2009); AfDB Nigeria Field Office in Abuja for (LEED BD+ C: New Construction v3-LEED 2009), No 4 Bourdilon Street in Lagos for (LEED BD+ C: New Construction v3-LEED 2009); and Asdads Building for (LEED BD+ C: New Construction v3-LEED 2009)" (Amasuomo et al., 2017:225).

Noteworthy are the initiatives to create a rating system appropriate for Nigeria (Adegbile, 2013; Amasuomo et al., 2017). Adegbile (2013) recommended LEED; however, Amasuomo et al. (2017) recommended a different approach. In their paper "Development of a building performance evaluation and design tool for residential buildings in Nigeria," Amasuomo et al.

(2017) suggested a model that may be used to measure building performance. The system is Nigeria's Comprehensive Performance Assessment System (CPASN). The suggested model incorporated several sustainable criteria, including those related to the environment, society, and economy, as well as to land use, building forms, and transportation facilities. Figure 5.1 shows the model. However, GBCN has yet to adopt any of the proposed models, nor has it developed any.

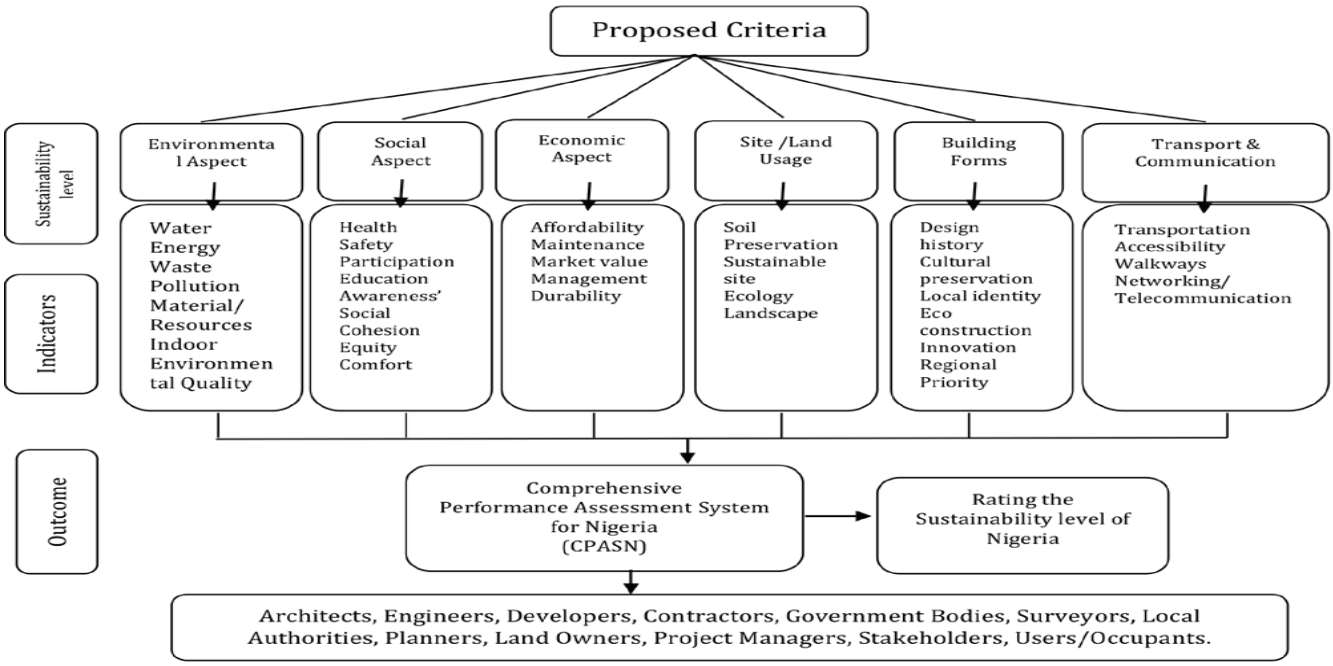


**Figure 5. 1**: Proposed building performance assessment tool for Nigeria (Amasuomo et al., 2017)

### *5.1.2.2 Usage of sustainable building materials in Nigeria*

Given the significant influence of the construction industry, adopting sustainable materials is the easiest way for building experts to begin implementing sustainable concepts in construction projects (Akadiri and Olomolaiye, 2012; Akadiri, 2015). In addition, Nigeria's government and private sector are searching locally for alternate sources of building materials to satisfy the needs of the country's expanding population. This is due to the country's high cost of conventional

building materials (Taiwo and Adeboye, 2013). According to Taiwo and Adeboye (2013), employing earth blocks, an indigenous material for construction, and composite building materials will help Nigeria's housing deficit and satisfy the needs of both rural and urban residents.

Similarly, earth-based bricks were suggested by Obianyo et al. (2021) as an additional sustainable and environmentally friendly building material in Nigeria. Ojo et al. (2021) also recommended it as a sustainable alternative. Industrial wastes, agro-waste ash, natural fibres, quarry dust, and bamboo are some of the other sustainable and environmentally friendly building materials (SEBMs) that are readily available (Safiuddin et al., 2010; Madurwar et al., 2013; Mustapha et al., 2016; Onyelowe and Obianyo, 2021; Stanislas et al., 2021; Obianyo et al., 2021).

Furthermore, Umar et al. (2021) claimed that everyone's definition of sustainability differs. They argued that while no material is completely sustainable, some are more so than others. As a result, their study included elements such as bamboo, cork, recycled wood and metals, pre-cast concrete, and sheep wool insulation (Pyzyk, 2018; Umar et al., 2021).

#### *5.1.2.3 Challenges to the adoption of sustainable building construction in Nigeria*

According to reports, Nigerians are not environmentally sensitive regarding building design and environmental management (Nduka and Ogunsanmi, 2015; Daniel et al., 2018). This is due to a lack of understanding and awareness regarding the construction methods and materials used in sustainable buildings (Aghimien et al., 2021). Also, there is a lack of education and training for construction professions (Toriola-Coker et al., 2021), Lack of expertise and low levels of sustainability among practitioners worsen the situation. (Daniel et al., 2018), Cost implications (Aghimien et al., 2018), Perceived high cost of sustainable options/implementing sustainable practices (Osuizugbo et al., 2021; Aghimien et al., 2021), Also, ignorance of lifecycle cost benefits (Toriola-Coker et al., 2021), inadequate scheduling of task and process phases (Daniel et al., 2018), reluctance to shift from the conventional methods (Daniel et al., 2018; Aghimien et al., 2021), lack of demand for sustainable building/products (Daniel et al., 2018; Osuizugbo et

al., 2020), lack of client's/stakeholders' interest (Aghimien et al., 2021), cultural change resistance (Toriola-Coker et al., 2021), lack of consideration for sustainability in design and short-term benefit culture (Daniel et al., 2018), lack of or insufficient legislation/regulation and policies (Aghimien et al., 2018; Daniel et al., 2018; Osuizugbo et al., 2020), lack of incentives/government support (Osuizugbo et al., 2020; Toriola-Coker et al., 2021) etc. Other critical hindrances to sustainable building construction in Nigeria are listed in Section 2.6 (Table 6).

### 5.1.3 Lesson learnt

Nigeria's construction industry is fraught with many project management challenges. There is a need to maximise the use of project management techniques and the adoption of the latest technological developments and modern building techniques. There is also the need to educate the public and construction participants to appreciate the importance of sustainable building construction on the environment, economy and society. Similarly, there is a great need for the Green Building Council of Nigeria (GBCN) to establish a sustainable building assessment tool for Nigeria. GBCN is not yet a bona fide member of the World Green Building Council; hence, more needs to be done to change the prospective member status. Moreover, there should be incentives from the government to encourage construction organisations to go green. Generally, the principles of sustainable building construction discussed in *section 2.2* should be adequately implemented to move the country and industry forward.

## 5.2 Ghana

### 5.2.1 Ghana construction industry overview

The building sector facilitates the development of Ghana's socioeconomic system (Ahiabu, Emuze and Das, 2022). The construction market in Ghana is comparable to the one in the UK in 1983, claims Osei (2013). The sector generates up to 11.8% of Ghana's GDP and employs between 3% to 10% of the workforce (Ghana Statistical Service (GSS), 2014; Anzagira, Badu, and Duah, 2019). Ghana's industry has reportedly contributed more to the GDP growth than

other sectors of the economy, including manufacturing (African Development Bank Group (AfDB Group), 2013; Anzagira et al., 2019).

According to Akinradewo et al. (2019), there are four basic categories of industry stakeholders: users and customers, demand-side operators, regulators, and supply-side operators. The extraction and processing of raw materials, the production of building supplies and parts, the cycle of a construction project from feasibility to deconstruction, and the management and operation of the constructed environment are all included in construction activities (Akinradewo et al., 2019; Ahiabu et al., 2022). The Ghanaian construction sector's activities are predominant in the capital city of Accra, resulting in many residential and commercial office buildings (Anzagira et al., 2019). However, there is still a great demand for housing in Ghana, and the country is challenged by housing deficits estimated to have reached 2 million units in 2020 (Ilamura, 2013). Additionally, the Ghana construction industry is fraught with project management challenges, improper planning, cost and schedule overruns, low product quality, low working efficiency (Asamoah and Decardi-Nelson, 2014; Ankomah, Ayarkwa and Agyekum, 2017) as well as unprofessional practices, and lack of sustainability standards (Anzagira et al., 2019).

Furthermore, the existence of unsustainable designs and poor construction methods and processes have caused deleterious effects on the climate, environment, and national economies (Zhang et al., 2011; Dzokoto et al., 2014; Ahiabu et al., 2022). The Built Environment of Ghana is to blame for habitat loss, air and water pollution, land degradation and high energy use (Ofori, 2012; Djokoto et al., 2014). This indicates the pressing need for environmentally friendly building practices. Hence, implementing sustainable building construction techniques can aid in reducing these adverse effects.

### 5.2.2 Sustainable building construction in Ghana

Environmental deterioration due to construction activities continues, as do unsustainable design and construction methods (Ayarkwa et al., 2017; Ahiabu et al., 2022). However, Ghanaian construction stakeholders know how harmful traditional construction methods can be (Ayarkwa

et al., 2017). As a result, clients, sponsors, construction experts, government organisations, and regulatory bodies are becoming more interested in sustainable construction methods (Ogungbile and Oke, 2019). Nevertheless, adopting sustainable building practices is still in an infancy stage (Ahiabu et al., 2022). Even though many buildings are built yearly, relatively few can be classified as green buildings (Ampratwum, Agyekum, Adinyira, and Duah, 2021).

#### *5.2.2.1 Building performance assessment tool*

In stark contrast to this deliberate practice by the developed world, where laws and Acts have been passed to promote the uptake of the GBC, many developing countries in Sub-Saharan Africa, including Ghana, have little to no such legislation, making the decision to adopt the concept up to the various industry practitioners and stakeholders (Anzagira et al., 2019). The body responsible for spreading awareness and providing the enabling environment for the development and execution of sustainable building construction initiatives is the Ghana Green Building Council (GhGBC) (Anzagira et al., 2019). It is a non-governmental organisation formed in 2009 and launched in 2011 (Anzagira et al., 2019). It is currently a prospective member of the World Green Building Council (WGBC) (GhGBC, 2023).

The GhGBC has a certification system called the Green Star SA-Ghana adapted from the Green Star South Africa Building rating system (Ampratwum et al., 2021; GhGBC, 2023). The choice was made based on ease of use, ease of customisation to Ghana and because of the logical transition from the existing tool to its own tool (Osae-Akonnor 2014; Ampratwum et al., 2021). Also, because Green Star South Africa was a branch of Green Star Australia, Australia has considerable authority over the certification tool (Ampratwum et al., 2021). For instance, one Airport Square in Accra, the first green building recognised in Ghana in 2009, was certified with authorisation from the Green Building Council of Australia to allow that Green Building South Africa approve the Green Star SA-Ghana certification (Ampratwum et al., 2021). Also, LEED has been used to certify some buildings in Accra; for instance, the United Nations Building underwent LEED certification (Ampratwum et al., 2021). Although attempts are being made to certify most of the new buildings in Ghana, research shows that green building is not widely used (Bangdome-Dery and Kootin-Sanwu, 2013; Ampratwum et al., 2021).

#### *5.2.2.2 Challenges of sustainable building construction in Ghana*

As reports have affirmed that green and sustainable building establishment in Ghana is still in the infancy stage, there are critical challenges that are stampeding the progress of sustainable building establishment in Ghana. They include: lack of knowledge and awareness of the sustainability principles among clients, organisations and the public (Opoku et al., 2019), Lack of professional knowledge and capabilities (Ametepey et al., 2015; Ahiabu et al., 2022), technological and technical difficulties (Ametepey et al., 2015; Ahiabu et al., 2022), financial/economic barriers (Ametepey et al., 2015), fear of perceived high initial cost (Ametepey et al., 2015), reluctance to shift from the conventional methods (Opoku et al., 2019), lack of demand for sustainable building/product (Djokoto et al., 2014), cultural change resistance and socio-cultural barriers (Ametepey et al., 2015), lack of commitment among participants (Ametepey et al., 2015), Lack of or insufficient legislation and policies to compel participation (Ametepey et al., 2015), lack of promotion by government (Djokoto et al., 2014; Ametepey et al., 2015), political barriers (Ametepey et al., 2015; Ahiabu et al., 2022), leadership barriers (Ametepey et al., 2015), and environmental conditions difference between developed and developing countries (Ofori, 2019; Opoku et al., 2019). Other critical hindrances to sustainable building construction in Ghana are enlisted in Section 2.6 (Table 6).

### 5.2.3 Lesson learnt

The Ghanaian construction industry is fraught with many project management challenges similar to that of Nigeria. The practice of sustainable building construction is not frequently done. There is a need for the adoption of technological developments and modern building techniques. There is also the need to educate the public and construction participants to appreciate the importance of sustainable building construction on the environment, economy, and society. Similarly, the government must do more to encourage participation through incentives and perhaps compulsory legislation. The Ghanian Green Building Council is currently a prospective member of the World Green Building Council. Hence, more needs to be done to become a bona fide member. This suggests that the principles of sustainable building construction discussed in chapter two *section 2.2* should be adequately implemented to move the country and industry forward.

## 5.3 Chapter Conclusion

This chapter reviewed the sustainable building construction practice in some developing countries, namely Nigeria and Ghana. Also, an overview of the countries' construction industry was reviewed while indicating the contributions to the economy and the environmental impact. Further, the current legislation and initiatives in the countries regarding implementing sustainable building construction were discussed. Finally, the critical hindrances towards building sustainably were highlighted, and the lessons learnt were captured. The next chapter will review sustainable building construction in South Africa, which is the primary country of study.

# CHAPTER SIX

# SUSTAINABLE BUILDING CONSTRUCTION PRACTICES IN SOUTH AFRICAN

## 6.0 Introduction

This chapter discusses the South African construction industry, on which the current study is centred. The discourse, therefore, includes an overview of the South African construction industry, its significance and contribution to the economy, its project delivery, and its challenges. Additionally, the discourse includes the state of sustainable building construction, policies and regulations that shape sustainable building construction in South Africa, the adoption of green features, modern building techniques and essence. Finally, the discourse incorporates the challenges encountered in implementing sustainable building construction in South Africa.

## 6.1 The South African Construction Industry Overview

### 6.1.1 Significance of the South African construction industry

The construction industry significantly contributes to the economic expansion of South Africa (Windapo and Cattell, 2013; Pillay and Mafini, 2017; Statistics South Africa, 2019). The industry contributes by planning, designing, constructing, maintaining, and demolishing unfit buildings and works (Ogunsanya, 2018). It is also not an isolated industry as it is interconnected and interdependent by sourcing its inputs and outputs from various economic sectors in complex ways (Sibiya, Aigbavboa and Thwala, 2015; Ogunsanya, 2018). Besides, the construction sector contributes roughly 4% of the country's GDP, accounting for nearly 50% of the national capital (CIDB, 2016; Tengan, 2018; Statistics South Africa, 2019). Similarly, it employs approximately 8% of the national labour force and is a significant contributor to job creation (Statistics South Africa, 2014; Pillay and Mafini, 2017; Statistics South Africa, 2019). The public and private sectors contribute to the construction industry’s expansion.

The public sector, which is the government, is the most significant contributor. For example, 2010 FIFA World Cup in South Africa, the government spent about 5 billion dollars (Schilling, 2018). Similarly, the government budgeted R813.1 billion in 2015 for significant transportation, water, and energy infrastructure projects (Nene, 2015; Tengan, 2018). Also, the government plans to invest more capital into construction by the end of 2023 through the mud-school building replacement project and the Human Settlements Vision 2030 (Tengan, 2018; NGOconnectSA, 2022).

### 6.1.2 Project delivery in South Africa

The delivery methods used for construction projects in South Africa include traditional (design-bid-build), design and build, construction management (manager at risk), management contracting, turnkey, integrated project delivery and the like. These methods are clearly explained in *Chapter 4 (subsection 4.1.3)*. Also, various procurement strategies are used, as discussed in subsection 4.1.4, including targeted procurement, public-private partnerships, two-stage open book. Similarly, various contract formats used in the South African construction industry are not different from other countries, which include lump-sum or fixed-price contracts, cost-reimbursable and cost-plus contracts, guaranteed maximum price contracts, unit price contracts and target price contracts (Puddicombe, 2009; Hashem et al., 2018). These contract formats are extensively discussed in *Chapter 4*, *subsection 4.1.5.*

Different tender options for obtaining contracts for projects, primarily through the traditional delivery system, include open tendering, selective tendering, and negotiated tendering (Mathonsi and Thwala, 2012). In *open tendering*, every contractor can submit a tender for the work. A public advertisement is usually placed through the client or the representatives (consultants) to inform potential tenderers, and cash deposits are usually required upon requesting a contract document (Mathonsi and Thwala, 2012). In *selective tendering*, contractors are shortlisted based on qualifications, technical competence and resource capacity and asked to tender (Mathonsi and Thwala, 2012). In *negotiated tendering*, the client selects one contractor to tender (Mathonsi and Thwala, 2012).

According to Ogunsanya (2018), construction procurement is not limited to engineering and construction works contracts but comprises supply contracts that include acquiring materials and equipment to be utilised. It also includes service contracts for professional services rendered, including demolitions and disposal of surplus materials (Ogunsanya, 2018).

#### *6.1.2.1 Construction industry development board (CIDB)*

CIDB is a "schedule 3A public entity, which promotes a regulatory and developmental framework that builds construction industry delivery capability for South Africa's social and economic growth and a proudly South African construction industry that delivers to globally competitive standards" (CIDB, 2023: online). It focuses on: "Sustainable growth, capacity development and empowerment; Improved industry performance and best practice; A transformed industry underpinned by consistent and ethical procurement practices; Enhanced value to clients and society" (CIDB, 2023: online). The CIDB is established by an Act of Parliament (Act 38 of 2000) (CIDB, 2023).

Generally, before companies are allowed to tender, especially in the public sector, they must have registered with the Construction Industry Development Board (CIDB) and obtained the required CIDB grading to carry out the works. According to the construction industry development regulations (2004), public sector clients are bound to only award contracts to CIDB-registered contractors (CIDB, 2023). Hence, registered contractors are indebted to the CIDB Act (38 of 2000), which demands that they add value in creating and maintaining fixed assets within the Built Environment (Ogunsanya, 2018). The CIDB grading ranges from 1 to 9. "There are no qualifying criteria for grade 1; however, contractors must meet financial and track record criteria for grades 2 to 9" (CIDB, 2023: online). Usually, companies with gradings 2 are micro companies, grades 3 to 7 are small and medium enterprises, and those above 7 are large contractors (Emere et al., 2019; Emere, 2020). According to CIDB (2023), the tender values range includes less than or equal to R1m (Grade 2), R3m (Grade 3), R6m (Grade 4), R10m (Grade 5), R20m (Grade 6), R60m (Grade 7), R200m (Grade 8), and No limit (Grade 9).

#### *6.1.2.2 Challenges of project delivery in South Africa*

The construction industry in South Africa, like other developing countries, suffers from project delivery challenges in performance and procurement (Emere et al., 2019). Poor performance is due to low levels of productivity, poor project management, technological challenges, high cost and time overruns, undue wastage, not adopting best practices, inefficient techniques, inadequate implementation of policies and regulatory frameworks, inexperienced and unskilled labour and the like. (Selleh, 2009; Windapo and Cattell, 2013; Windapo, 2016; Ogunsanya, 2018; Emere et al., 2019). Also, it was discovered that budgeting concerns among contractors were a factor in the liquidation of nearly 40% of construction SMEs at the beginning of 2011 (CIDB, 2011; Emere et al., 2019). Similarly, roughly 75% of SMEs in South Africa experience project failure (South Africa, 2010; Monks, 2010). Moreover, CIDB informed that due to subpar labour and materials, 5 out of 10 structures degrade a few months after construction in South Africa (CIDB, 2011; Emere et al., 2019).

Procurement problems include limited resources, high labour and building material prices, difficulty attracting and developing a competent local labour force, failure to provide fully integrated solutions and trouble sourcing timely and required funding, usage of procurement systems that are price and preference-centred above quality/functionality, corruption, rigging of tenders, overreliance on foreign firms and donor funding, inadequate information for selecting the required qualified professionals and contractors that will meet the quality specifications, lack of green procurement etc. (Construction industry master plan (CIMP), 2008; Windapo and Cattell, 2013; Khumalo, Mashiane, and Roberts, 2014; Ogunsanya, 2018). These challenges culminate in poor profitability and unsustainable business growth, which, when properly addressed, will skyrocket the construction industry's contribution to the South African economy (Emere et al., 2019).

Therefore, considering the challenges suggest that adequate implementation of formally recognised project management techniques and the adoption of modern building techniques will tremendously improve project performance in South Africa.

### 6.1.3 Policy Document Relating to Procurement and Delivery in South Africa

#### *6.1.3.1 Standard for a construction procurement system*

This standard establishes a construction procurement system that an institution may use to fulfil its obligations in the procurement of goods, services and engineering and construction works within the construction industry in accordance with requirements outlined in the Republic of South Africa's 1996 constitution (Act No 108 of 1996), Public Finance Management Act of 1999 (Act 1 of 1999), Construction Industry Development Board (Act 38 of 2000) and other pertinent Acts ((National Treasury, 2012). It also establishes an auditable system that adheres to both national and international best practices (National Treasury, 2012). However, the standard does not apply to: "the storage of goods and equipment following their delivery to an institution which is stored and issued to contractors or to officials; the procurement of non-construction industry-related goods and services or land, except as provided for in the document; the sale, exchange, donation or letting of land; public-private partnerships contemplated in Regulation 16 of the Treasury Regulations for Departments, Trading Entities, Constitutional Institutions and Public Entities issued in terms of the Public Finance Management Act, 1999; the conclusion of any form of land availability agreement; and leasing and rental of assets" (National Treasury, 2012:1)

#### *6.1.3.2 Standard for infrastructure procurement and delivery management (SIPDM)*

This standard covers the supply chain management system for infrastructure delivery. The framework for the procurement system has been based on the five key areas suggested by the National Planning Commission, and it incorporates the findings of the 2015 Public Sector Supply Chain Management Review (National Treasure, 2016). "It is issued as an instruction in terms of Section 76(4)(c) of the Public Finance Management Act of 1999 (Act No.1 of 1999) and is applicable to the following organs of state: a national or provincial department as defined in the Public Finance Management Act; a constitutional institution entity as listed in Schedule 1 of the Public Finance Management Act; a public entity as listed in schedules 2 and 3 of the Public Finance Management Act of 1999; and any organ of state which implements infrastructure delivery projects on behalf of another organ of state" (National treasure, 2016:iii). This standard

also forms an integral part of the Model SCM Policy for Infrastructure Delivery Management. This standard is based on the idea that value for money and high-quality service delivery can be achieved through the efficient and effective operation of the supply chain management system for the acquisition and delivery of infrastructure (National Treasure, 2016).

#### *6.1.3.3 Model supply chain management (SCM) policy for infrastructure procurement and delivery management*

This is "a treasury guideline determining a standard for municipal supply chain management policies in terms of Section 168 of the Municipal Finance Management Act of 2003 (Act No.56 of 2003) in support of Regulation 3(2) of the Supply Chain Management Regulations" (National Treasury, 2016: iii). This document provides a control framework for planning, designing and implementing infrastructure projects and infrastructure procurement (National Treasury, 2015; King Sabata Dalindyebo Municipality (KSDM), 2020). It also provides and establishes requirements for matters as applied to the supply chain management system, such as institutional arrangements, demand management, acquisition management, contract management, logistics management, disposal management, reporting of supply chain management performance, and risk management and internal control (National Treasury, 2015; KSDM, 2020). Similarly, the policy provides the minimum requirements for infrastructure procurement and governs infrastructure procurement that concerns the provision of new infrastructure, or the rehabilitation refurbishment or alteration of existing infrastructure (KSDM, 2020). Furthermore, it covers a broad and varied range of goods and services that are necessary to provide for or modify the condition of immovable assets on site (KSDM, 2020).

### 6.1.4 The South African National Infrastructure Plan 2050

This is an initiative by the public sector to utilise infrastructure delivery as one of the tools to ensure South Africa's transition from a historically closed minerals economy to one that is globally and regionally integrated, low carbon, inclusive and promoting dynamism in the industries of the future (Government Gazette, 2022). The National Infrastructure Plan 2050 (NIP

2050) aims to lay the groundwork for the actualisation of the national development plan's vision of inclusive growth. It is categorised into phase 1 and phase 2.

#### *6.1.4.1 NIP 2050 phase 1*

This phase focuses on four vital network sectors that serve as a platform - energy, water, digital infrastructure, and freight transport (Government Gazette, 2022).

Energy: It was projected that by 2050, energy demand would double (Government Gazette, 2022). Therefore, the aim is to supply energy that will enable economic growth and development. The energy mix will be bolder on sustainability and in achieving the least cost (Government Gazette, 2022). This will require reduced reliance on coal and growing reliance on renewable energy, especially solar and wind, which play a dominant role as part of a least-cost energy mix and where South Africa has a significant advantage (Government Gazette, 2022).

Water: The government plans to provide everyone with consistent, dependable access to sufficient amounts and quality water to promote both a robust, inclusive economy and a safe environment (Government Gazette, 2022). By NIP 2050, this can be accomplished in several ways, such as through evidence-based, proactive, robust, and responsive water resource planning; coherent water sector policy and support for municipal implementation; maintenance and rehabilitation of current water infrastructure; and increased water use efficiency (Government Gazette, 2022). (Government Gazette, 2022).

Digital communications: According to the NIP 2050, "government services and buildings will be digitally enabled, partnerships will be strong, and there should be centres of digital excellence promoting a growing knowledge base of delivery and innovation, the information and communications technology (ICT) skills base will be broad, robust and ready for the future, and high-speed broadband will be universally accessible, regulation will enable competitive and universally accessible broadband, and private sector participation in achieving universal broadband access will be prevalent" (Government Gazette, 2022:7-8).

Freight transport: This will make it easier for goods to move both domestically and internationally, promoting trade, industrialisation, and diversification. It will fulfil its three responsibilities of promoting industrial and economic advancement, facilitating rural development, and guaranteeing that environmental goals pertaining to the decrease of emissions, traffic, accidents, and waste are satisfied (Government Gazette, 2022:6).

The NIP 2050, in general, provides guidance on topics shared by the four sectors, placing a special emphasis on building capacity. For instance, regarding knowledge and innovation services, it seeks to develop capability in planning, monitoring, budgeting, finance, procurement, project preparation, project management and sector-specific innovation (Government Gazette, 2022). This makes it possible to make decisions based on facts, increases cost-effectiveness, reduces risk, and helps to optimise infrastructure quality, delivery, and sustainability (Government Gazette, 2022). NIP 2050 also seeks to build capacity in public infrastructure delivery by encouraging public-private collaboration and competition stimulation where appropriate (Government Gazette, 2022). Similarly, it seeks to enhance executive management and technical capability within the state and its entities, so that they can lead and deliver with confidence and be stable (Government Gazette, 2022). Besides, it encourages compliance with the National Spatial Development Framework (NSDF), innovative green finance combined with project finance, and efficient modes of delivery (Government Gazette, 2022). Furthermore, it aims to foster economic regulation, industrial development and localisation in implementation strategy and design, and promotes a safe, secure and ethical environment for public infrastructure delivery (Government Gazette, 2022).

#### *6.1.4.2 NIP 2050 phase 2*

This Phase centres on distributed infrastructure. It is divided into two sections. The first section provides insight into infrastructure areas, namely human settlements; municipal electricity, water and sanitation, and solid waste; passenger transport; road infrastructure; education infrastructure; and health infrastructure (Government Gazette, 2022). The other section focuses on digital infrastructure, crime and corruption, and governance of distributed infrastructure delivery (Government Gazette, 2022). To this end, the NIP 2050 provides guidance in strengthening and

augmenting the government's Strategic Integrated Projects (SIPs) that are relevant to the sectors (Government Gazette, 2022).

## 6.2 Sustainable Building Construction in South Africa

The construction industry activities in South Africa are not without an effect on the environment and natural resources. There is pressure to deliver green buildings in South Africa, considering the challenges such as climate change, the energy crisis, and ongoing water shortages (Simpeh and Smallwood, 2018). Building construction at least leads to 23% of greenhouse gas (GHG) emissions, while emissions from its material production account for 18 mtCO2 annually, accounting for about 4% of the total CO2 emissions (CIDB, 2009; Simpeh and Smallwood, 2020). Similarly, according to the Department of Science and Technology (DST) (2014), about 23% of the electricity in South Africa is consumed in buildings, while an additional 5% is used to manufacture construction products. Building construction operation also contributes to waste generation and landfill disposal (Aboginije, Aigbavboa, Thwala, and Samuel, 2020). Solid waste production is estimated to be 42 million cubic meters yearly in South Africa, with most of this waste produced in Gauteng province (Simelane and Mohee, 2012; Nkosi and Muzenda, 2013; Aboginije et al., 2020).

Although there is a great need to adopt sustainable building construction in South Africa, it has not received sufficient attention in practice compared to developed countries like USA, UK, Singapore, Australia among others. (Simpeh and Smallwood, 2020). Arguably the South African construction industry is still slow in adopting green and sustainable building principles (Simpeh and Smallwood, 2020). Also, adoption is still in the infancy stage among property developers and clients compared to developed countries (Masia, Kajimo-Shakantu, and Opawole, 2020). Nevertheless, there has been an improvement in awareness creation and the embrace of green building guidelines compared to other developing countries of Africa like Nigeria and Ghana. This is evident as, currently, South Africa is the only country in Africa with a green building council that is a fully certified member of the world green building council and has fully adopted a sustainable building assessment tool (GBCSA, 2017).

### 6.2.1 Green building council of South Africa (GBCSA) and assessment tools

This council was established in 2007 to work with its membership community to transform the Built Environment for people and the planet to thrive (Nurick and Cattell, 2013; GBCSA, 2017). The goal is to ensure that buildings and homes are designed, built and operated environmentally sustainably (GBCSA, 2017). To achieve this, the council adopted the Green Star assessment tool launched in 2002 by the Green Building Council of Australia (GBCA). However, the GBCSA adopted it in 2009 and named it green star SA (Hoffman, Huang, Van Rensburg, and Yorke-Hart, 2020). The green star assessment is based on nine distinct areas, each with a range of credits that address environmental and sustainability issues related to building design, construction, and use (GBCSA, 2017; Green Star SA, 2022), as discussed in *chapter two (subsection 2.4.9)*. The rating tools assess the building performance of new buildings and major refurbishments, existing buildings, interiors etc. (GBCSA, 2017).

Other rating tools certified by the GBCSA associated with green star SA include Net Zero, Energy Water Performance (EWP), Excellence in Design for Greater Efficiencies (EDGE), and EDGE Residential (GBCSA, 2017). Net Zero can certify "projects that achieve Net Zero/Net Positive Ratings in carbon, water, waste and ecology. It can be applied to new construction projects, fit-out projects and existing buildings" (GBCSA, 2017: online). EWP is usually used to assess the performance of existing and new office buildings. It helps owners of buildings to understand where their buildings sit in terms of performance compared to other similar office buildings and buildings in their category (GBCSA, 2017). "It clarifies decision-making on whether to retrofit, hold or sell and is a powerful communication tool to prospective tenants or buyers. This bench-marking tool makes up 40% of the Existing Building Performance tool but is also available as a separate certification" (GBCSA, 2017: online). EDGE, on the hand, is free software that provides measures to minimise the resource intensity of your structure (GBCSA, 2017). It was created as a straightforward, user-friendly green building grading online tool." (GBCSA, 2017).

Generally, GBCSA operates in the residential, commercial and public sectors, with a passion for a higher cause, thought leadership, collaboration and warmth (GBCSA, 2017).

### 6.2.2 Other regulations that can add to sustainable building construction in South Africa

#### *6.2.2.1 Department of public works green building policy*

The Department of Public Works (DPW) provides leadership and practice concerning green buildings in the public and private sectors (DPW Green Building Policy, n.d.). DPW is the custodian of all immovable assets vested in the national government, which are not otherwise vested in the custodianship of other departments through legislation (DPW Green Building Policy, n.d:4). Hence, DPW through its green building unit (established in 2015) launched the Green Building Policy in 2018 in Cape town (DPW, 2023). The policy aims to provide leadership in the sustainable buildings sector, primarily green buildings (DPW Green Building Policy, n.d.; DPW, 2023). "The principles of the green building policy include Leadership; Energy, water and waste management; Indoor environmental quality and comfort; Product and materials management; Promotion of indigenous knowledge systems; Acceptable horticulture and landscaping construction practices; Green procurement; Monitoring and reporting." (DPW, n.d:5). By implementing the Green Building Policy, "DPW will support sustainable development within South Africa; job creation and the development of green jobs; the development of improved working and living conditions; and the development of cost-effective solutions and the efficient use of resources during the life of buildings" (DPW Green Building Policy, n.d:19).

The DPW green building policy is not isolated but also works together with other regulations and standards that promote, support and implement green building practices, such as GBCSA (green star), National Building Regulations and Buildings Standards Act 103 of 1977, National Environmental Management Act (NEMA) 107 of 1998 etc. (Windapo and Goulding, 2015; Aboginije et al., 2020).

#### *6.2.2.2 National building regulation and building standards act (NBRBSA)*

This was instituted as Act 103 of 1977 to "provide for the promotion of uniformity in the law relating to the erection of buildings in the areas of jurisdiction of local authorities; for the prescribing of building standards; and for matters connected therewith" (Government of South

Africa, 2023: online). However, it commenced on the 1st of September 1985 and has undergone several amendments (Government of South Africa, 2023). It was amended in 1984, 1989, 1995, and 2008 (Government of South Africa, 2023). According to Abonginije et al. (2020), it was enlisted as one of the Acts that unites with the Department of public works' green building policy to implement green building practices in South Africa.

#### *6.2.2.3 National environmental management act (NEMA)*

This regulation was established as Act 107 of 1998 to "provide for cooperative, environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected therewith." (Government of South Africa, 2023: online). It commenced on the 29th of January 1999 and has undergone several amendments, including the latest in 2022 (Government of South Africa, 2023). It was enlisted as one of the Acts that united with the Department of public works' green building policy to implement green building practices in South Africa (Windapo and Goulding, 2015; Aboginije et al., 2020).

### 6.2.3 Adoption of green building features in South Africa

The number of green buildings in South Africa's building stock is minimal, as is their contribution to the country's construction market (Simpeh, Smallwood, Ahadzie, and Mensah, 2023). According to Saad (2016), there is a great need to switch from traditional construction methods to those that align with green building principles and concepts, including adopting green features in the South African construction industry (Saad, 2016; Owoha et al., 2022). Sinha (2009) affirmed that features like energy efficiency is highly neglected in most building practices in South Africa, including overall neglect of green building principles. Nevertheless, the adoption of green buildings worldwide has increased awareness of green building features and projects in the South African construction industry (Nurick et al., 2015; Owoha et al., 2022). Although Masia et el. (2020) argued that green building is a relatively new idea in the construction industry of South Africa, they suggested that adoption will grow as real estate or

property developers quickly grasp its investment advantages and consequences. Also, Nurick and Cattell (2013) opined that the desire for green building features, especially in office space, will enhance green building adoption.

Nonetheless, South Africa is argued to have one of the fastest-growing green building markets that will even expand further both professionally and technologically (Jones and Mandyck, 2016; Dodge Data and Analytics, 2018; Simpeh et al., 2020; Owoha et al., 2022). Also, they are top-ranked in adopting green buildings compared to other African countries, as discussed earlier. For example, the early market leaders and promoters of green building practices since the launching of the Sustainable Buildings for Africa project in 1997 were from South Africa (Simpeh et al., 2023). This includes the Council for Scientific and Industrial Research (CSIR) and South African Property Owners Association (SAPOA) (Greencape Market Intelligence Report (GMI), 2014; Simpeh et al., 2023).

Additionally, in South Africa, it was predicted that the number of construction firms that integrate green building practices in their business would rise from 28% to 48% in 2018 and 2021, respectively (Dodge Data and Analytics, 2018; Owoha et al., 2022). Besides, according to Dodge Data and Analytics (2018), the country that has the highest green share for the retrofitting of existing buildings is South Africa, with 49% more than the global average (37%) for green retrofits. Furthermore, between 2015 and 2019, the country certified 100 and 500 Green Star SA-rated buildings, respectively (GBCSA, 2019; Owoha et al., 2022). This suggests that the adoption rate is improving progressively. Similarly, contrary to Sinha's (2009) claim, energy efficiency programs are being implemented in the public sector, and the residential building market sector is increasingly adopting certain green building technologies like solar water heaters, rooftop solar panels, net metering and the like. (Joubert and Cloete 2013; Simpeh et al., 2023). These developments have fuelled the growth of the green building industry (Joubert and Cloete, 2013). However, the industry is not without great impediments to the full adoption of green building practices.

### 6.2.4 Adoption of modern building techniques for sustainable building construction

According to Hussin et al. (2013), using advanced methods like Building Information Management Modeling, Lean techniques, Value Engineering (VE), Industrialised Building System (IBS), Sustainable Supply Chain Management (SSCM) etc., can improve sustainable construction project performance. In South Africa, these modern and advanced techniques are receiving increasing awareness but are not fully implemented in practice (Bowen, Cattell, Edwards, and Jay, 2010; Kekana, Aigbavboa, and Thwala, 2014; Ojo, Mbohwa, and Akinlabi, 2014; Shakantu and Froise, 2014; Watkins and Sunjka, 2020; Kedir et al., 2022).

Ku and Taiebat (2011) affirm that BIM technology can improve project performance in terms of environmental sustainability and quality and reduce time and cost. Watkins and Sunjka (2020) posit that the interaction between lean construction and green building can assist in achieving more sustainable development in South Africa. Maradzano, Dondofema, and Matope (2019) also posit that applying lean construction principles will decrease waste and improve overall the South African construction industry performance. Akinradewo et al. (2018) also extended that lean construction will help minimise accidence and improve health and safety in the industry. Hence, project participants are encouraged to engage fully in lean thinking and adoption (Allu and Emuze, 2017).

Similarly, Aigbavboa, Oke, and Mojele (2016) found that using the value management technique optimises value for money, creates a more explicit focus on the project objectives and works towards a more effective design in the South African construction industry. This, therefore, appreciates the principles of sustainable building construction. On the other hand, Ojo et al. (2014) posit that sustainable/green supply chain management in South Africa will tremendously improve the economy. Besides, Kedir et al. (2022) affirms that using industrial building systems in the South African construction industry will ensure the efficiency of delivering houses in demand.

However, these modern building techniques are not adequately implemented due to challenges such as licencing; contractual issues; lack of education, skills and training; lack of interest from

clients; lack of commitments and involvement from stakeholders/project participants; poor communication, resistance to change etc. (Bowen et al., 2010; Ojo et al., 2014; Chimhundu, 2016; Kekana et al., 2014; Aigbavboa et al., 2016; Kedir et al., 2022; Onososen and Musonda, 2022). Therefore, as the problems suggest, mitigation of these challenges is highly recommended and can be done through knowledge sharing, establishing policies that encourage participation, and so on.

### 6.2.5 Challenges of sustainable building construction in South Africa

There are prevailing problems encountered in implementing sustainable building construction practices in South Africa. They include a lack of knowledge and awareness of the methods and technologies (Saad, 2015; Aigbavboa et al., 2016; Mashwama et al., 2020; Marsh et al., 2021), Limited information that will allow practical implementation of practices (Saad, 2015), Absence of dependable exact cost data/information (Mashwama et al., 2020), lack of proper communication on strategies (Saad, 2015), Limited understanding from clients/stakeholders on the benefits (Aigbavboa et al., 2017), the High cost of sustainable building materials (Saad, 2016; Aigbavboa et al., 2017; Mashwama et al., 2020), Fear of higher investment costs/perceived high cost (Aigbavboa et al., 2017; Aghimien et al., 2019), Use of expensive technologies (Saad, 2016), Lack of effective enforcement, and mobilisation of resources to support technological changes (Saad, 2016), Reluctance to shift from the conventional methods (Aghimien et al., 2019), Lack of demand for sustainable building/product (Marsh et al., 2021), Lack of client's/stakeholders' interest (Saad, 2016; Aghimien et al., 2019; Marsh et al., 2021), (Aghimien et al., 2019), Lack of team integration among stakeholders (Saad, 2016), limited government involvement, the complexity of codes and regulations on green building and sustainable construction (Mashwama et al., 2020).

Considering these challenges, it is vital to adopt an integrated sustainable building construction model, which this study presents, to eradicate the challenges of the South African construction industry. The challenges were also highlighted in Chapter two, Table 2.6 which contained a comprehensive tabulation of the barriers to sustainable building construction worldwide.

## 6.3 Chapter Conclusion

This chapter presented an overview of the South African construction industry and the practice of project delivery and sustainable building construction. The various project delivery and procurement strategies and contract forms were highlighted. The challenge of project management and project performance were also highlighted. Besides, the chapter discussed the contribution of the construction industry development board and the aim to improve project delivery performance among the registered companies. Also, it discussed the policy documents relating to construction procurement and delivery in South Africa. Moreover, it provided information contained on the South Africa's National Infrastructure Plan 2050. Similarly, sustainable building construction practice was discussed, including the essence of the Green Building Council of South Africa. Besides the essence of the Green Star rating, the Department of Public Works' green building policy, the National Regulation and Building Standards Act, and the National Environmental Management Act were also discussed. It was evident that the South African construction industry has increased awareness of sustainable building construction compared to their African counterparts and is setting measures to implement practices fully. Nonetheless, challenges still hinder the full implementation of sustainable building construction, which were also highlighted.

The next chapter will present a detailed discussion of the methodology adopted for this study.

# CHAPTER SEVEN

# RESEARCH METHODOLOGY

## 7.0 Introduction

This chapter discusses the procedures undertaken to develop an integrated sustainable building construction (SBC) model for project delivery in South Africa. These procedures include the philosophical positions, research methodology and paradigm, research design, data collection strategy, data analysis, measures for determining the goodness of fit of the model, validity and reliability of the study components, and ethical considerations. The model to be investigated include factors considered in previous models and those not considered. The old factors include the regulatory environment, knowledge sharing, and corporate disposition, while the new factors include project delivery strategies, project management techniques, and modern building techniques. The aim is to determine their relationship with the features of SBC implementation and construction project success outcomes into a model.

## 7.1 Research Philosophical Positions

Philosophical considerations are imperative in deciding the research strategy. According to Emuze (2011), research methodology includes the rationale and philosophical presuppositions that support a study. Research philosophy is a set of presumptions and beliefs (Saunders, Lewis, Thornhill and Bristow, 2019). According to Neuman (2014), a philosophical perspective on social research legitimises the objectives and requirements of the study, including moral and political values and research conduct. Additionally, the philosophical assumption in research describes the nature and growth of knowledge (Collins, 2010). Research philosophical considerations include ontology, epistemology and axiology (Creswell, 2014; Tengan, 2018; Adjei, 2020). However, the predominant philosophies are ontology and epistemology (Aigbavboa, 2013; Arthur-Aiddo, 2017; Ogunsanya, 2018), and these two are extensively

discussed in subsections 8.1.1 and 8.1.2. These philosophical positions underpin the research methods for the present study.

### 7.1.1 Ontology

According to David and Sutton (2004), ontological consideration is a crucial component of the research process that permits awareness of human nature to expose the social truth. Ontology focuses on the nature of reality (Crotty, 1998). This perspective entails the researcher's worldview commitment and assumption about how the world functions (Ogunsanya, 2018). What exists, what would appear to be, what components make it up, and how the components interact with one another are all topics of ontology (Hitchcock and Hughes, 1989; Ametepey, 2019). Ontology comprises subjectivism and objectivism (Ametepey, 2019; Adjei, 2020). Both can underpin a study as they constitute reliable knowledge (Ogunsanya, 2018; Tengan, 2018). Subjectivism contends that social phenomena are produced by social actors' perceptions and subsequent acts (Ogunsanya, 2018). In other words, what is real is created by people as they interact with the environment in which they live rather than being discovered (Collins, 2010; Tengan, 2018). Similarly, subjectivity or constructivism holds that the universe comprises labels, names, and concepts utilised to create the meaning of reality (Burrell and Morgan, 2005; Tengan, 2018).

On the contrary, objectivism maintains that social entities exist independently of social actors (Ogunsanya, 2018). Reality is complete, tangible, and unchanged regardless of the perceived meaning attributed by people (Burrell and Morgan, 2005; Dainty, 2008; Aliyu, Bello, Kasim and Martin, 2014). This suggests that reality is the same irrespective of its context or meaning. Another argument is that individuals are born into a social world already in existence, and that individuals cannot change reality (Burrell and Morgan, 2005; Ametepey, 2019). Therefore, objectivist researchers emphasise the need to consider the causal relationships among the elements that establish reality to better understand the truth (Jean, 1992; Ametepey, 2019). The current study supports this notion. Hence, the research method used for this study was underpinned by objective ontology as it sought to determine the causal relationships between the variables in the integrated SBC model for project delivery in South Africa.

### 7.1.2 Epistemology

Epistemology deals with the study of the nature of knowledge, including its breadth and limitations (Collins, 2010). In other words, it concerns knowledge and its theory acceptable in a field of study (Crotty, 1998; Knight and Turnbull, 2008; Ogunsanya, 2018). It is derived from two Greek words, *episteme* and *logos* (Tengan, 2018). *Episteme* denotes knowledge in the sense of science, whereas *Logos* denotes knowledge in an orderly arrangement of what is known (Crawford and Ghormley, 1999; Wenning, 2009; Tengan, 2018). Wenning (2009) expounded on the meaning of epistemology when he stated that three essential questions should be dealt with. They include "What is knowledge, and what do we mean when we say we know something? What is the source of knowledge, and how do we know if it is reliable? finally, what is the scope of knowledge and its limitation?" (Wenning, 2009:3).

The epistemic stance chosen for a study underpins and determines the suitability, sufficiency, and legitimacy of knowledge for the research (Crotty, 1998). Therefore, research investigators must draw attention to, explain, and validate the epistemology that guides their choice of research methodology (Crotty, 1998; Ametepey, 2019). Similarly, Hitchcock and Hughes (1995) posit that epistemology can significantly impact the techniques used to gather information as it does the research process methodology. This suggests the three fundamental themes used to characterise epistemology in literature: the relationship between the researcher and the subject of the study, theories about the nature of reality, and the method by which knowledge is attained (Tengan, 2018). There are several perspectives associated with epistemology. They include positivistic, pragmatic, operationalist, referential, instrumental, empiricist, rationalist, or realist (Tennis, 2008; Tengan, 2018). These perspectives can also be categorised as subjective or objective epistemic data regarding ontological considerations in a specific discipline (Quattrone, 2000).

Positivism is strongly linked with objective epistemic data and searches for a reliable link between connected components (Adjei, 2020). Positivist philosophy is well acclaimed in social science research. According to Greener (2008), positivist philosophy necessitates hypothesis testing for determining what is thought to be the objective truth and

potential outcomes. Positivism ideology has implications for methodology, value-freedom, causation, operationalisation, independence, and reductionism in social science research (Bond, 1993; Hughes, 1994; Ogunsanya, 2018). Considering that this study necessitates hypothesis testing, positivistic epistemic paradigm has been adopted to examine the connections between sustainable building construction practice and its related factors.

### 7.1.3 Axiology

This philosophical position investigates value judgments and values' role in research (Creswell, 2014). "The role that a researcher's values play in all stages of the research process is of great importance if the results from the research will be adjudged to be credible" (Tashakkori and Teddlie, 1998:30). Heron (1996) contends that all human conduct is motivated by our values. He continues by saying that the ability to explain one's values as a foundation for making decisions concerning the research's subject and the methods used is a sign of axiological proficiency. Axiology requires considering the values attributed to various investigational components, respondents, data, and the audience for whom reporting the examination results is necessary (Kivunja and Kuyini, 2017). Hence, the researcher considered the right values and ethics in conducting this research, and inter-alia sought to ensure that the right respondents are selected to extract the primary data.

## 7.2 Research Methodology and Paradigm

This study adopted a positivism paradigm as it sought to generated explanatory associations or causal relationships that ultimately lead to prediction based on the objectives unlike other research paradigms (Artino, Konge, and Park, 2020). The choice of research methodology is guided by the research aims and objectives and the type of research data to be collected (Creswell, 2014; Tengan, 2018; Adjei, 2020). The research method (s) used equally stems from the research paradigm(s) (Jean, 1992, Tengan, 2018). A researcher's paradigm indicates how the researcher perceives the world in approaching challenges to solve them. This is true as a paradigm is defined as a "set of beliefs that researchers rely on to make sense of the world or a

segment of the world" Crotty (1998:35). Similarly, Schwandt (2001) also described it as a common worldview that expresses the beliefs and values in a discipline and serves as a manual for problem-solving. For scholars to understand and make sense of reality, paradigms provide the framework for their technique, inquiry strategies, methodology, and structure (Crotty, 1998). Hence, research paradigms influence what academics consider acceptable information and research methodologies (Crotty, 1998).

Moreover, a research paradigm is characterised by reality (ontology), what and how knowledge is known about reality and the world (epistemology), and methodology (the process by which information is acquired) (Guba, 1990; Tengan, 2018). There are several approaches to be used in tackling research problems. However, the most popular research methodologies in social science research include quantitative, qualitative, and mixed methods. Because the mixed method combines quantitative and qualitative research approaches, the following subsections will only discuss the two to provide insights into their implications.

### 7.2.1 Quantitative research approach

Scholars utilise the quantitative approach to gain new insight into a phenomenon by relating the empirical evidence collected to pre-existing ideas or concepts (Neuman, 2014). This approach uses pre-determined tools and employs factual information procedures such as investigations, explorations, and overviews (Adjei, 2020). The quantitative research approach references tallies and item proportions (Ametepey, 2019). Some scholars affirm that quantitative data results in a more comprehensive understanding of an investigation (Creswell and Clark, 2011; Ngulube and Ngulube, 2015). The philosophical foundation of the quantitative research approach is steady positivism, a common paradigm in social science (Saunders, Lewis and Thornhill, 2009; Babbie and Mouton, 2010). Creswell (2014) also claims that this method uses positivist and post-positivist assumptions in seeking knowledge. Therefore, it is objective in nature. According to Jean (1992), the positivist philosophical tenets of epistemology are encouraged by the objectivist perspective of a complete and autonomous reality.

Positivist epistemology promotes adopting a research approach led by science to explain and forecast the causal and effective relationships between the components of reality (Quattrone, 2000; Tengan, 2018). Likewise, Kent (2015) posits that the fundamental tenet of the objectivist researcher's pursuit of reality is based on observation, measurement, analysis, and prediction of the interactions between the elements that make up reality. Therefore, the quantitative research method begins with theories, develops research questions/hypotheses about a specific phenomenon, collects data from a provable/reputable source, and then analyses and interprets the data to determine if the findings confirm or refute the suggested research hypotheses (Welman, Kruger and Mitchell, 2005; Field, 2009). Furthermore, Creswell (2014) affirms that quantitative methodology uses strategies of inquiry like surveys and experiments to generate statistical data using a specified tool (questionnaire) for data collection.

To this effect, the present study adopted this scientific approach for collecting, analysing, and interpreting the collected data with statistical tools such as the SPSS (Statistical Package for the Social Sciences) and Amos (Structural Equation Modelling) software. This method was therefore used to determine the relationship between SBC determinants and SBC implementation for project delivery success in South Africa.

### 7.2.2 Qualitative research approach

According to Mason (2002), this approach adopts an interpretivism philosophical approach. It is a subjective approach based on a subjectivist epistemic stance (Ogunsanya, 2018; Adjei, 2020). Ikpe (2009) defines it as an inquiry procedure for knowing social or human phenomena through in-depth reporting of informants' opinions that is carried out in a natural environment. Consequently, qualitative research yields results that are not from the quantification of statistical methods (Rahman, 2016; Tengan, 2018). By incorporating the subjectivity of researchers into the study process, this approach seeks to generate ideas instead of measuring (Tengan, 2018). This subjectivist epistemic stance asserts that meaning is imposed on the object by the subject (the researcher) rather than discovered (Crotty, 1998). In other words, reality is influenced by the researcher in defining its meaning. This also aligns with (Aigbavboa, 2013), who affirms that regarding subjectivity epistemology, the researcher assigns meanings to reality through constructivism and interpretivism, aligning constructivism and interpretivism as concepts (Aigbavboa, 2013).

Regarding interpretivism, researchers look for perspectives, opinions, perceptions, and interpretations of people (Aigbavboa, 2013, Ametepey, 2019). Interpretivism is also linked to secondary data used in research (Aigbavboa, 2013). Hence, the literature review of the current study as secondary data, contributed to interpreting reality. There are several ways to elicit data through a qualitative approach. They include interviews, direct observation, case studies, expert study (Delphi), enography, grounded theory, phenomenology, narrative, and focus groups (Morgan, 1996; Creswell, 2014; Jamshed, 2014; Aczel, 2015; Aigbavboa, 2015; Sutton and Austin, 2015).

The qualitative research method has received increasing criticism. For instance, Sarantakos (2005) asserts that it is ineffective since it does not examine the causal connection between the various factors that constitute reality in the world. Similarly, the impacts of the values and viewpoints of the researcher on the collected data undermine the reliability and generalisability of the results from qualitative research (Sarantakos, 2005; Bryman, 2012). Although Mitchell (1983) argued that this shortcoming would be overcome through sound theoretical reasoning, Creswell (1994) posits that it is problematic to validate its findings. Qualitative research aims to generate ideas instead of measuring/quantifying the object of inquiry (Creswell, 1994; Ametepey, 2019). Sarantakos (2005) also laments that it cannot guarantee high precision between the studied variables. Scholars also found that collecting and interpreting qualitative data takes more time and money, yet it is characterised by a relatively small number of participants (Griffin, 2004; Rahman, 2016). Besides, manipulation is possible with a minimal number of participants; therefore, it is problematic to reproduce and generalise the results (Atieno, 2009; Rahman, 2016). As a result, many academics, practitioners, and decisions or policymakers are reluctant to take a qualitative research approach seriously (Griffin, 2004; Tengan, 2018).

Consequently, qualitative approach was not used in this study. The current study preferred a quantitative to a qualitative approach due to the nature of the study which necessitates cause and effect relationship determination using a mathematical model without subjectivism and biasness in interpretation (McCuen, Ezzell and Wong, 2011).

### 7.2.3 Mixed-method research approach

This approach involves the combination and integration of qualitative and quantitative data, in a research study (Creswell, 2014). As discussed previously, the qualitative data is subjective and associated with open-ended questions while the quantitative data is objective in nature and usually include close ended responses. Because of the methodological and conceptual differences between the two techniques, there is a continuing discussion among academics regarding whether to combine them (Ogunsanya, 2018; Dawadi, Shrestha and Giri, 2021). There are difficulties in combining the two approaches to arrive at valid conclusion of findings (Dawadi et al., 2021). However, the mixed-methods approach was proposed to be valuable for addressing complex research questions and providing a more comprehensive understanding of phenomena (Ogunsanya, 2018; Dawadi et al., 2021). Nevertheless, mixed-method approach was not chosen for this study due to the straightforwardness of the research questions and objectives, and the detailed literature review that provided a thorough understanding of the theoretical background.

### 7.2.4 Justification of the research method adopted

The study adopted a quantitative method considering the type of study and the shortcomings associated with the qualitative approach. Nevertheless, a thorough literature review as secondary data was conducted considering subjective and objective epistemic data from various related studies worldwide. Through literature synthesis, reality has been established. Hence, the literature synthesis provided a good ground for the quantitative research approach. In other words, the reality created by the body of knowledge has been considered through insights from literature as secondary data and objectively adopted to conduct the current study with positivist philosophy. Hence, the quantitative method was chosen to collect and analyse the data necessary for developing an integrated sustainable building construction model for South Africa.

McCuen, Ezzell and Wong (2011) affirm that the quantitative approach reduces complexity and simplifies situations to the point where they can be examined and tested using statistical techniques. Besides, as described earlier, this method begins with theories, develops research questions about a specific phenomenon, collects data from a provable source, and then analyses

and interprets the data to determine if the findings confirm or refute the suggested research hypotheses (Welman et al., 2005; Field, 2009). Therefore, the quantitative method was deemed sufficient to be used for the current study. Besides, this scientific approach was used to explain the cause-and-effect relationship between the dependent and independent variables considered using mathematical models. Thus, there was little room for personal bias throughout the study (Sarantakos, 2005; Tengan, 2018). It also maintains control and high accuracy of the data quantified (Field, 2009).

## 7.3 Research Design

Creswell (2014) defines research design as a plan or procedure for carrying out research that specifies the approach to data collection, analysis, and result interpretation. It aims to justify choices made about the research process (Sekaran and Bougie, 2016). Hence, this study employed an objectivist ontology and a positivist epistemological perspective, which resulted in adopting a quantitative research methodology and the survey method as the instrument for data collection (Sarantakos, 2005; Ametepey, 2019). Similarly, according to Robson and McCartan (2016), the primary justification for a study design should consider the following five factors: the research must be objective, as well as the theoretical framework, the research questions, the research techniques, and the sampling strategy. Therefore, these elements of research design are incorporated into the structure of the current investigation. Table 7.1 summarises this study's process, including the objectives, data collection strategy, data analysis and expected outputs. The subsequent sections and subsections also elaborated on the approaches used for this study.

**Table 7. 1**: Research methods employed for the achievement of the objectives

| | Objectives | Data Collection | Data Analysis | Output |
|---|---|---|---|---|
| **1.** | To establish the predominant factors facilitating the effective implementation of sustainable building construction (SBC) for project delivery in South Africa. | Questionnaire design | Descriptive statistics | Predominant factors facilitating the effective implementation of SBC for project delivery in South Africa. |
| **2** | To evaluate the impact of sustainable building construction determinants on sustainable building construction implementation in South | Questionnaire design | Factor analysis (Exploratory factor analysis (EFA) and | Refined factors (empirical) contributing to the most variance in SBC practices. |

| | | | | |
|---|---|---|---|---|
| | Africa. | | Principal components analysis (PCA)) | |
| | | | Structural equation model (SEM) | The impact of the SBC determinants on SBC practices. |
| **3** | To assess the impact of sustainable building construction features on project success outcomes. | Questionnaire design | PCA and SEM (Regression analysis) | The impact of SBC on project success outcomes. |
| **4.** | To evaluate the impact of sustainable building construction determinants on project success outcomes in South Africa. | Questionnaire design | SEM (Regression analysis) | The impact of the SBC determinants on project success outcomes. |
| **5.** | To develop an integrated sustainable building construction model for project delivery in South Africa. | Questionnaire design | SEM | Integrated sustainable building construction model. |
| **6.** | To validate the developed model for sustainable building construction regarding the goodness of fit. | Questionnaire design | SEM | Information to validate the conceptual model. |
| | | | Structural model (SEM) | Validated best-fit model. |

### 7.3.1 Questionnaire survey

The questionnaire survey was used as the primary tool for collecting empirical data due to the quantitative nature of the study. Bird (2009) defines it as a formal framework comprising questions and scales to produce primary raw data. McQueen and Knussen (2002) posit that it is an essential technique for obtaining empirical data. A structured questionnaire subjects each responder to the same set of questions, allowing for the interpretation of variations in response rather than variations in the procedures that produced the answers (Siniscalco and Auriat, 2005; Brace, 2008). This aligns with Yuen (2007), who posits that it can be used to gather specific information about a group of respondents' attitudes, views, and perceptions that may be difficult to measure using observational techniques. Besides, it is beneficial for quickly collecting data from numerous respondents over a vast area (McQueen and Knussen, 2002), and a greater level of anonymity can be guaranteed since respondents are not forced to reveal their identities (Burns and Bush, 2002; Ametepey, 2019). Therefore, for this study, data was collected through a structured questionnaire and was analysed using SPSS and Amos version 29 computer software.

#### *7.3.1.1 Design of the questionnaire survey*

The questionnaire for collecting primary data for the current study was a structured questionnaire. It was developed based on the detailed literature review regarding sustainable building construction and its related factors. The questionnaire comprised four sections (A to D) (see Appendix B). Section A aims was to elicit the demographical data, while Section B focuses on information on the factors determining sustainable building construction. On the other hand, section C aims to establish the sustainable building construction expected deliverables, while section D aims to establish the project success outcomes for sustainable building construction.

Closed-ended questions were used to give respondents a series of possible answers from which one must be chosen and ensures that information is recorded without bias (Willems, 2009). Section A consisted of questions which were based on a nominal (or label) scale, while sections B, C, and D were designed with an ordinal scale (Likert scale). A nominal scale was used to classify the respondents of this study (Ametepey, 2019). Conversely, an ordinal scale was used to elicit the respondent's views on the identified constructs as it allows for rank order (Ametepey, 2019). Hence, Likert scales (1 to 5) were adopted to give proper weight to the response to the posed question (Kumar, 2008) and have been found very reliable by many scholars, than scales developed with other methods (Hayes, 1998; Bertram, 2007; Tengan, 2018). It was also affirmed that responses with Likert scales would most likely reflect the exact opinions of the respondents and increase the spread of variance of responses which in turn provides stronger measures of association (Zikmund, 2000; Aaker, Kumar, Leone and Day, 2012). Hence, the Likert scales used in this study included *1-No extent, 2 – Low extent, 3 – Moderate extent, 4 – High extent, and 5 – Very high extent.*

#### *7.3.1.2 Variables*

Apart from the demographics, the research instrument was designed to elicit data for measuring the effects of exogenous variables on endogenous variables. The exogenous variables included Regulatory Environment (RE), Knowledge Sharing (KS), Corporate Disposition (CD), Project Delivery Strategy (PDS), Project Management Techniques (PMT), and Modern Building Techniques (MBT). The endogenous variables were categorised into two, namely, the Primary

endogenous variable (Sustainable building construction features - which also served as a mediating latent variable), and the secondary endogenous variable (Project success outcomes for sustainable building construction). The latent variables/constructs were discussed in chapter 8 portraying their individual measuring variables.

## 7.4 Data Collection Strategy

This section discusses the techniques and procedures used in collecting the required primary data with the research questionnaire instrument. It includes discussing the target population and sampling frame, sampling technique, sample size, questionnaire administration and collection, and data entry and screening.

### 7.4.1 Target population and sampling frame

The target population of this study was the Built Environment professionals in South Africa. The population number was 333000 (Statista, 2023) while 400 were sampled as proposed by several scholars for a population of 5000 or more (Neuman, 2014; Leedy and Ormrod, 2016; Tengan, 2018; Ametepey, 2019). The respondents were Built Environment professionals in Gauteng with backgrounds in project management, construction management, architecture, quantity surveying, engineering and town and regional/urban planning (Statista, 2023). These professionals' roles in a project included project engineers, project managers, construction managers, principal agents, quantity surveyors, town/urban planners etc. The researcher ensured that respondents knew the subject to provide information to address the research problem.

### 7.4.2 Sampling technique

Sampling techniques are used for selecting a subset of people from a population. Some popular sampling technique include random sampling, purposive sampling, stratified sampling, cluster sampling and convenience sampling (McCombes, 2023). Random sampling is based on chance while purposive sampling is based on a predetermined criterion (McCombes, 2023; Mcleod, 2023). Stratified sampling involves segmenting the population into subgroups and then random samples are drawn from each category (McCombes, 2023; Mcleod, 2023). Similarly, cluster sampling involves

segmenting the population into clusters and then a random selection of a few clusters is made, and every item within is examined (McCombes, 2023; Mcleod, 2023).

Conversely, convenient sampling is based on availability or convenience (Etikan, Musa, and Alkassim, 2016; McCombes, 2023). The disadvantages of convenience sampling are that it lacks clear generalisability and can easily provide false data if care is not taken (Obilor *et al.,* 2023). Nevertheless, it was found suitable to use in the context of this study. According to Etikan *et al.* (2016), an advantage of convenience sampling is that it is useful when randomisation is impossible, such as when the population is enormous. Hence, this sampling technique was chosen to represent the population of construction practitioners in the Gauteng province, which is approximately 333,000 (Statista, 2023), not to mention South Africa at large. Additionally, the nature of the research necessitates experienced and knowledgeable respondents to contribute meaningfully. Hence, randomisation may not be suitable in achieving this goal. Besides, the convenient sampling technique is cost-effective, less time-consuming, efficient, and simple to implement (Golzar *et al.,* 2022). Therefore, it was chosen considering the limited time frame to complete the study, the availability of respondents, and the willingness to participate (Etikan *et al.,* 2016). Furthermore, the data elicited was based on respondents' perceptions, and the researcher planned to test the formulated hypotheses which makes the convenience sampling technique suitable as opposed to purposive sampling (Golzar *et al.,* 2022). These considerations (including the study's sample size, which enhanced the statistical power of this sampling technique) ensured that the sample represented the population. As recommended by Golzar *et al.* (2022), the researcher dispersed the questionnaires at various times and locations to obtain a suitable cross-section of the target population.

### 7.4.3 Sample size and selection

Several contrasting views regarding sample size selection from a population exists in the literature. However, there is agreement that the sample size depends on the type of investigation (Neuman, 2014; Ogunsanya, 2018). According to Neuman (2014), the sample size for a study should consider the population's characteristics, the level of precision required, the type and extent of data analysis used, and the level of accuracy required. Hence, this study used a sample size of 281, considering the nature of the methodology and data analysis techniques (Factor analysis and SEM). Pallant (2020) posits that a minimum of 150 respondents are required for factor analysis. Nunnally (1994) suggests

a 10 to 1 ratio (i.e 10 cases) for each item to be factor analysed while other authors suggest that 5 cases for each item are suitable (Tabachnick and Fidell, 2013; Pallant, 2020). Consequently, the sample size for this study met all the criteria stipulated and considering the number of items in each construct to be factor analysed.

For, structure equation modelling (SEM), several authors proposed a sample size of at least 200 (Harris and Schaubroeck, 1990; Kline, 2010; Bagozzi and Yi, 2012; Oke, Ogunsami, and Ogunlana, 2012) and a maximum of 400 for a population of 5000 or more (Neuman, 2014; Leedy and Ormrod, 2016; Tengan, 2018; Ametepey, 2019). According to Statista (2023), the total number of construction practitioners in the Gauteng province of South Africa is approximately 333000. Therefore, considering that the study population is more than 5000 (Statista, 2023), the researcher circulated the questionnaire to 400 respondents. However, only 284 construction professionals responded, indicating a 71% response rate. However, only 281 responded questionnaires were found adequate for data analysis. Nonetheless, the used sample size and questionnaires were adequate for the analysis and less susceptible to generating negative results.

### 7.4.4 Questionnaire administration and collection

#### *7.4.4.1 Pilot study and review*

The draft questionnaire was first administered to 10 respondents with construction backgrounds, including academics. The aim was to identify any problem that may arise in answering the questions among the respondents for adjustments and amendments (Sampson, 2004; Gehlbach and Brinkworth, 2011). Problems such as unclear wording and ambiguous questions can be discovered, corrected and rephrased through the help of a pilot study (Grimm, 2010; Creswell, 2014). Although the result of the pilot study was not included in this document, it was a critical prerequisite for the final questionnaire administration. As affirmed by Creswell (2014), pre-testing and pilot surveys are crucial to ensure and demonstrate methodological and systemic rigour in data collection and evaluate the questionnaire's clarity, comprehensiveness, and viability. Therefore, before the final draft questionnaire was circulated, the pilot study and the supervisor reviews ensured that errors were corrected, questions were properly rephrased, and ambiguous wordings were simplified. [See final questionnaire in appendix B].

#### *7.4.4.2 Main study questionnaire administration and collection*

The circulation of the questionnaire was primarily electronic, considering COVID-19 sentiments, distance, and cost implications. An online Google form link was created and sent to the respondents through emails, and social media websites. Data was collected between 15th February and 30th May 2023. The questionnaire was circulated to 400 respondents, primarily in the Gauteng province of South Africa, with a response rate of 71%. The respondents were identified through researcher's industry network, social media, and professional bodies platforms/websites.

## 7.5 Data Analysis

### 7.5.1 Data Screening and Entry

The researcher diligently screened the data for eligibility throughout the analysis process. Also, he ensured that no missing data in the analysis was included because it could affect the study's validity (Hair, Black, Babin and Anderson, 2010). Hence, the questions in the online questionnaire were made compulsory to help respondents track any unanswered questions. Considering this, listwise exclusion was never necessary. However, case pairwise was employed to guarantee that no data was inappropriately deleted from the analysis (Pallant, 2020). Also, respondent misconduct was examined (whereby a respondent marked the same answer for every question). This was checked by examining the standard deviation of answers for each specific respondent. Hence, responses with standard deviation of less than 0.25 were removed because there was little to no variance among the responses across the survey (Collier, 2020).

The questionnaire data was initially entered into the Statistical Package for the Social Science (SPSS) software version 29 for the purpose of doing descriptive statistics and exploratory factor analysis before exporting to Amos software version 29. The Amos SPSS software was used for the confirmatory factor analysis (CFA) and SEM analysis.

### 7.5.2 Descriptive statistics

According to Willems (2009), descriptive statistics is crucial for gathering and summarising or giving an overview of the information collected in quantitative analysis. It allows for the definition of

the main features of the entire sample (Naoum, 2007; Adjei, 2020). Consequently, descriptive analysis was performed in this study. It gave a pictorial summary of the gathered data and clearly described the responses to the specific research questions. It was essential in portraying the summary of the demographical data with frequencies (percentages). Additionally, it includes the calculation of a central tendency (mean values) and the measurement of data dispersion (standard deviation) (Pallant 2020). Therefore, frequencies were used as outputs for the section A of the questionnaire while means, and standard deviations were used for the descriptive outputs of the other sections of the questionnaire, and the analysis was performed with SPSS.

### 7.5.3 Inferential Statistics

The method used for making inferences in this study was SEM, a multivariate analysis. Arguably, it was the best technique for making inferences compared to the general linear modelling (GLM) class of statistics, like Analysis of Variance (ANOVA) and multiple regression (Field, 2009; Kline, 2010; Ogunsanya, 2018). Factor analysis was carried out beforehand to support the SEM analysis of the constructs' variables (Bentler, 2005; Kline, 2010). It serves as a prelude to SEM and is therefore essential for enhancing the robustness of SEM analysis (Bentler, 2005; Kline, 2010; Ogunsanya, 2018). The analysis techniques are discussed in the ensuing subsections.

#### *7.5.3.1 Exploratory Factor Analysis*

Exploratory Factor Analysis (EFA) recognises fundamental variables or factors that explain the relationships between a group of related factors (Conway and Huffcutt, 2003; Adjei, 2020). However, it was not intended to test hypotheses or determine whether one group significantly differs from another (Pallant, 2020). It is also employed as a reduction technique that takes a big set of variables and seeks to summarise or reduce the information using a smaller group of variables (Pallant, 2020). This is realised by its capability to search for clusters or groupings among the intercorrelations of a collection of variables (Pallant, 2020). Pallant (2020), further states that factor analysis reduces many related variables to a more manageable number before using them in other analyses, such as multiple regression or multivariate analysis of variance. Hence, this method was used prior to conducting the confirmatory factory analysis, via SEM.

The different facets of factor analysis, which include exploratory factor analysis (EFA), principal component analysis (PCA), and confirmatory factor analysis (CFA), were all utilised in this study. Early in the data analysis, EFA was employed to collect data or explore the correlations between variables. An empirical summary of the data set from the exploratory factor analysis (EFA) was provided using PCA. PCA was crucial in reducing many correlated variables and resizing the variables into a set of components (Tabachnick and Fidell, 2013; Pallant, 2020). Contrarily, CFA helped test or confirm the specific hypotheses or theories concerning the structure of the set of variables (Pallant, 2020). Moreover, CFA was essential for determining the variables in each latent construct and determining the best fit for the model before performing the SEM.

Several tests were performed to ensure that the sample size and collected data met the criteria for factor analysis. For instance, the Kaiser-Meyer-Olkin (KMO) sampling adequacy test was used to assess the sample size adequacy and factorability, and it passed the test having a value above 0.6, which was the minimum set value (Neteyemer and Bearden, 2003; Burton and Mazerolle, 2011). Furthermore, the data passed Bartlett's Test of Sphericity, which checks for intercorrelation among variables as it was found significant at $p=0.000,$ lower than the set statistical significance value of $p=0.05$ (Tabachnick and Fidell, 2013; Pallant, 2020).

Other tests were conducted, such as Cronbach's alpha, communality and the like. All factors passed Cronbach's alpha test exceeding the benchmark of 0.7. The factor loading with commonalities below 0.5 dropped. Eigenvalues above 1 were used to decide which factors to retain or reject. Scree tests were also performed to justify rejecting or accepting the component factors (Hayton, Allen, and Scarpello, 2004; Ledesma and Valero-Mora, 2007). Varimax rotation was the most suitable for grouping the component variables. The accepted components were then used for SEM. All the tests were able to be performed using SPSS. The results of the factor analysis are presented in chapter ten (10).

#### *7.5.3.2 Structural equation modelling*

Structural Equation Modelling (SEM) is predominantly known for its ability to determine the causal relationships between variables and model validation (Lowry and Gaskin, 2014). "It surpasses traditional regression models by including multiple independent and dependent variables to test associated hypothesises about relationships among observed and latent variables." (De Carvalho and Chima, 2014:6). Consequently, SEM was used to determine the factors influencing sustainable building construction (SBC) practices for project delivery in South Africa. It was used to determine the causal relationships and validate the integrated SBC model. SEM assessed the strength of relationships in the model and their significance. SEM allowed both direct and indirect effects of variables to be examined (Raykov and Marcoulides, 2012). Besides specifying the structural relationships among the latent variables, SEM considers error measurement unlike other general linear modelling techniques (Kline, 2010, Henseler, Hubona and Ray, 2016; Ogunsanya, 2018). Hence, it was utilised to differentiate between the true and error variance in the model analysis. Considering the attributes of SEM, it was chosen as the best analytic technique for developing the integrated sustainable building construction model for South Africa.

### 7.5.4 Model fit measurement

This encapsulates the relevant measures taken to ensure the suitability of the proposed model in the current study. According to Kline (2010), there are four most common measures for the goodness of fit test. They include Chi-square (x2/df), Root-means-square error of approximation (RMSEA), Normed fit index (NFI), and Comparative fit index (CFI). Hence, these measures, (used for path analysis) and others, such as Incremental fit index (IFI), and Modification, are discussed in the ensuing subsection.

#### *7.5.4.1 Chi-square (x2/df)*

The chi-square check is represented as "x2/df". The notation x2 is the chi-square, and df is the degrees of freedom. The check was used to establish whether there is a significant relationship or association between variables in this study. The chi-square check is obtained by dividing the

chi-square (x2) value by the degrees of freedom (df). According to Hsu et al. (2012), a value less than 2 is acceptable and standard. However, Hair et al. (2010) assert that a value less than 3 is acceptable.

#### *7.5.4.2 Root-means-square error of approximation (RMSEA)*

This critical check indicates whether there is an inconsistency between the population covariance matrices per degree of freedom and the model (Kline, 2010). Hence, values between 0.08 and 0.10 are a reasonable fit, while those greater than 0.10 are a poor fit (Hsu et al., 2012; Tengan, 2018; Ogunsanya, 2018). Similarly, Steiger (2007) states that a cut-off value of 0.08 is acceptable for RMSEA.

#### *7.5.4.3 Standardised root means square residual (SRMR)*

This is an index of the average of standardised residuals between the observed and the hypothesised covariance (Kline, 2010). According to Kline (2010), a good fit index should be less than or equal to 0.05.

#### *7.5.4.4 The normed fit index (NFI)*

The difference between the chi-squares of the null and target models, divided by the chi-square, is known as the normed fit index (NFI). When the NFI value is 0.90, the model of interest improves the fit by 90% relative to the null or independent model (Tengan, 2018; Ogunsanya, 2018). The NFI solves the overestimation issue when there is an increase in the number of parameters (Tengan, 2018).

#### *7.5.4.5 Comparative fit index (CFI)*

This is the revised form of the NFI and considers the sample size of a study (Byrne, 2010). The CFI contrasts the null mode with the same covariance matrix and hypothesizes that all latent variables are independent and uncorrelated (also known as a null model or independence model) (Kline, 2010; Ogunsanya, 2018). According to Hsu et al. (2012), it is an acceptable or good fit if the CFI cut-off value is equal to or more than 0.09.

#### *7.5.4.6 Incremental fit index (IFI)*

This is also regarded as Bollen's fit index (BFI). For the IFI test to be acceptable, the value should be more than 0.90. and can surpass 1. IFI is unaffected by sample size (Bentler, 2005).

#### *7.5.4.7 Modification*

The SEM software provided the modification indices for each fixed parameter for the goodness of fit test. Modification aims to improve the model. Modification is accomplished by linking all indicators to the latent variables and permitting or preventing correlations between measurement errors among different variables (Hair et al., 2010). Hence, modification indices were used to ensure the goodness of fit for the model fit measurement variables.

## 7.6 Validity and Reliability

To guarantee the validity and reliability of the study's findings, precautions were taken. To improve validity, insights from earlier studies were used for creating the questionnaire. As a result, the questions were developed after a thorough assessment and synthesis of the literature. The researcher's supervisor and co-supervisor also repeatedly examined the study tool (questionnaire). This Questionnaire was also pilot tested. The questionnaire's face validity and content were improved based on the aforementioned metrics (Brink and Wood, 1998; Olson, 2010).

The accuracy of the research data was also examined. This study assessed the degree of consistency of the questionnaire scale's questions using Cronbach's alpha test (Willems, 2009; Pallant, 20). A reliability assessment aims to ensure that if the study were to be repeated, the data would provide an accurate or comparable conclusion (Bell, 2014). According to Pallant (2020), numbers with a 0.6 imply acceptable reliability, while some claim that values above 0.70 show high internal consistency of the data (Ziaontz, 2014). Cronbach's alpha test was used to evaluate the internal consistency of the items in the various constructs of the integrated sustainable building construction model, considering these standards for establishing the dependability of data. Hence, this improved construct validity. Besides, composite reliability was considered in

this study through the CFA, with the lowest and highest value being 0.912 and 0.972 respectively exceeding the 0.70 threshold (Salkind, 2012).

Convergent validity was also observed in this study. It refers to the degree to which multiple measures of a construct that theoretically should be related, are actually related (Gefen, Straub and Boudreau, 2000). Hence, items are assessed to determine if they convergent together to measure the underlying construct (Hair et al., 2010). It is assessed through average variance extracted (AVE). AVE is calculated by taking the sum of the squares of the factor loadings and dividing it by the number of items in the unobserved latent variable. Hence, the AVE of the factor loadings in each latent construct were all greater than 0.5, which was the threshold for retaining or rejecting variables.

This study also observed discriminant validity after establishing the preliminary data analysis. The discriminant validity of the study was evaluated by comparing the square root of the AVE for each construct and its connection to other constructs (Fornell and Larcker, 1981; Tengan, 2018). The degree to which a latent variable is distinct and captures some phenomena that other variables do not, show discriminant validity. Hence, each construct's AVE in this study is higher than its correlations with other constructs, demonstrating that discriminant validity was obtained. Also, items on one construct did not convergent too closely with items from other scales when calculating the discriminant validity in this study.

## 7.7 Ethical Consideration

The research questionnaire was approved by the ethics committee at the University of Johannesburg. The field study reinforced the idea of voluntary engagement. People were not forced to participate, as a result. Leading questions were also omitted from the questionnaire. Therefore, respondents were required to respond according to their views.

The data collected for the study was only used for academic purposes. When it is published, it will provide information on the most efficient factors that will guarantee the implementation of

sustainable building construction for successful project delivery. There was no incentive or reward provided for taking part.

Prioritising confidentiality was another ethical action done. The participants' privacy was carefully protected by maintaining confidentiality. The questionnaire did not include personal information, preventing any data links to the responder or organisation and potential harm to their welfare.

Finally, the respondents received explicit information to prevent distortion and biased responses. To prevent the acquisition of unreliable data, construction industry professionals in the Built Environment were chosen as respondents. The ethical clearance certificate is portrayed in appendix D.

## 7.8 Generalisability

The results of this study can be generalised to the entire population because of the sample size. Arguably, it is widely accepted in quantitative research that the larger the sample, the more the results will be applied to the population (Aigbavboa, 2013; Tengan, 2018; Ametepey, 2019).

## 7.9 Conclusion

This chapter discussed the procedures to develop the integrated sustainable building construction model. Philosophical positions were discussed. This study adopted objective ontology and positivist epistemology. Hence, the research paradigm was based on the positivism assumption. A quantitative research approach was therefore used. Besides, the reason for choosing the quantitative approach was justified. The research design was discussed in detail, including the procedures undertaken from the literature and the development of the questionnaire in alignment with the selected variables of the study. Additionally, the data collection strategy was discussed in detail, including the target population, sampling frame, sampling technique, sample size selection, and questionnaire administration and collection (pilot study and main study).

Moreover, data analysis approaches were discussed, including descriptive statistics, inferential statistics (factor analysis and structural equation modelling), and model fit measurement. The model fit measurement included the necessary measures for path analysis and model validation, such as chi-square, root-mean-square error of approximation, normed fit index, comparative fit index, incremental fit index, and modification. The SPSS version 28 and Amos version 28 software were used to achieve descriptive and inferential statistics objectives. Amos version 28 software was predominantly used to develop and confirm the model. Descriptive statistics were used particularly for the purpose of presenting the frequency, mean and standard deviation of the outputs.

Furthermore, the validity and reliability of the research instrument, ethical considerations, and generalisability of the study were discussed. The next chapter discusses the conceptual latent variables for the integrated sustainable building construction model.

# CHAPTER EIGHT

# THE CONCEPTUAL INTEGRATED SUSTAINABLE BUILDING CONSTRUCTION MODEL

## 8.0 Introduction

This chapter presents a brief discourse on the proposed conceptual integrated sustainable building construction model. Therefore, it portrays the assumed relationship between the constructs and discusses the variables. The proposed conceptual model is developed based on the findings from the literature review and supported by the questionnaire survey.

## 8.1 Proposed Conceptual Model for Sustainable Building Construction Project Delivery

Sustainable building construction is a relatively new concept in developing countries and has not been fully implemented in most developing countries, especially African countries. This has resulted in a lack of consensus regarding drivers of sustainable building construction (SBC). Hence, a well-designed measurement system with accompanying robust measuring indices is required to adopt SBC in developing nations like South Africa.

As described in section 3.3.6 and Table 7, various research have identified various constructs as factors or drivers of SBC. The current research, however, largely rests on the shoulders of important studies like Eden et al. (2008), Lam et al. (2010), and Windapo (2014). The constructs for the current study were carefully chosen based on their significance from the literature review while considering country peculiarities. Consequently, the current study selected six primary independent latent constructs that describe the integrated SBC model for project delivery in South Africa. They include regulatory environment (RE) with eleven variables, knowledge sharing (KS) with twelve variables, corporate disposition (CD) with thirteen variables, project delivery strategies (PDS) with nineteen variables, project management techniques (PMT) with

twelve variables, modern building techniques (MBT) with seven variables. Also, the model includes an intervening latent construct SBC implementation (SBCI) with twenty-four variables which also serves as an independent construct to integrated SBC project delivery. Furthermore, the model includes the ultimate dependent latent construct known as integrated SBC project delivery (ISBCPD) with ten variables.

The conceptual model for SBC showing the relationship between dependent and independent variables is shown in Figure 6. The following subsections provide a brief discourse and summary of the latent constructs for the integrated SBC model.

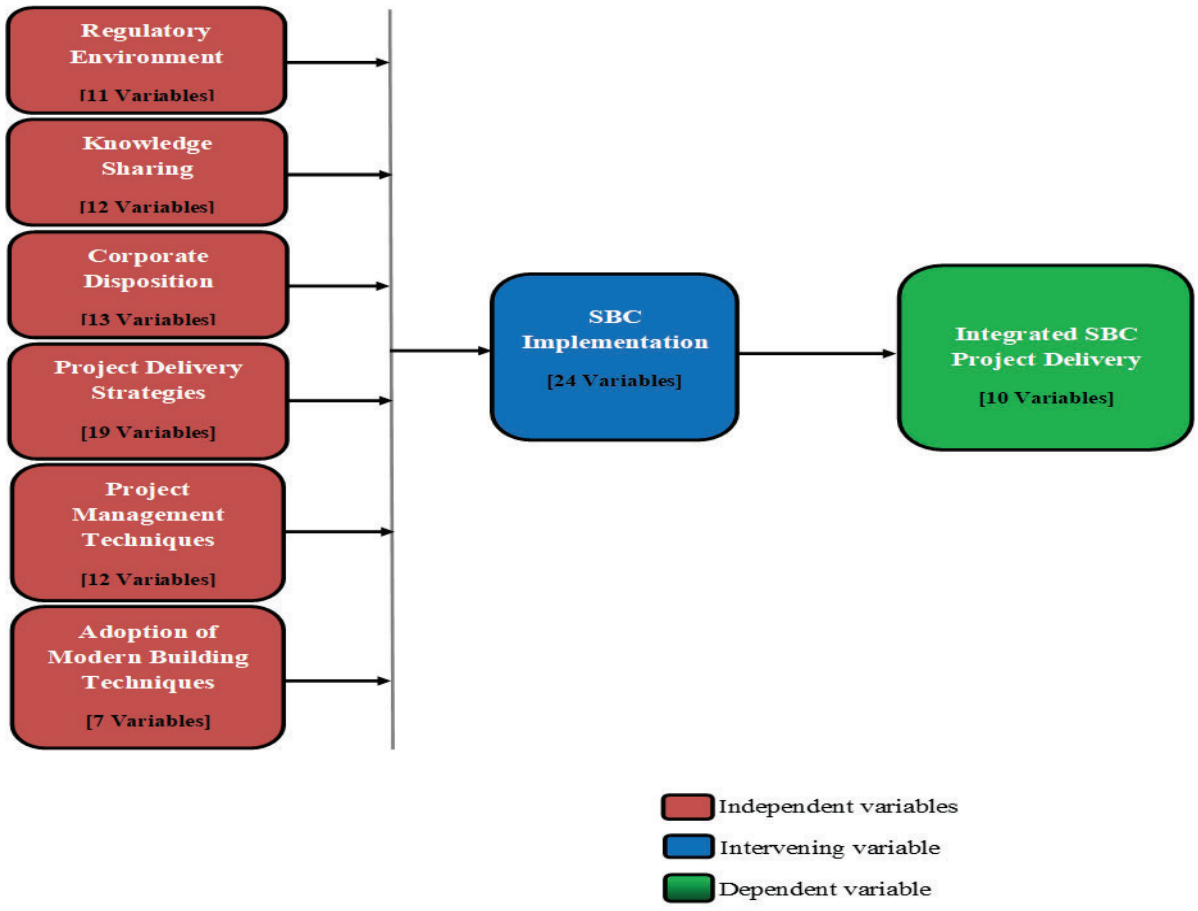


**Figure 8. 1**: Integrated conceptual model for SBC project delivery in South Africa.

### 8.1.1 Regulatory environment

This can be referred to as requirements, legislations, standards, policies, and regulations (Ogunsanya, 2018) influencing the practice of sustainable building construction. Many authors believe that the regulatory environment is one of the biggest facilitators of the implementation of sustainable principles in construction (Manoliadis et al., 2006; Salam, 2008; Arif et al., 2009a, 2009b; Diabat and Govindan, 2011; Strandberg, 2012; Serpell et al., 2013; Wong et al., 2016; Wang et al., 2018). Therefore, adequate attention is required, especially in developing countries to ensure that sustainable construction principles are implemented. This is because the lack of government policies, building codes, and regulations for the conscious promotion of sustainable construction is predominant in developing countries (Serpell et al., 2013; Ayarkwa et al., 2017; Wang et al., 2018). As indicated by Gomes and Silva (2005), the government should be the driver for sustainable development instead of the market since construction firms may zero in on quantitative delivery disregarding life-cycle evaluation.

Manoliadis et al. (2006) categorised policy measures that can contribute to establishing sustainable construction into two; namely, general policy and specific policy. General policy measures centre on sustainable urban development and the development of educational training programs. On the other hand, construction policy measures focus on introducing energy and resource conservation measures and establishing a suitable legislative framework for sustainable construction, including land use laws and waste reduction measures. Manoliadis et al. (2006) further suggest that the legislative framework should be modified considering a few issues like urban development, integration of environmental studies in building construction and quality, and eco-labelling standards to help the entire cycle towards sustainability.

Serpell et al. (2013) suggest that a governmental policy such as company tax reduction incentives should be initiated, especially in developing countries, to enhance their level of investment in sustainable construction. This initiative will help to curtain one of the obstacles to sustainable building, which is the perception of higher costs (Serpell et al., 2013). This position is also consistent with Wang et al. (2018) , as they mentioned that the lack of legal framework

for green specifications, governmental regulations, and incentives for green adoption are critical barriers to sustainable construction.

Wang et al. (2018) assert that the fundamental guarantee for the successful adoption of green specifications is by having an efficient legal framework and procedures which involves related policies, regulations, codes, and specifications to guide all the stakeholders including government officials. The authors advised that these policies should be mandatory (with supervision) and not voluntary if sustainable principles are to be adhered to. This position is supported by many scholars (Walker et al., 2008; Diabat and Govindan, 2011; Yang and Zhang, 2012; Zhai, 2014) as they contended that compulsory environmental policies and regulations are of most extreme significance to the fruitful implementation of green procurement. According to Adetunji et al. (2008), the implementation of environmental policy in business practices significantly enhances construction organisations' mindfulness and participation in green procurement.

Further, Wang et al. (2018) affirm that the government should establish financial policies such as tax reduction incentives(as previously mentioned), financial discounts, deficit subsidies, and pretax loans for building green. It is assumed that with the benefits of these policies, construction companies will be more willing to adopt green specifications (Wang et al., 2018). Other authors also concur with this notion that incentive policies are a reliable method that will drive even private firms to embrace environmental initiatives (Rivers and Jaccard, 2006; Qian and Chan, 2010; Shen et al., 2016; Wong et al., 2016).

Similarly, the establishment of viable standards and guidelines, like assessment measures, green specifications, green label schemes, and ISO 14000 certification for suppliers, is viewed as a reliable method to improve the implementation of green procurement in the industry (Salam, 2008; Diabat and Govindan, 2011; Strandberg, 2012; Wong et al., 2016). DuBose, Bosch, and Pearce (2007) mentioned certifications and rating systems such as LEED or the equivalent, for ensuring adequate implementation of sustainable principles.

Arif et al. (2009b) suggested that there should be a more unified regulatory framework between states and federal laws as some states have more stringent regulations than others. Abidin and Powmya (2014) extend that the rules should be made compulsory at the municipal level regarding environmental protection and the green concept. For instance, green belts or plantation areas should be provided for new construction works (Abidin and Powmya, 2014). Abiding and Powmya (2014) also enlisted tax breaks as measures which government needs to establish for building green.

However, the options regarding the efficacy of a policy rely on many components explicit to the context of implementation, for example, inter-alia, the degree of experiential knowledge and expertise regarding green building in that context, as well as the structure and culture of the company in which the programs are to be implemented (DuBose et al., 2007). Table 8.1 presents the measuring variables for the latent construct – Regulatory Environment (RE) in this study.

**Table 8. 1**: RE measuring variables

| Label | Measuring variables | Citations |
|---|---|---|
| RE1 | National building standards acts | Aboginije et al. (2020) |
| RE2 | Green building council of South Africa standards | Nurick and Cattell (2013); GBCSA (2017); Hoffman et al. (2020) |
| RE3 | Department of public works green building policy | Windapo and Goulding (2015); Aboginije et al. (2020); DPW (2023). |
| RE4 | National environmental management regulations | Windapo and Goulding (2015); Wang et al. (2018); Aboginije et al. (2020) |
| RE5 | Laws ensuring the sustainability of resources | Arif et al. (2009a), (2009b); Diabat and Govindan (2011); Strandberg (2012); Serpell et al. (2013); Wong et al. (2016); Wang et al. (2018) |
| RE6 | Government-a driving force more than the market | Gomes and Silva (2005); |
| RE7 | Incentives for the companies that are building sustainably | Liu et al. (2012); Serpell et al. (2013); Abiding and Powmya (2014); Shen et al. (2016); Wong et al. (2016); Wang et al. (2018) |
| RE8 | Integrating environmental studies in construction | Manoliadis et al. (2006); |
| RE9 | Compulsory sustainable building assessment | Wang et al. (2018); Walker et al. (2008); Diabat and Govindan (2011); Yang and Zhang (2012); Zhai (2014) |
| RE10 | Compulsory enforcement of sustainable construction laws | Wang et al. (2018); Walker et al. (2008); Diabat and Govindan (2011); Yang and Zhang (2012); Zhai (2014) |
| RE11 | Compulsory sustainable building certification | Wang et al. (2018); Walker et al. (2008); Diabat and Govindan (2011); Yang and Zhang (2012); Zhai (2014) |

### 8.1.2 Knowledge sharing

This can be described as the activity through which information, skills, or expertise can be exchanged among people, communities, or organisations (Serban and Luan, 2002; Ipe, 2003; Abdeldayem, 2020). Hence, the knowledge of sustainable building construction practices can be shared through education, training, and awareness. According to Manoliadis et al. (2006), education and training in sustainable construction ideas and strategies are presumably the primary methods for facilitating and adopting sustainable construction practices. Hence, there is a need to upgrade the existing educational and training programs to accommodate the principles established in the current knowledge base of sustainable construction.

Knowledge and cognition of the benefits of sustainable practices should be taught to improve adoption (Shi et al., 2013). Ahn et al. (2013) assert that it is essential to educate and train subcontractors and workers in construction projects for complete understanding and integration of sustainability consideration into their daily practice as this will change their modus operandi toward sustainability. The authors suggest that the project managers and superintendents should be at the forefront of motivating their subordinates and subcontractors toward adopting sustainable practices in their daily lives and during construction projects (Ahn et al., 2013).

Abidin and Powmya (2014) recommend that reaching out to people through media, advertisement, seminars, and training are the best approaches to promote green construction. The authors suggest that education can start early from school or higher education level. Also, that collaborations should be made with local Colleges and Universities to initiate interest among students. Additionally, knowledge can be transferred from foreign construction companies to local companies through networking and business linkages. With the government's help, construction companies should bring in foreign expertise to work together in realising green concepts in new projects and thereby providing learning opportunities to local engineers, architects, and contractors to gain experience (Abidin and Powmya, 2014). This training, therefore, will enhance the local companies' technical capacity in sustainable building construction. Technical capacity is a "unique and practical knowledge possessed by the project

team, whereas training is a planned experience that assists individuals to acquire new skills, knowledge, and attitude to address developmental problems." (Tengan, 2018:77). Abidin and Powmya (2014) also suggest promoting local green products through research and development. This aligns with Arif et al. (2009a). They also found that lack of research and development and lack of sufficient educational programs at school and college levels to promote green are barriers to sustainable construction.

Murtagh et al. (2016) posit that adopting sustainable practices can be enhanced by embedding technical expertise as a part of professional development requirements. They suggest that through in-house training and professional development, organisations and professional bodies could require technical expertise in sustainable design as a model for career advancement. This is consistent with Shafii, Ali, and Othman (2006), who found that a lack of professional capabilities and a lack of awareness and education on sustainable design and construction are significant obstacles to sustainable building construction in the South-east Asian region.

Public awareness can play a crucial role in the quest for a wider uptake of green building practices for sustainability. Wang et al. (2018) suggest that the knowledge of green building specifications and the creation of public awareness on environmental issues are critical for adopting sustainable practices. Qian and Chan (2010) also posit that public awareness of green construction is critical; clients can only request green building products (GBPs) when they are knowledgeable about their benefits. Also, as suggested by Liu et al. (2012), the government and businesses should play a role by publicising the merits of green building to the citizens and guiding them to circumvent high carbon lifestyles. "The public ought to know the specifics about these GBPs. Awareness of these practices may significantly facilitate the desire to go green. It may also influence the development of a general appreciation for green facilities amongst the public" (Kalua, 2015:76). Public awareness of green building benefits is a vital strategy for green building in developed countries. According to Korkmaz et al. (2009), the rise in environmental awareness among the public was a significant facilitator in moving towards green building in the USA. Hence, construction companies in developing countries such as South Africa, must implement this strategy to enhance sustainability. Lack of awareness of green building concepts

and benefits may inhibit investment in green products as the public may not appreciate their value (Kalua, 2015).

Furthermore, knowledge of green building should not be limited to technocrats from the traditionally Built Environment disciplines like architecture, engineering, and land management, as anybody can start construction work from an entire range of professional backgrounds (Kalua, 2015). Table 8.2 presents the measuring variables for the latent construct – Knowledge Sharing (KS) in this study.

**Table 8. 2**: KS measuring variables

| Label | Measuring variables | Citations |
|---|---|---|
| KS1 | Education on sustainable practices among staff | Manoliadis et al. (2006); Gou et al. (2012); Ahn et al. (2013); Shi et al. (2013); Ershadi et al. (2021); Toriola-Coker et al. (2021) |
| KS2 | Mentoring younger professionals in sustainable practices | Murtagh et al. (2016); Tengan (2018); Ershadi et al. (2021); Toriola-Coker et al. (2021) |
| KS3 | Educational and training programs upgrade | Manoliadis et al. (2006); Niroumand et al. (2013); Khoshnava et al. (2014); Aktas and Ozorhon (2015); Tengan (2018) |
| KS4 | Sustainable building construction integration in professional certifications | Shafii et al. (2016); Murtagh et al. (2016) |
| KS5 | Content of Sustainable building construction training | Murtagh et al. (2016); Oguntona et al. (2019) |
| KS6 | Information hub or repository for sustainable construction | Arif et al. (2009a) |
| KS7 | Collaboration with foreign companies for knowledge transfer | Abidin and Powmya (2014) |
| KS8 | Promoting local green products through research | Hwang and Tan (2012); Arif et al. (2009a); Abidin and Powmya (2014) |
| KS9 | Sustainable building materials awareness creation | Wang and Adeli (2014); Hussain and Kamal (2015); Kumar et al. (2015); Wang et al. (2018) |
| KS10 | Creating public awareness for sustainable practices | Liu et al. (2012); Abidin and Powmya (2014); Kalua (2015); Wang et al. (2018) |
| KS11 | Awareness creation of green building products | Wang et al. (2018); Oguntona et al. (2019) |
| KS12 | Public awareness of environmental issues | Korkmaz et al. (2009); Qian and Chan (2010); Wang et al. (2018) |

### 8.1.3 Corporate disposition

This includes the factors such as image, vision, culture, policy, and social responsibility (Darko et al., 2017) that can influence the practices of sustainable building construction. According to Duplessis (2007), institutions, including government, academics, research, professional bodies, and construction firms, must accept sustainable development concepts as an integral part of their operations in order to create an environment that is supportive of sustainable construction. This will enable them to build their capacity to support sustainable construction and utilise the related technology (Du Plessis, 2007).

Similarly, Andelin et al. (2015) reveal that corporate image and culture are essential for sustainable building construction. The corporate image portrays the values an organisation represents, and it characterises the organisation's appeal and its products according to the stakeholders' point of view (Andelin et al., 2015). The expression "corporate culture" alludes to the convictions, behaviours, or practices of a specific corporation. A few organisations look to connect themselves with a particular arrangement of values, for example, by characterising themselves as an "inventive" or "environmentally-conscious" organisation (Tarver and Brock, 2021). It might likewise reflect how an organisation enrols and advances workers dependent on the statement of purpose, as well as how the employees and the executives cooperate and handle outside deals (Tarver and Brock, 2021).

According to Yang and Zhang (2012), environmental vision in a company is viewed as significant in deciding the degree of green procurement as well as the mid-level manager’s support. Other scholars affirm that executive management’s commitment is also vital (Green Council, 2010; Lam et al., 2010; Wong, Chan, and Wadu, 2016). Adetunji et al. (2008) and Koebel et al. (2015) affirm that internal pressure within a company, especially at the administration level, will propel the subordinate to go green in the quest to mitigate environmental impacts and risks during the selection of materials. Besides, how important environmental regulations and policies are perceived depends on the degree of corporate involvement in green procurement (Min and Galle, 2001; Wong et al., 2016). Andelin et al.

(2015) indicate that organisations can align themselves to sustainable principles by following the widely known and used Global Reporting Initiative (GRI) sustainable guidelines. "The guidelines require standard contents for sustainability reporting regarding an organisation's profile, governance structures, and processes; and the management practices for sustainability issues which include goals and environmental, social and economic performance indicators" (Andelin et al., 2015:31). The GRI enables companies to compare their reports concerning sustainable guidelines (Thompson and Ke, 2012).

Regarding Corporate Social Responsibility, Prakash (2001) cited in Boyle and McGuirk (2012:397) defined it as "corporate strategies promoting 'beyond compliance' voluntary measures that deliver ecological, social, and economic outcomes." There are several understandings of what propels a firm to be socially responsible regarding sustainability. According to Garriga and Mele (2004), some companies could be socially responsible to fulfill the ethical obligation of their business to society, while some, due to economic objectives and as a strategic tool to create more wealth.

Other variables which can influence the practices of a company towards sustainability include the size of the company and its core business (Serpell et al., 2013), as well as pressure from the competitor's corporate involvement to be sustainable (Yang and Zhang, 2012). Table 8.3 presents the measuring variables for the latent construct – Corporate Disposition (CD) in this study.

**Table 8. 3***: CD* measuring variables

| Label | Measuring variables | Citations |
|---|---|---|
| CD1 | Identification of organisational benefits of adopting sustainable building construction | Duplessis (2007); Andelin et al. (2015) |
| CD2 | Social responsibility to protect the environment | Garriga and Mele (2004); Potbhare et al. (2009); Boyle and McGuirk (2012); Niroumand et al. (2013); Ayarkwa et al. (2017); Darko et al. (2017) |
| CD3 | Top management support | Abidin (2010); Green Council, 2010; Lam et al. (2010); Yang and Zhang (2012); Aktas and Ozorhon (2015); Ametepey et al. (2015); |

| | | |
|---|---|---|
| | | Wong et al. (2016); Darko et al. (2017); Yas and Jaafer (2020) |
| CD4 | Availability of competent personnel | Ametepey et al. (2015); AlSanad (2015); Daniel et al. (2018); Durdyev et al. (2018a); Tafazzoli (2018) |
| CD5 | Availability of finance for the project operation | Ametepey et al. (2015); Kalua (2015); Susanti et al. (2019); Karji et al. (2020) |
| CD6 | Alternate funding systems consideration for sustainable building construction | Kalua (2015); Ayarkwa et al. (2017); Oguntona et al. (2019) |
| CD7 | Pressure from the competitor's corporate involvement | Yang and Zhang (2012); Wong et al. (2016); Darko et al. (2017) |
| CD8 | Good project management culture | Emere et al. (2019); Tarver and Brock (2021) |
| CD9 | Commitment to innovative construction | Tarver and Brock (2021) |
| CD10 | Quest for competitive advantage over counterparts | Low et al. (2014a); Windapo (2014); Wong et al. (2016); Ayarkwa et al. (2017); Shittu (2021); Darko et al. (2017) |
| CD11 | Good intra-organisational leadership | Richardson and Lynes (2007); Lam et al. (2009/2010); Koebel et al. (2015); Tabassi et al. (2016); Darko et al. (2017); Mukerji (2017); Illeperuma and Abeynayake (2022); |
| CD12 | Stakeholders' involvement and commitment | DuBose et al. (2007); Duplessis (2007); Lam et al. (2009/2010); Andelin et al. (2015); Wong et al. (2016); Ayarkwa et al. (2017); Darko et al. (2017); Dosumu and Aigbavboa (2018); Chen et al. (2022) |
| CD13 | Cultural change promotion for sustainability | Ochieng et al. (2014); Amepetey et al. (2015); Darko et al. (2017); Daniel et al.(2018); |

### 8.1.4 Project delivery strategies

This encapsulates the project delivery methods, procurement approaches, and contract formats for the construction project delivery (DBIA, 2018) and can influence sustainable building construction practices. According to Oke et al. (2018), project delivery methods and procurement strategies are levers for re-engineering the construction project. Many studies have suggested that the project's performance largely depends on the project delivery strategy (Gad et al., 2015; Mehany et al., 2017; Hashem et al., 2018). This suggests a comprehensive understanding of the available options to select the best delivery method and procurement approach for effective and

efficient project delivery. Oke et al., (2018) affirm that delivery systems are the focal point as they decide the tendering and contractual procedures throughout the project stages. Therefore, clients should understand the consequences of each choice because "the delivery method establishes when parties become engaged; it impacts the choices of contractual relationships, and it influences ownership and the impact of changes and modification of project costs." (DBIA, 2018:2).

Various types of project delivery methods include design-bid-build, design and build system, construction management/general contractor method, integrated project delivery system, turnkey system, etc. (Feuer et al., 2015; Gad et al., 2015; Aknar, 2016; Garcia et al., 2016; DBIA, 2018; Hashem et al., 2018; Ogunsanya, 2018; Gunhan, 2019; Olanike et al., 2020). Many scholars avow that delivery methods that encourage the early involvement of stakeholders, and the collaboration of project participants are crucial for effective project delivery (Kent and Bercerik-Gerber, 2010; Aknar, 2016; Garcia et al., 2016; Akiner and Akiner, 2018; Hashem et al., 2018; Gunhan, 2019; Olanike et al., 2020).

Various procurement approaches involve, targeted procurement, sole-sourcing, public-private partnerships, and two-stage open book (Hodge and Greve, 2010; Adediran and Windapo, 2017; Ogunsanya, 2018; Raouf and Al-Ghamdi, 2019; Designing Buildings, 2022). The procurement approach can also be based on price, value, and qualification (Gransberg and Shane, 2015; Alleman et al., 2017; Hashem et al., 2018). Based, on these criteria tendering methods can be open, negotiated, or selected (Mathonsi and Thwala, 2012).

On the other hand, contract forms for payment of the completed project include lump-sum or fixed-price, cost-reimbursable and cost-plus contracts, guaranteed maximum price, unit price, and target price contracts (Puddicombe, 2009; DBIA, 2018; Hashem et al., 2018; Raouf and Al-Ghamdi, 2019). Notably, these contract formats have their pros and cons. Hence, the clients could be selected based on their needs and the project type. Project delivery strategies was extensively discussed in chapter four, section 4.1. Table 8.4 presents the measuring variables for the latent construct – Project Delivery Strategies (PDS) in this study.

**Table 8. 4**:PDS measuring variables

| Label | Measuring variables | Citations |
|---|---|---|
| PDS1 | Client needs assessment | Ghadamsi and Braimah (2012); Watermeyer (2012); DBIA (2018) |
| PDS2 | Traditional project delivery system (Design-Bid-Build) | Rashid et al. (2006); Shrestha et al. (2012); Gad et al. (2015); Jimoh et al. (2015); DBIA (2018); Hashem et al. (2018); Gunhan (2019) |
| PDS3 | Design and build system | Korkmaz et al. (2010); Reichstein et al. (2013); Jimoh et al. (2015); Chen et al. (2016); Akiner and Akiner (2018); DBIA (2018); Hashem et al., (2018); Antoine et al., 2019; Olanike et al. (2020); |
| PDS4 | Construction management/general contractor method | Korkmaz et al. (2010); Feuer et al. (2015); Hanks (2015); Jimoh et al. (2015); Akiner and Akiner (2018); DBIA (2018); Hashem et al. (2018) |
| PDS5 | Integrated project delivery system | AIA (2007); Kent and Bercerik-Gerber (2010); Aknar (2016); Garcia et al. (2016); Kantola and Saari (2016); Gunhan (2019) |
| PDS6 | Turnkey system | Rashid et al. (2006); Arditi and Ongkasuwan (2009); Chang (2009); Ashworth et al. (2013); Ogunsanya (2018); Akiner and Akiner (2018); Olanike et al. (2020) |
| PDS7 | Public-private partnerships | Campbell (2001); Hodge and Greve (2010); National Treasury (2015); Ogunsanya (2018) |
| PDS8 | Delivery methods with a single contracting point | Hashem et al. (2018); Gunhan (2019) |
| PDS9 | Collaboration of project participants | Garcia et al. (2016); Aknar (2016); Akiner and Akiner (2018); Hashem et al. (2018); Gunhan (2019) |
| PDS10 | Early involvement of stakeholders | Mollaoglu-Korkmaz et al. (2013); Hashem et al. (2018); Gunhan (2019) |
| PDS11 | Usage of open tendering method | Mathonsi and Thwala (2012); Hashem et al. (2018) |
| PDS12 | Usage of negotiated tendering method | Mathonsi and Thwala (2012); Hashem et al. (2018) |
| PDS13 | Usage of the selective tendering method | Mathonsi and Thwala (2012); Hashem et al. (2018) |
| PDS14 | Usage of targeted procurement method | Ofori (2009); Adediran and Windapo (2017) |
| PDS15 | Usage of lump sum contracts | Puddicombe (2009); Chan et al. (2011); Ghassemi and Becerik-Gerber (2011); Hashem et al. (2018) |
| PDS16 | Usage of cost-reimbursable contracts | Puddicombe (2009); Robichaud and Anantatmula (2011); Hashem et al. (2018); Raouf and Al-Ghamdi (2019) |
| PDS17 | Usage of multiple criteria selection method | Hashem et al. (2018); Ogunsanya (2018) |
| PDS18 | Usage of government budgetary allocations | Ogunsanya (2018) |
| PDS19 | Usage of private sector funds | Ogunsanya (2018) |

### 8.1.5 Project management techniques (PMTs)

This refers to the systematic procedures to produce specific project management deliverables for successful sustainable building construction. PMTs are systematic procedures or practices project managers and professionals use to produce specific project management deliverables (Patanakul et al., 2010; Emere et al., 2019). Horine (2013) avows that a project could only succeed by applying management practices such as techniques and skills. Project management and its techniques have been acclaimed as essential in (as organisations move toward project-based management) getting more done with fewer resources (Patah, 2010; Horine, 2013). Patah (2010) asserts that good project management lessens money-related misfortunes by annihilating poor undertaking speculations at a very early stage in their life cycles, thereby providing value for the money invested. Consequently, the utilisation of project management methodologies and techniques is relevant to delivering sustainable building construction projects successfully. The current study emphasised utilising the relevant techniques recommended by the project management body of knowledge (PMBoK). They include scope management techniques, integration management techniques, exploratory techniques (meeting, brainstorming etc.), procurement management techniques, time management techniques, cost management techniques, quality management techniques, risk management techniques, stakeholder management techniques, and communication management techniques. Similarly, Darus et al. (2009) recommend an environmental management system in project management as critical for the effective implementation of sustainable building practices. Project management techniques were extensively discussed in Chapter Four, section 4.2 and especially subsection 4.2.4. Table 8.5 presents the measuring variables for the latent construct – Project Management Techniques (PMT) in this study.

**Table 8. 5**: PMT measuring variables

| Label | Measuring variables | Citations |
|---|---|---|
| PMT1 | Appropriate project management methodology | Patanakul et al. (2010); Horine (2013); Rehacek (2014); Emere et al. (2019); PMI (2021); Abdelkhalik and Azmy (2022) |
| PMT2 | Scope management techniques | Patanakul et al. (2010); Kerzner and Kerzner (2017); Emere et al. |

| | | |
|---|---|---|
| | | (2019); PMI (2021) |
| PMT3 | Integration management techniques | Patanakul et al. (2010); Emere et al. (2019); PMI (2021) |
| PMT4 | Exploratory techniques | Stojcetovic et al. (2013); Michael et al. (2014); Emere et al. (2019) |
| PMT5 | Procurement management techniques | Patanakul et al. (2010); Emere et al. (2019); PMI (2021) |
| PMT6 | Time management techniques | Patanakul et al. (2010); Kerzner and Kerzner (2017); Emere et al. (2019); PMI (2021) |
| PMT7 | Cost management techniques | Patanakul et al. (2010); Emere et al. (2019); PMI (2021) |
| PMT8 | Quality management techniques | Patanakul et al. (2010); Emere et al. (2019); PMI (2021) |
| PMT9 | Risk management techniques | Patanakul et al. (2010); Emere et al. (2019); PMI (2021) |
| PMT10 | Stakeholder management techniques | Patanakul et al. (2010); Emere et al. (2019); PMI (2021) |
| PMT11 | Communication management techniques | Patanakul et al. (2010); Emere et al. (2019); PMI (2021) |
| PMT12 | Environmental management system | Darus et al. (2009) |

### 8.1.6 Modern building techniques

This refers to the newer and advanced methodologies to facilitate sustainable building construction practices (Hussin et al., 2013). They include Building Information Management/modelling, lean techniques, value engineering, industrialised building system, sustainable supply chain management (Hussin et al., 2013), big data analytics (Srai and Lorentz, 2019) and two-stage open book procurement model (Ogunsanya, 2018). These techniques were acknowledged as vital for project performance efficiency and effectiveness, productivity enhancement, speedy delivery and replication of projects, cost reduction, value for money, waste reduction, information management, and others (Nawi et al., 2011; Hussin et al., 2013; Abell et al., 2017; Li et al., 2020; Kineber et al., 2022). Modern building techniques were extensively discussed in Chapter Four, section 4.3, and especially subsection 4.3.2. Table 8.6 presents the measuring variables for the latent construct –Modern Building Techniques (MBT) in this study.

**Table 8. 6**: MBT measuring variables

| Label | Measuring variables | Citations |
|---|---|---|
| MBT1 | Building Information Management (BIM) | Bynum, Issa and Olbina (2013); Hussin et al. (2013); Mollaoglu-Korkmaz et al. (2013); McArthur (2015); Bui et al. (2016); Bashir (2018); Ndhlela (2018); Gurung (2020) |
| MBT2 | Lean techniques | Nahmens and Ikuma (2009); Aziz and Hafez (2013); Hussin et al. (2013); Ogunbiyi et al. (2014); Goit (2016) |
| MBT3 | Value Engineering/Management | Abidin and Pasquire (2007); El-Alfy (2010); Hussin et al. (2013); Potts and Ankrah (2013); Mahadik (2015); Wao (2015); Heralova (2016); Rachwan et al. (2016); Wao et al. (2016); Gunarathne et al. (2022); Kineber et al. (2022) |
| MBT4 | Industrialised Building Systems (IBS) | Gorgolewski (2005); Jaillon et al. (2009); Kamar et al. (2010); Yunus and Yang (2011); Bari et al. (2012); Hussin et al. (2013); Shamsuddin et al. (2013); Zhang et al. (2014); Ghaffarianhoseini et al. (2018); Saleh and Alalouch (2020) |
| MBT5 | Supply Chain Management systems | Vollmann et al. (2005); Carte and Rogers (2008); Misra et al. ( 2010); Green et al. (2012); Ahi and Searcy (2013); Hussin et al. (2013) |
| MBT6 | Big data analytics | Abell et al. (2017); Soroka et al. (2017); Veras et al. (2018); Ren et al. (2019); Srai and Lorentz (2019) |
| MBT7 | Two-stage open-book procurement models | Ogunsanya (2018); Designing Buildings (2022) |

### 8.1.7 Sustainable Building Construction Implementation

Building sustainably is in increasing demand and essential to ensure that the depletion of resources is mitigated. The building industry is known to be one of the most resource-intensive industries in the use of raw materials, water, and energy and is a significant contributor to environmental pollution, ozone layer depletion, and waste (Osmani et al., 2008; Ilha et al., 2009; Willar et al., 2020). Additionally, the practice of sustainable building construction alludes to different strategies, tools, and techniques used to implement building projects that are less harmful to the environment, reduce/prevent waste production, increase waste management (reuse of waste in the production of building material), advantageous to the society, and is profitable to the company (Asokan et al., 2009; Ruggieri et al., 2009; Tam, 2009; Willar et al., 2020).

Sustainable building construction also focuses on reducing the rate of energy consumption during construction and the entire life of the building considering the materials used, building components, construction technologies, and energy-related design concepts (Abd Jamil and Fathi, 2016; Ismail, Halog and Smith, 2017; Oke, Aigbavboa, and Semenya, 2017; Balasubramanian and Shukla, 2017).

Moreover, Ochieng et al. (2014) mentioned ten key themes of sustainable principles that can be integrated into construction project delivery. They include designing for minimum waste (using recyclable material); renovating an existing building to improve its sustainability if possible; aiming for lean construction; minimising energy in construction and usage, eliminating pollution, preserving and enhancement of biodiversity, minimising the use of water, responsiveness to local community and workforce, and benchmarking performances and setting goals for constant improvement.

Therefore, sustainable building construction implementation encapsulates sustainable and efficient designs, sustainable structural materials, sustainable energy systems, minimisation of the use of non-renewable goods, green procurement, usage of smart appliances, impact consideration on social background, minimisation of pollution and greenhouse gas emission, compliance with regulations on sustainable practices, compliance with sustainability assessment measures, improved use of construction resources, diminished operational and utility costs in building and the like. Wang and Adeli, 2014; Hosenuzzaman et al., 2015; Hussain and Kamal, 2015; De Amorim et al., 2018; Malinauskaite et al., 2017; Inayat et al., 2019; Abdelkareem et al., 2019; Nassef et al., 2019). Table 8.7 presents the measuring variables for the latent construct – Sustainable Building Construction Implementation (SBCI) in this study.

**Table 8. 7**: SBCI measuring variables

| Label | Measuring variables | Citations |
|---|---|---|
| SBCI1 | Sustainability indicators in project briefs | Wang and Adeli (2014) |
| SBCI2 | Sustainable and efficient designs | Efthymiou et al. (2010); Wang and Adeli (2014) |
| SBCI3 | Sustainable structural materials | Asdrubali et al. (2012); Hussain and Kamal (2015); Kumar et al. (2015) |
| SBCI4 | Minimisation of the use of non-renewable goods | Hussin et al. (2013); Ochieng et al. (2014) |

| | | |
|---|---|---|
| SBCI5 | Usage of biodegradable materials | Ochieng et al. (2014); Wang et al. (2014); Lawrence (2015); Guo et al. (2020) |
| SBCI6 | Decrease in generating waste | Ochieng et al. (2014); Wang et al. (2014) |
| SBCI7 | Promotion of waste material recyclability | Ochieng et al. (2014); Lawrence (2015) |
| SBCI8 | Usage of waste in making construction materials | Amin (2011); Madurwar et al. (2013); Yang et al. (2019) |
| SBCI9 | Usage of materials with low carbon footprint | Hussin et al. (2013); Wang and Adeli (2014) |
| SBCI10 | Decrease in the use of toxic materials | Akadiri et al. (2012); Hussin et al. (2013); Wang and Adeli (2014) |
| SBCI11 | Protection of biodiversity and ecology | Akadiri et al. (2012); Hussain and Kamal (2015) |
| SBCI12 | Energy consumption minimisation | Oke et al. (2017); Rabaia et al. (2021) |
| SBCI13 | Consideration of supplementary energy systems | Furlan and Mortarino (2018); Rabaia et al. (2021) |
| SBCI14 | Usage of renewable resources | Hussin et al. (2013); Jouhara and Olabi (2018); Malinauskaite et al. (2020); Abdelkareem et al. (2021); Rabaia et al. (2021) |
| SBCI15 | Consideration of the project's effect on air, soil, water etc. | Hussin et al. (2013); Ochieng et al. (2014); Windapo and Machaka (2018) |
| SBCI16 | Water usage minimisation | Akadiri et al. (2012); Ochieng et al. (2014) |
| SBCI17 | Green procurement | Hussin et al. (2013); Wong et al. (2016); DPW (2023) |
| SBCI18 | Usage of Smart Appliances | Ko et al. (2012); Olanipekun et al. (2017); Willar et al. (2020) |
| SBCI19 | Impact consideration on social background | Akadiri et al. (2012); Hussin et al. (2013); Hussain and Kamal (2015) |
| SBCI20 | Minimisation of pollution and greenhouse gas emission | Akadiri et al. (2012); Hussain and Kamal (2015) |
| SBCI21 | Compliance with regulations on sustainable practices | Kang (2015); Windapo and Goulding (2015); Shurrab et al. (2019) |
| SBCI22 | Compliance with sustainability assessment measures | Reed et al. (2011); Kang (2015); Windapo and Goulding, (2015); Shurrab et al. (2019) |
| SBCI23 | Improved use of construction resources | Hussin et al. (2013); Windapo and Machaka (2018) |
| SBCI24 | Diminished operational and utility costs in building | Ko et al. (2012); Olanipekun et al. (2017); Willar et al. (2020) |

### 8.1.8 Integrated SBC Project Delivery

This refers to the overall project delivery success outcomes based on efficiency and effectiveness in the implementation of sustainable building construction. According to Olanipekun et al. (2017) effective implementation of sustainable building construction is linked with delivery

performance success. These benefits include Project completion with no time overrun, Project completion with no cost overrun, Achievement of prescribed quality requirements, Construction Stakeholders/Client Satisfaction, End-user satisfaction, Value for money, Environmental objectives met, Health safety and comfort, Construction innovation, and Improvement in sustainability rating (Daim et al., 2009; Smith and Earl, 2009; Korkmaz et al., 2010; Rosenbaum et al., 2013; Popaitoon, and Siengthai, 2014; Olanipekun et al., 2017; Tengan, 2018; Emere et al., 2019). Hence, this study proposes that project delivery success criteria can be obtained if sustainable building construction is effectively practised considering the facilitating factors such as the Regulatory environment, Knowledge sharing, Corporate disposition, Project delivery strategy, Project management techniques, and Modern building techniques. Table 8.8 presents the outcome variables for the latent construct – Integrated Sustainable Building Construction Project Delivery (ISBCPD) in this study.

**Table 8. 8**: Integrated SBC project delivery outcome variables

| Label | Measuring variables | Citations |
|---|---|---|
| ISBCPD1 | Projects completion with no time overrun | Ogunsanya (2018); Tengan (2018); Emere et al. (2019) |
| ISBCPD2 | Project completion with no cost overrun | Ogunsanya (2018); Tengan (2018); Emere et al. (2019) |
| ISBCPD3 | Achievement of prescribed quality requirements | Ogunsanya (2018); Tengan (2018); Emere et al. (2019) |
| ISBCPD4 | Construction stakeholders/Client Satisfaction | Ogunsanya (2018); Tengan (2018); Emere et al. (2019) |
| ISBCPD5 | End-user satisfaction | Ogunsanya (2018); Tengan (2018); Emere et al. (2019) |
| ISBCPD6 | Value for money | Ogunsanya (2018); Tengan (2018); Emere et al. (2019) |
| ISBCPD7 | Environmental objectives met | Du et al. (2016); Tengan (2018) |
| ISBCPD8 | Health safety and comfort | Ngacho and Das (2014); Jimoh et al. (2015); ); Emere et al. (2019) |
| ISBCPD9 | Construction innovation | Eriksson and Westerberg (2009) |
| ISBCPD10 | Improvement in sustainability rating | Korkmaz et al. (2010); Oke et al. (2018); Olanipekun et al. (2018) |

## 8.2 Chapter Conclusion

This chapter discussed the proposed conceptual model, which expressed that Sustainable Building Construction (SBC) is a multi-dimensional structure comprising six latent independent

variables such as regulatory environment, knowledge sharing, corporate disposition, project delivery strategy, project management techniques, and modern building techniques. It further presented an intermediate construct, SBC implementation, and dependent construct, integrated SBC project delivery outcomes. The latent constructs measuring variables were derived from the literature review and supported by the questionnaire survey. The next chapter discusses the result of the questionnaire survey.

# CHAPTER NINE

# RESULTS PRESENTATION

## 9.0 Introduction

This chapter presents the results of the analysis from the questionnaire data collected. Firstly, it presents the descriptive statistics results. Secondly, it presents the results of the inferential statistics which includes exploratory and confirmatory factor analysis. Thirdly, it presents the results of the reliability and validity of the measuring instruments/variables, and the model fit measurements of the latent constructs. Finally, it presents the full structural model results.

## 9.1 Descriptive Statistics

### 9.1.1 Demographic profile of respondents

This section presents the demographic summary of the respondents which includes educational qualifications, professional background, work/organisational sector, project type, project role, and industrial experience. Table 9.1 presents the results with the frequencies and percentages arranged according to rankings.

According to Table 9.1, respondents with Honours/Btech degrees were predominant and ranked first. Followed by those with master's degrees, bachelor's degrees, national diplomas, and doctorates in descending order. Considering the educational backgrounds, the respondents were found most eligible to participate in the current study and results showed that the distribution of the responses were fair enough.

Regarding *professional background* in Table 9.1, most of the respondents were from *construction management (1st)*, followed by *engineering*, *quantity surveying, project management, architecture, town/urban and regional planning in descending order*. The sample

accommodated the various backgrounds within the South African Built Environment (Council for the Built Environment (CBE), 2018). This contributed to authenticating the collected data.

The study also investigated the different *organisation/work sectors* the respondents were engaged in. Hence, results in Table 9.1 shows that those in the *consultant sector* were predominant, followed by *contractors, government agency*, and *private sector* respectively. The consideration of these sectors ensured that the generalisation of the findings will not be centred solely on one sector's point of view.

**Table 9. 1**:Demographic profile of respondents

| Classification | Features | Frequency | Percentage (%) | Rank |
|---|---|---|---|---|
| Educational Qualification | Honours/Btech. degree | 126 | 44.8 | **1st** |
| | Master's degree | 68 | 24.2 | **2nd** |
| | Bachelor's degree | 41 | 14.6 | **3rd** |
| | National diploma | 30 | 10.7 | **4th** |
| | Doctorate | 16 | 5.7 | **5th** |
| Professional Background | Construction management | 60 | 21.4 | **1st** |
| | Engineering | 58 | 20.6 | **2nd** |
| | Quantity surveying | 56 | 19.6 | **3rd** |
| | Project management | 48 | 17.1 | **4th** |
| | Architecture | 41 | 14.6 | **5th** |
| | Town and urban/regional planning | 17 | 6.0 | **6th** |
| | Other | 1 | 0.4 | **7th** |
| Organisational/Work sector | Consultant | 97 | 34.5 | **1st** |
| | Contractor | 74 | 26.3 | **2nd** |
| | Government agency | 70 | 24.9 | **3rd** |
| | Private sector | 40 | 14.2 | **4th** |

Regarding the *type of project works*, Table 18 shows that respondents in *building construction works* were preeminent, followed by *civil*, *electrical*, and *mechanical engineering works* respectively. Other, project works, was the least ranked and they included human settlement

projects. Hence, the findings covered the predominant project works affiliated with construction and generalisation can be based on the mentioned project types.

The respondents also participated in various project roles in construction. Table 9.1 shows that those who participated as *project managers/leaders* were ranked first. This is followed by *construction managers*, *quantity surveyors, project engineers,* and *principal agents*. Those who participated as *town planners* were the penultimately least ranked roles. The least ranked included other roles not mentioned. Nonetheless, the project roles in this study indicate that respondents were suitable to participate in the current study.

**Table 9.1 (continued):** Demographic profile of respondents

| Classification | Features | Frequency | Percentage (%) | Rank |
|---|---|---|---|---|
| Project Works Type | Building construction works | 151 | 53.7 | **1st** |
| | Civil engineering works | 89 | 31.7 | **2nd** |
| | Electrical engineering works | 15 | 5.3 | **3rd** |
| | Mechanical engineering works | 14 | 5.0 | **4th** |
| | Other | 12 | 4.3 | **5th** |
| Project Role | Project Manager | 93 | 33.1 | **1st** |
| | Construction Manager | 48 | 17.1 | **2nd** |
| | Quantity Surveyor | 46 | 16.4 | **3rd** |
| | Project Engineer | 42 | 14.9 | **4th** |
| | Principal Agent | 25 | 8.9 | **5th** |
| | Town Planner | 16 | 5.7 | **6th** |
| | Other | 11 | 3.9 | **7th** |
| Industrial Experience | 6-10 years | 55 | 19.6 | **1st** |
| | 1-5 years | 51 | 18.1 | **2nd** |
| | 11-15 years | 44 | 15.7 | **3rd** |
| | 16-20 years | 41 | 14.6 | **4th** |
| | 21-25 years | 32 | 11.4 | **5th** |
| | 26-30 years | 23 | 8.1 | **6th** |
| | Less than 12 months | 19 | 6.8 | **7th** |
| | More than 30 years | 16 | 5.7 | **8th** |

Finally, respondents' construction industrial experience was ascertained. Results in Table 9.1 shows that those with 6 to 10 years' experience were many as they were ranked first. They were followed by those with 1 to 5 years, and 11 to 15 years respectively. The least ranked was those with more than 30 years' experience, and less than 12 months experience in ascending order.

## 9.1.2 Description of sustainable building construction determinants

This section presents the descriptive statistics of each measuring variable in each exogenous latent constructs of this study. The latent exogenous constructs include Regulatory Environment (RE), Knowledge Sharing (KS), Corporate Disposition (CD), Project Delivery Strategies (PDS), Project Management Techniques (PMT), and Modern Building Techniques (MBT).

### *9.1.2.1 Regulatory environment (RE)*

Table 9.2 presents the regulatory environment factors influencing sustainable building construction implementation for project delivery in South Africa. The Built Environment respondents were asked to rate the extent of influence of the measuring variables under this latent construct on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables. Table 9.1 shows that all the variables achieved MS value $\geq 3.86 \leq 4.22$ which indicates a significant influence. However, some variables were more notable than orders. The *green building council of South Africa standards* was ranked first, recording a MS value of 4.22 and SD value of 0.821. Second and third were the *national environmental management regulations* (MS=4.15; SD=0.814), and the *department of public works green building policy* (MS=4.14; SD=0.826) respectively. However, *government-a driving force more than the market* (MS=3.93; SD=0.963), and *incentives for the companies that are building sustainably* (MS=3.86; 0.929) were ranked tenth and eleventh respectively. Nevertheless, the MS values showed a general indication of the significant influence of the variables. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.916 above the threshold of 0.70 (Pallant, 2020).

**Table 9. 2**: RE factors influencing SBC implementation for project delivery

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **RE2** | Green building council of South Africa standards | 281 | 4.22 | 0.821 | **1st** |
| **RE4** | National environmental management regulations | 281 | 4.15 | 0.814 | **2nd** |
| **RE3** | Department of public works green building policy | 281 | 4.14 | 0.826 | **3rd** |
| **RE11** | Compulsory sustainable building certification | 281 | 4.12 | 0.897 | **4th** |
| **RE10** | Compulsory enforcement of sustainable construction laws | 281 | 4.10 | 0.854 | **5th** |
| **RE9** | Compulsory sustainable building assessment | 281 | 4.08 | 0.912 | **6th** |
| **RE8** | Integrating environmental studies in construction | 281 | 4.00 | 0.864 | **7th** |
| **RE1** | National building standards act | 281 | 4.00 | 0.839 | **7th** |
| **RE5** | Laws ensuring the sustainability of resources | 281 | 3.98 | 0.857 | **9th** |
| **RE6** | Government-a driving force more than the market | 281 | 3.93 | 0.963 | **10th** |
| **RE7** | Incentives for the companies that are building sustainably | 281 | 3.86 | 0.929 | **11th** |
| **CRONBACH'S ALPHA** | | **0.916** | | | |

### *9.1.2.2 Knowledge sharing (KS)*

Table 9.3 presents the knowledge sharing factors influencing sustainable building construction implementation for project delivery in South Africa. The respondents were asked to rate the extent of influence of the measuring variables under this latent construct on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables. Table 9.3 shows that all the variables recorded MS value $\geq 4.09 \leq 4.38$ which indicates a significant contribution. However, some variables were more notable than others. The first ranked were *Mentoring younger professionals in sustainable practices* (MS=4.38; SD=0.771) and *public awareness of environmental issues* (MS=4.38 and SD=0.765). Although both had the same MS value of 4.38, the one with larger SD showed a lot of variance in the observed data around the mean while the other with smaller SD showed a high level of consensus to the mean (Altman and Bland, 2005). The third was *awareness creation of green building products (MS=4.30; SD=0.813) respectively.*

**Table 9. 3**: KS factors influencing SBC implementation for project delivery

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **KS12** | Mentoring younger professionals in sustainable practices | 281 | 4.38 | 0.771 | **1st** |
| **KS2** | Public awareness of environmental issues | 281 | 4.38 | 0.765 | **1st** |
| **KS11** | Awareness creation of green building products | 281 | 4.30 | 0.813 | **3rd** |
| **KS1** | Education on sustainable practices among staff | 281 | 4.28 | 0.856 | **4th** |
| **KS3** | Educational and training programs upgrade | 281 | 4.27 | 0.836 | **5th** |
| **KS4** | Sustainable building construction integration in professional certifications | 281 | 4.24 | 0.795 | **6th** |
| **KS10** | Creating public awareness for sustainable practices | 281 | 4.19 | 0.827 | **7th** |
| **KS6** | Information hub or repository for sustainable construction | 281 | 4.18 | 0.876 | **8th** |
| **KS9** | Sustainable building materials awareness creation | 281 | 4.15 | 0.861 | **9th** |
| **KS5** | Content of Sustainable building construction training | 281 | 4.11 | 0.825 | **10th** |
| **KS7** | Collaboration with foreign companies for knowledge transfer | 281 | 4.10 | 0.937 | **11th** |
| **KS8** | Promoting local green products through research | 281 | 4.09 | 0.862 | **12th** |
| **CRONBACH'S ALPHA** | | **0.956** | | | |

However, *collaboration with foreign companies for knowledge transfer* (MS=4.10; SD=0.937) and *promoting local green products through research* (MS=4.09; 0.862) were ranked eleventh and twelfth respectively. Nevertheless, the MS values of all the measuring variables showed a general indication of their significant contribution. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.956 above the threshold of 0.70 (Pallant, 2020).

### *9.1.2.3 Corporate disposition (CD)*

Table 9.4 presents the corporate disposition factors influencing sustainable building construction implementation for project delivery in South Africa. The respondents were asked to rate the extent of influence of the measuring variables under the latent construct on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables. Table 9.4 shows that all the variables recorded MS value $\geq 4.03 \leq 4.38$ which indicates a significant contribution. However, some variables were more distinguished than others. The first ranked was *top management support*

with a MS value of 4.38 and SD value of 0.829. Second and third were the *availability of competent personnel* (MS=4.35; SD=0.848), and the *availability of finance for the project operation* (MS=4.32; SD=0.805) respectively. However, *alternate funding systems consideration for sustainable building construction* (MS=4.06; SD=0.830), and *pressure from the competitor's corporate involvement* (MS=4.03; 0.892) were ranked twelfth and thirteenth respectively. Nevertheless, the MS values showed an overall indication of the significant influence of the variables. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.956 above the threshold of 0.70 (Pallant, 2020).

**Table 9. 4:** CD factors influencing SBC implementation for project delivery

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **CD3** | Top management support | 281 | 4.38 | 0.829 | **1st** |
| **CD4** | Availability of competent personnel | 281 | 4.35 | 0.848 | **2nd** |
| **CD5** | Availability of finance for the project operation | 281 | 4.32 | 0.805 | **3rd** |
| **CD8** | Good project management culture | 281 | 4.27 | 0.796 | **4th** |
| **CD12** | Stakeholders' involvement and commitment | 281 | 4.23 | 0.842 | **5th** |
| **CD9** | Commitment to innovative construction | 281 | 4.22 | 0.863 | **6th** |
| **CD2** | Social responsibility to protect the environment | 281 | 4.16 | 0.800 | **7th** |
| **CD11** | Good intra-organisational leadership | 281 | 4.15 | 0.795 | **8th** |
| **CD1** | Identification of organisational benefits of adopting sustainable building construction | 281 | 4.13 | 0.917 | **9th** |
| **CD13** | Cultural change promotion for sustainability | 281 | 4.12 | 0.864 | **10th** |
| **CD10** | Quest for competitive advantage over counterparts | 281 | 4.10 | 0.858 | **11th** |
| **CD6** | Alternate funding systems consideration for sustainable building construction | 281 | 4.06 | 0.830 | **12th** |
| **CD7** | Pressure from the competitor's corporate involvement | 281 | 4.03 | 0.892 | **13th** |
| **CRONBACH'S ALPHA** | | **0.956** | | | |

### *9.1.2.4 Project delivery strategies (PDS)*

Project delivery strategies is the first gap identified for this study. Table 9.5 presents the project delivery strategies influencing sustainable building construction implementation in South Africa. The respondents were asked to rate the extent of influence of the measuring variables under this latent construct on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables. Table 9.5 shows that all the variables recorded MS value $\geq 3.34 \leq 4.36$. Some variables were firmly recognised, when compared to others.

**Table 9. 5**:Project delivery strategies influencing SBC implementation

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **PDS10** | Early involvement of stakeholders | 281 | 4.36 | 0.795 | **1st** |
| **PDS9** | Collaboration of project participants | 281 | 4.25 | 0.768 | **2nd** |
| **PDS1** | Client needs assessment | 281 | 4.21 | 0.808 | **3rd** |
| **PDS5** | Integrated project delivery system | 281 | 3.95 | 0.893 | **4th** |
| **PDS7** | Public-private partnerships | 281 | 3.94 | 0.922 | **5th** |
| **PDS8** | Delivery methods with a single contracting point | 281 | 3.90 | 0.898 | **6th** |
| **PDS4** | Construction management/general contractor method | 281 | 3.82 | 0.894 | **7th** |
| **PDS14** | Usage of targeted procurement method | 281 | 3.75 | 0.887 | **8th** |
| **PDS6** | Turnkey system | 281 | 3.72 | 0.938 | **9th** |
| **PDS18** | Usage of government budgetary allocations | 281 | 3.70 | 0.979 | **10th** |
| **PDS3** | Design and build system | 281 | 3.70 | 0.904 | **10th** |
| **PDS17** | Usage of multiple criteria selection method | 281 | 3.68 | 0.872 | **12th** |
| **PDS19** | Usage of private sector funds | 281 | 3.68 | 0.952 | **12th** |
| **PDS12** | Usage of negotiated tendering method | 281 | 3.63 | 0.985 | **14th** |
| **PDS13** | Usage of the selective tendering method | 281 | 3.62 | 0.931 | **15th** |
| **PDS16** | Usage of cost-reimbursable contracts | 281 | 3.58 | 0.990 | **16th** |
| **PDS11** | Usage of open tendering method | 281 | 3.54 | 1.049 | **17th** |
| **PDS15** | Usage of lump sum contracts | 281 | 3.41 | 1.059 | **18th** |
| **PDS2** | Traditional project delivery system (Design-Bid-Build) | 281 | 3.34 | 1.043 | **19th** |
| **CRONBACH'S ALPHA** | | **0.943** | | | |

The first ranked was *early involvement of stakeholders* with a MS value of 4.36 and SD value of 0.795. Second and third were the *collaboration of project participants* (MS=4.25; SD=0.768), and the *client needs assessment* (MS=4.21; SD=0.808) respectively. Additionally, the fourth and fifth ranked were *integrated project delivery system* (MS=3.95; 0.893) and *public-private partnerships* (MS=3.94; 0.922). However, *usage of open tendering method* (MS=3.54; SD=1.049), *usage of lump sum contracts* (MS=3.41; 1.059), *traditional project delivery system (Design-Bid-Build)* were ranked seventeenth, eighteenth, and nineteenth respectively. Nevertheless, the MS values showed an indication of the significant influence of all the variables. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.943 above the threshold of 0.70 (Pallant, 2020).

#### *9.1.2.5 Project management techniques (PMT)*

Project management techniques is the second gap identified in this study. Table 9.6 presents the project management techniques influencing sustainable building construction implementation for project delivery. The respondents were asked to rate the extent of influence of the measuring variables under this latent construct on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables.

Table 9.6 shows that all the variables recorded MS value $\geq 4.21 \leq 4.51$ which indicates a significant contribution. However, some variables were more notable than others. The first ranked was *quality management techniques* with a MS value of 4.51 and SD value of 0.723. Second was the *cost management techniques* (MS=4.50; SD=0.728). Third were *stakeholder management techniques* (MS=4.42; SD=0.713) and *risk management techniques* (MS=4.42; SD=0.825). Although both had the same MS value of 4.42, the one with smaller SD showed a high level of consensus to the mean while the other with larger SD showed a lot of variances in the observed data around the mean (Altman and Bland, 2005). The eleventh and twelfth ranked techniques were *exploratory techniques* (MS=4.27; 0.777), and *appropriate project management methodology* (MS=4.21; 0.873) respectively. Nevertheless, the MS values showed a good

indication of the significant influence of all the variables. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.952 above the threshold of 0.70 (Pallant, 2020).

**Table 9. 6**:Project management techniques influencing SBC implementation for project delivery

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **PMT8** | Quality management techniques | 281 | 4.51 | 0.723 | **1st** |
| **PMT7** | Cost management techniques | 281 | 4.50 | 0.728 | **2nd** |
| **PMT10** | Stakeholder management techniques | 281 | 4.42 | 0.713 | **3rd** |
| **PMT9** | Risk management techniques | 281 | 4.42 | 0.825 | **3rd** |
| **PMT6** | Time management techniques | 281 | 4.41 | 0.774 | **5th** |
| **PMT5** | Procurement management techniques | 281 | 4.38 | 0.718 | **6th** |
| **PMT12** | Environmental management system | 281 | 4.37 | 0.764 | **7th** |
| **PMT2** | Scope management techniques | 281 | 4.35 | 0.801 | **8th** |
| **PMT11** | Communication management techniques | 281 | 4.31 | 0.811 | **9th** |
| **PMT3** | Integration management techniques | 281 | 4.30 | 0.807 | **10th** |
| **PMT4** | Exploratory techniques | 281 | 4.27 | 0.777 | **11th** |
| **PMT1** | Appropriate project management methodology | 281 | 4.21 | 0.873 | **12th** |
| **CRONBACH'S ALPHA** | | **0.952** | | | |

### *9.1.2.6 Modern building techniques (MBT)*

This latent construct is the third gap of the current study. Table 9.7 presents the modern building techniques influencing sustainable building construction implementation for project delivery. The respondents were asked to rate the extent of influence of the measuring variables under this latent construct on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables. Table 9.7 shows that all the variables recorded MS value $\geq 3.93 \leq 4.35$ which indicates a significant contribution. However, some variables were more notable than others. The first ranked was *value engineering/management* with a MS value of 4.35 and SD value of 0.769. Second was the *industrialised building systems (IBS)* (MS=4.18; SD=0.779) and third was *lean*

*techniques* (MS=4.17; SD=0.866). However, the penultimate ranked was *big data analytics* (MS=3.99; 0.900), while the least ranked was *two-stage open-book procurement models* (MS=3.93; 0.944). Nevertheless, the MS values showed an overall indication of the significant influence of all the variables. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.926 above the threshold of 0.70 (Pallant, 2020).

**Table 9. 7**:Modern building techniques influencing SBC implementation for project delivery

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **MBT3** | Value engineering/management | 281 | 4.35 | 0.769 | **1st** |
| **MBT4** | Industrialised building systems (IBS) | 281 | 4.18 | 0.779 | **2nd** |
| **MBT2** | Lean techniques | 281 | 4.17 | 0.866 | **3rd** |
| **MBT1** | Building information management (BIM) | 281 | 4.16 | 0.919 | **4th** |
| **MBT5** | Supply chain management systems | 281 | 4.12 | 0.808 | **5th** |
| **MBT6** | Big data analytics | 281 | 3.99 | 0.900 | **6th** |
| **MBT7** | Two-stage open-book procurement models | 281 | 3.93 | 0.944 | **7th** |
| **CRONBACH'S ALPHA** | | **0.926** | | | |

### 9.1.3 Description of sustainable building construction implementation (SBCI)

This latent construct (SBCI) served as a mediating construct to integrated SBC project delivery. In this construct, the expected deliverables for practising sustainable building construction were presented as shown in Table 9.8. The respondents were asked to rate the extent to which the deliverables are essential in achieving sustainable building construction on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables. Table 9.8 shows that all the variables recorded MS value $\geq 4.07 \leq 4.41$. Nonetheless, some variables were more notable than others. The first and second ranked were *sustainable and efficient designs* (MS=4.41; SD=0.726) and *sustainable structural materials* (MS=4.39; SD=0.719) respectively. The third were *energy consumption minimisation* (MS=4.33; SD=0.838), *consideration of supplementary energy systems* (MS=4.33; SD=0.820), and *usage of renewable resources* (MS=4.33; 0.802). However,

the penultimate ranked feature was *Impact consideration on social background* (MS=4.12; 0.910), while the least ranked was *Usage of biodegradable materials* (MS=4.07; 0.985). Nevertheless, the MS values showed a good indication of the significance of all the variables. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.978 above the threshold of 0.70 (Pallant, 2020).

**Table 9. 8**:Sustainable building construction implementation features

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **SBCI2** | Sustainable and efficient designs | 281 | 4.41 | 0.726 | **1st** |
| **SBCI3** | Sustainable structural materials | 281 | 4.39 | 0.719 | **2nd** |
| **SBCI12** | Energy consumption minimisation | 281 | 4.33 | 0.838 | **3rd** |
| **SBCI13** | Consideration of supplementary energy systems | 281 | 4.33 | 0.820 | **3rd** |
| **SBCI14** | Usage of renewable resources | 281 | 4.33 | 0.802 | **3rd** |
| **SBCI22** | Compliance with sustainability assessment measures | 281 | 4.32 | 0.804 | **6th** |
| **SBCI7** | Promotion of waste material recyclability | 281 | 4.32 | 0.818 | **6th** |
| **SBCI21** | Compliance with regulations on sustainable practices | 281 | 4.32 | 0.772 | **6th** |
| **SBCI17** | Green procurement | 281 | 4.32 | 0.812 | **6th** |
| **SBCI15** | Consideration of the project's effect on air, soil, water etc. | 281 | 4.31 | 0.819 | **10th** |
| **SBCI4** | Minimisation of the use of non-renewable goods | 281 | 4.30 | 0.795 | **11th** |
| **SBCI16** | Water usage minimisation | 281 | 4.30 | 0.825 | **11th** |
| **SBCI6** | Decrease in generating waste | 281 | 4.29 | 0.828 | **13th** |
| **SBCI23** | Improved use of construction resources | 281 | 4.28 | 0.795 | **14th** |
| **SBCI8** | Usage of waste in making construction materials | 281 | 4.25 | 0.847 | **15th** |
| **SBCI11** | Protection of biodiversity and ecology | 281 | 4.25 | 0.837 | **15th** |
| **SBCI9** | Usage of materials with low carbon footprint | 281 | 4.25 | 0.833 | **15th** |
| **SBCI20** | Minimisation of pollution and greenhouse gas emission | 281 | 4.25 | 0.874 | **15th** |
| **SBCI18** | Usage of Smart appliances | 281 | 4.24 | 0.852 | **19th** |
| **SBCI1** | Sustainability indicators in project briefs | 281 | 4.24 | 0.786 | **19th** |
| **SBCI24** | Diminished operational and utility costs in building | 281 | 4.23 | 0.828 | **21st** |
| **SBCI10** | Decrease in the use of toxic materials | 281 | 4.22 | 0.834 | **22nd** |
| **SBCI19** | Impact consideration on social background | 281 | 4.12 | 0.910 | **23rd** |
| **SBCI5** | Usage of biodegradable materials | 281 | 4.07 | 0.985 | **24th** |
| **CRONBACH'S ALPHA** | | **0.978** | | | |

### 9.1.4 Description of integrated SBC project delivery

This latent construct (ISBCPD) served as the endogenous construct to be achieved due to effective implementation of SBC and SBC-determinants' contributions. Hence, in this construct, the expected deliverables were presented as shown in Table 9.9. The respondents were asked to rate the extent to which the deliverables will be achieved because of effective implementation of SBC and due to SBC-determinants' contributions on a 5-point Likert scale ranging from 1 (no extent) to 5 (very high extent). The mean score (MS) and standard deviation (SD) were used as outputs to rank the measuring variables. Table 9.9 shows that all the variables recorded MS value $\geq 4.00 \leq 4.42$. Nonetheless, some variables were more notable than others. The first and second ranked were *improvement in sustainability rating* (MS=4.42; SD=0.775) and *construction innovation* (MS=4.40; SD=0.705) respectively. The third were *environmental objectives met* (MS=4.35; SD=0.712) and *construction stakeholders/client satisfaction* (MS=4.35; SD=0.787). Although both had the same MS value of 4.35, the one with smaller SD showed a high level of consensus to the mean while the other with larger SD showed a lot of variance in the observed data around the mean (Altman and Bland, 2005). The penultimate ranked variable was *project completion with no cost overrun* (MS=4.03; 0.790), while the least ranked was *Usage of biodegradable materials* (MS=4.00; 0.817). Nevertheless, the MS values showed a good indication of the significance of all the variables. Furthermore, the measuring variables' internal consistency and reliability were excellent, with Cronbach's alpha value of 0.954 above the threshold of 0.70 (Pallant, 2020).

**Table 9. 9**:Integrate SBC project delivery outcomes

| Code | Variable | N | MS | SD | Rank |
|---|---|---|---|---|---|
| **ISBCPD10** | Improvement in sustainability rating | 281 | 4.42 | 0.775 | **1st** |
| **ISBCPD9** | Construction innovation | 281 | 4.40 | 0.705 | **2nd** |
| **ISBCPD7** | Environmental objectives met | 281 | 4.35 | 0.712 | **3rd** |
| **ISBCPD4** | Construction stakeholders/Client Satisfaction | 281 | 4.35 | 0.787 | **3rd** |
| **ISBCPD3** | Achievement of prescribed quality requirements | 281 | 4.32 | 0.729 | **5th** |
| **ISBCPD8** | Health safety and comfort | 281 | 4.32 | 0.744 | **5th** |
| **ISBCPD5** | End-user satisfaction | 281 | 4.31 | 0.761 | **7th** |

| | | | | | |
|---|---|---|---|---|---|
| **ISBCPD6** | Value for money | 281 | 4.30 | 0.753 | **8th** |
| **ISBCPD2** | Project completion with no cost overrun | 281 | 4.03 | 0.790 | **9th** |
| **ISBCPD1** | Projects completion with no time overrun | 281 | 4.00 | 0.817 | **10th** |
| **CRONBACH'S ALPHA** | | **0.954** | | | |

## 9.2 Inferential Statistics

This process started with exploratory factor analysis (EFA) after which confirmatory factor analysis (CFA) was done as well as the structural equation modelling. This process of making inferences was predominantly done using the technique of structural equation modelling (SEM) through the AMOS software version 29. With SEM, all the model's coefficients were simultaneously estimated, and the model's overall significance and relationship strength were assessed. However, factor analysis (EFA and CFA) was done as a prelude to support the SEM analysis of the constructs' variables and was pivotal in enhancing the robustness of the SEM analysis (Bentler, 2005; Kline, 2010; Ogunsanya, 2018). EFA helped in producing fewer linear combinations of the original variables that reflect most of the variability in the correlation pattern through principal component analysis (Pallant, 2020). CFA on the other hand, helped in confirming the specific hypotheses or theories concerning the structure of the set of variables (Pallant, 2020). CFA was also essential for determining the variables in each latent construct, the best fit for the model before performing the SEM.

### 9.2.1 Exploratory factor analysis (EFA)

The integrated conceptual model variables were subjected to exploratory factor analysis (EFA) using the extraction method of principal component analysis (PCA) and varimax rotation. Varimax rotation enabled the use of rotated component matrix to yield and accomplish simple robust structure and results easy to identify and interpret (Field, 2009). However, before the run of EFA, relevant checks were performed to ascertain the suitability of the collected data. Besides, the sample size determination detailed in chapter 7 (Research methodology) section 7.4.3, checks such as the Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) test for

sampling adequacy were undertaken. The sample size 281 met all the criteria stipulated (Nunally, 1994; Pallant, 2020; Tengan, 2018).

The Bartlett's test of sphericity assesses the significance level of the data for factor analysis and the value must be less than 0.05 ($p<0.05$). Similarly, a minimum of 0.6 was proposed for KMO value for a good factor analysis (Netemeyer and Bearden 2003; Burton and Mazerolle, 2011 Tabachnick and Fidell, 2013; Pallant, 2020).

Regarding the run of EFA and extraction of principal components, eigenvalues greater than one (>1) were considered and was used to explain the variance captured by a factor/component. Hence, eigenvalues less than one were rejected (Tabachnick and Fidell, 2013; Pallant, 2020). Communalities extractions were checked. The communality check allows for the removal of variables with values less than 0.5 (Hair et al., 2013). Similarly, regarding the rotations, variables with cross loadings were not considered to be part of the grouping of any of the component factors (Pallant, 2020). Furthermore, reliability and internal consistency check were done for the component factors to ensure all met the cut of value of 0.7.

#### *9.2.1.1 EFA for regulatory environment (RE)*

Tables 9.10 to 9.14 present the results of the EFA for regulatory environment factors influencing sustainable building construction for project delivery in South Africa. Eleven (11) RE measuring variables were analysed with EFA. Principal component analysis (PCA) and varimax methods were used for extraction and rotation respectively. Table 9.10 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.**

**Table 9. 10**:KMO and Bartlett's test for RE variables

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.889 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 2134.112 |
| | df | 55 |
| | Sig. | <0.001 |

KMO value was 0.889 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity results showed statistical significance value of 0.001 (<0.05).

Table 9.11 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 11**: Communalities for RE

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **RE1** | National building standards acts | 1.000 | 0.555 |
| **RE2** | Green building council of South Africa standards | 1.000 | 0.588 |
| **RE3** | Department of public works green building policy | 1.000 | 0.696 |
| **RE4** | National environmental management regulations | 1.000 | 0.573 |
| **RE5** | Laws ensuring the sustainability of resources | 1.000 | 0.702 |
| **RE6** | Government-a-driving force more than the market | 1.000 | 0.598 |
| **RE7** | Incentives for the companies that are building sustainably | 1.000 | 0.618 |
| **RE8** | Integrating environmental studies in construction | 1.000 | 0.591 |
| **RE9** | Compulsory sustainable building assessment | 1.000 | 0.862 |
| **RE10** | Compulsory enforcement of sustainable construction laws | 1.000 | 0.836 |
| **RE11** | Compulsory sustainable building certification | 1.000 | 0.813 |

Likewise, Table 9.12 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering Kaiser's criterion, two principal component factors achieved values greater than one and were extracted with a cumulative percentage variance of 67.57 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018). The principal component one (1) accounted for 55.08% of the total variance explained while the other accounted for 12.49%.

**Table 9. 12**:Total variance explained for RE

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 6.059 | 55.082 | 55.082 | 6.059 | 55.082 | 55.082 |
| 2 | 1.374 | 12.488 | 67.570 | 1.374 | 12.488 | 67.570 |
| 3 | 0.844 | 7.670 | 75.240 | | | |
| 4 | 0.639 | 5.805 | 81.045 | | | |
| 5 | 0.491 | 4.461 | 85.506 | | | |
| 6 | 0.412 | 3.749 | 89.255 | | | |
| 7 | 0.378 | 3.440 | 92.694 | | | |
| 8 | 0.331 | 3.006 | 95.701 | | | |
| 9 | 0.177 | 1.607 | 97.308 | | | |
| 10 | 0.168 | 1.524 | 98.832 | | | |
| 11 | 0.128 | 1.168 | 100.000 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

Table 9.13 presents the rotated component matrix results showing the factor loadings of the regulatory environment measuring variables categorised according to the principal components. The varimax rotated component matrix helped in achieving a simple robust structure and results easier identify and interpret (Field, 2009; Tengan, 2018). The variables loadings in each principal component extracted were strong recording values above 0.5. Similarly, the principal components extracted had more than one variable on them which suggests reasonable results devoid of complicated structures (Field, 2009). The Cronbach's alpha reliability and internal consistency test was also assessed to ascertain the suitability of the items in each of the principal components. However, variables with cross loadings were not considered. Hence, Table 9.14 presents the Cronbach's alpha values of component one (1) and two (2) recording 0.904 and 0.818 respectively.

Principal component factor 1 (compulsory regulatory enforcement and assessment) comprised four variables with their loadings namely, Compulsory sustainable building assessment (0.918), Compulsory enforcement of sustainable construction laws (0.896), Compulsory sustainable building certification (0.874), and Incentives for the companies that are building sustainably

(0.649). Similarly, principal component factor 2 (national green building policies and standards) comprised five variables with their loadings namely, National building standards acts (0.743), National environmental management regulations (0.738), Department of public works green building policy (0.729), and Government-a-driving force more than the market (0.679). The loadings explain the influence of variables on the extracted principal components/factors.

The two principal components extracted were named considering the interrelationships and loadings of the variables/items between them. Component one (1) was named *compulsory regulatory enforcement and assessment* while component two (2) was named *national green building policies and standards.*

**Table 9. 13**: Rotated component matrix for RE

| Code | Variable | Component | |
|---|---|---|---|
| | | 1 | 2 |
| **RE9** | Compulsory sustainable building assessment | 0.918 | |
| **RE10** | Compulsory enforcement of sustainable construction laws | 0.896 | |
| **RE11** | Compulsory sustainable building certification | 0.874 | |
| **RE7** | Incentives for the companies that are building sustainably | 0.649 | |
| **RE8** | Integrating environmental studies in construction | 0.552 | 0.535 |
| **RE1** | National Building Standards acts | | 0.743 |
| **RE4** | National Environmental Management regulations | | 0.738 |
| **RE3** | Department of Public Works Green Building Policy | | 0.729 |
| **RE6** | Government-a driving force more than the market | | 0.679 |
| **RE5** | Laws ensuring the sustainability of resources | 0.541 | 0.640 |
| **RE2** | Green Building Council of South Africa standards | | 0.617 |

**Table 9. 14**:Cronbach's alpha for RE principal components

| Principal Component | Cronbach's Alpha | Number of items |
|---|---|---|
| **1** | 0.904 | 4 |
| **2** | 0.818 | 5 |

### *9.2.1.2 EFA for knowledge sharing (KS)*

Tables 9.15 to 9.17 present the results of the EFA for knowledge sharing factors influencing sustainable building construction for project delivery in South Africa. Twelve (12) KS measuring variables were analysed with EFA. Principal component analysis (PCA) and varimax method were used for extraction and rotation respectively. Table 9.15 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.** KMO value was 0.930 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity result showed statistical significance value of 0.001 (<0.05).

**Table 9. 15**: KMO and Bartlett's test for knowledge sharing variables (KS)

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.930 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 3137.047 |
| | df | 66 |
| | Sig. | <0.001 |

Table 9.16 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 16**:Communalities for KS

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **KS1** | Education on sustainable practices among staff | 1.000 | 0.583 |
| **KS2** | Mentoring younger professionals in sustainable practices | 1.000 | 0.689 |
| **KS3** | Educational and training programs upgrade | 1.000 | 0.661 |
| **KS4** | Sustainable building construction integration in professional certifications | 1.000 | 0.712 |
| **KS5** | Content of Sustainable building construction training | 1.000 | 0.760 |
| **KS6** | Information hub or repository for sustainable construction | 1.000 | 0.698 |
| **KS7** | Collaboration with foreign companies for knowledge transfer | 1.000 | 0.641 |
| **KS8** | Promoting local green products through research | 1.000 | 0.633 |
| **KS9** | Sustainable building materials awareness creation | 1.000 | 0.684 |

| | | | |
|---|---|---|---|
| **KS10** | Creating public awareness for sustainable practices | 1.000 | 0.778 |
| **KS11** | Awareness creation of green building products | 1.000 | 0.724 |
| **KS12** | Public awareness of environmental issues | 1.000 | 0.593 |

Likewise, Table 9.17 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering the Kaiser's criterion, only one principal component factors achieved values greater than one and were extracted and achieved the same percentage and cumulative percentage variance of 67.98 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018).

**Table 9. 17**:Total variance explained for KS

| **Component** | **Initial Eigenvalues** | | | **Extraction Sums of Squared Loadings** | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 8.157 | 67.976 | 67.976 | 8.157 | 67.976 | 67.976 |
| 2 | 0.780 | 6.496 | 74.473 | | | |
| 3 | 0.634 | 5.280 | 79.753 | | | |
| 4 | 0.525 | 4.374 | 84.127 | | | |
| 5 | 0.432 | 3.597 | 87.724 | | | |
| 6 | 0.347 | 2.894 | 90.618 | | | |
| 7 | 0.271 | 2.258 | 92.875 | | | |
| 8 | 0.222 | 1.849 | 94.725 | | | |
| 9 | 0.189 | 1.575 | 96.300 | | | |
| 10 | 0.174 | 1.450 | 97.749 | | | |
| 11 | 0.155 | 1.288 | 99.037 | | | |
| 12 | 0.116 | 0.963 | 100.000 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

Notably, there was no rotation because only one component factor was extracted. Similarly, the Cronbach's alpha reliability and internal consistency test result were the same for descriptive statistics in Table 9.3 which was 0.956. Moreover, the principal component extracted retained the name, *knowledge sharing*, considering there was no rotation. This indicates that all the knowledge sharing measuring variables will be considered for the structural equation modelling (SEM) analysis.

### *9.2.1.3 EFA for corporate disposition (CD)*

Tables 9.18 to 9.20 present the results of the EFA for corporate disposition factors influencing sustainable building construction for project delivery in South Africa. Thirteen (13) CD measuring variables were analysed with EFA. Principal component analysis (PCA) and varimax method were used for extraction and rotation respectively. Table 9.18 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.** KMO value was 0.939 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity result showed statistical significance value of 0.001 (<0.05).

**Table 9. 18**:KMO and Bartlett's test for corporate disposition variables (CD)

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.939 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 3153.522 |
| | df | 78 |
| | Sig. | <0.001 |

Table 9.19 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 19**:Communalities for CD

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **CD1** | Identification of organisational benefits of adopting sustainable building construction | 1.000 | 0.634 |
| **CD2** | Social responsibility to protect the environment | 1.000 | 0.666 |
| **CD3** | Top management support | 1.000 | 0.708 |
| **CD4** | Availability of competent personnel | 1.000 | 0.650 |
| **CD5** | Availability of finance for the project operation | 1.000 | 0.600 |
| **CD6** | Alternate funding systems consideration for sustainable building construction | 1.000 | 0.607 |
| **CD7** | Pressure from the competitor's corporate involvement | 1.000 | 0.593 |
| **CD8** | Good project management culture | 1.000 | 0.698 |

| | | | |
|---|---|---|---|
| **CD9** | Commitment to innovative construction | 1.000 | 0.737 |
| **CD10** | Quest for competitive advantage over counterparts | 1.000 | 0.631 |
| **CD11** | Good intra-organisational leadership | 1.000 | 0.712 |
| **CD12** | Stakeholders' involvement and commitment | 1.000 | 0.672 |
| **CD13** | Cultural change promotion for sustainability | 1.000 | 0.647 |

Similarly, Table 9.20 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering the Kaiser's criterion, only one principal component factors achieved values greater than one and were extracted and achieved the same percentage and cumulative percentage variance of 65.80 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018). Notably, there was no rotation because only one component factor was extracted. Similarly, the Cronbach's alpha reliability and internal consistency tests result were the same for descriptive statistics in Table 9.4 which was 0.956. Moreover, the principal component extracted retained the name, *corporate disposition*, considering there was no rotation. This indicates that all the corporate disposition measuring variables will be considered for the structural equation modelling (SEM) analysis.

**Table 9. 20**:Total variance explained for CD

| **Component** | **Initial Eigenvalues** | | | **Extraction Sums of Squared Loadings** | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 8.554 | 65.800 | 65.800 | 8.554 | 65.800 | 65.800 |
| 2 | 0.884 | 6.797 | 72.597 | | | |
| 3 | 0.658 | 5.061 | 77.659 | | | |
| 4 | 0.487 | 3.746 | 81.405 | | | |
| 5 | 0.400 | 3.074 | 84.478 | | | |
| 6 | 0.374 | 2.876 | 87.355 | | | |
| 7 | 0.352 | 2.707 | 90.061 | | | |
| 8 | 0.273 | 2.102 | 92.164 | | | |
| 9 | 0.265 | 2.039 | 94.203 | | | |
| 10 | 0.239 | 1.840 | 96.043 | | | |
| 11 | 0.219 | 1.684 | 97.727 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | 0.165 | 1.272 | 98.999 | | | |
| 13 | 0.130 | 1.001 | 100.000 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

### *9.2.1.4 EFA for project delivery strategies (PDS)*

Tables 9.21 to 9.25 present the results of the EFA for project delivery strategies influencing sustainable building construction in South Africa. Eleven (19) PDS measuring variables were analysed with EFA. Principal component analysis (PCA) and varimax method were used for extraction and rotation respectively. Table 9.21 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.** KMO value was 0.926 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity result showed statistical significance value of 0.001 (<0.05).

**Table 9. 21**:KMO and Bartlett's test for project delivery strategies (PDS)

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.926 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 3713.124 |
| | Df | 171 |
| | Sig. | <0.001 |

Table 9.22 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 22**:Communalities for PDS

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **PDS1** | Client needs assessment | 1.000 | 0.588 |
| **PDS2** | Traditional project delivery system (Design-Bid-Build) | 1.000 | 0.523 |
| **PDS3** | Design and build system | 1.000 | 0.647 |
| **PDS4** | Construction management/general contractor method | 1.000 | 0.625 |
| **PDS5** | Integrated project delivery system | 1.000 | 0.590 |

| | | | |
|---|---|---|---|
| **PDS6** | Turnkey system | 1.000 | 0.674 |
| **PDS7** | Public-private partnerships | 1.000 | 0.773 |
| **PDS8** | Delivery methods with a single contracting point | 1.000 | 0.684 |
| **PDS9** | Collaboration of project participants | 1.000 | 0.691 |
| **PDS10** | Early involvement of stakeholders | 1.000 | 0.672 |
| **PDS11** | Usage of open tendering method | 1.000 | 0.537 |
| **PDS12** | Usage of negotiated tendering method | 1.000 | 0.763 |
| **PDS13** | Usage of the selective tendering method | 1.000 | 0.778 |
| **PDS14** | Usage of targeted procurement method | 1.000 | 0.742 |
| **PDS15** | Usage of lump sum contracts | 1.000 | 0.639 |
| **PDS16** | Usage of cost-reimbursable contracts | 1.000 | 0.726 |
| **PDS17** | Usage of multiple criteria selection method | 1.000 | 0.595 |
| **PDS18** | Usage of government budgetary allocations | 1.000 | 0.680 |
| **PDS19** | Usage of private sector funds | 1.000 | 0.530 |

Likewise, Table 9.23 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering the Kaiser's criterion, three principal component factors achieved values greater than one and were extracted with a cumulative percentage variance of 65.559 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018). The principal component one (1) accounted for 49.995% of the total variance explained, component two (2) accounted for 9.297 while component three (3) accounted for 6.267%.

**Table 9. 23**:Total variance explained for PDS

| **Component** | **Initial Eigenvalues** | | | **Extraction Sums of Squared Loadings** | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 9.499 | 49.995 | 49.995 | 9.499 | 49.995 | 49.995 |
| 2 | 1.767 | 9.297 | 59.292 | 1.767 | 9.297 | 59.292 |
| 3 | 1.191 | 6.267 | 65.559 | 1.191 | 6.267 | 65.559 |
| 4 | 0.963 | 5.068 | 70.627 | | | |
| 5 | 0.780 | 4.108 | 74.735 | | | |
| 6 | 0.669 | 3.523 | 78.258 | | | |
| 7 | 0.547 | 2.880 | 81.138 | | | |
| 8 | 0.510 | 2.684 | 83.822 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | 0.446 | 2.348 | 86.171 | | | |
| 10 | 0.402 | 2.116 | 88.287 | | | |
| 11 | 0.376 | 1.978 | 90.265 | | | |
| 12 | 0.319 | 1.677 | 91.941 | | | |
| 13 | 0.278 | 1.464 | 93.406 | | | |
| 14 | 0.254 | 1.336 | 94.741 | | | |
| 15 | 0.249 | 1.310 | 96.051 | | | |
| 16 | 0.230 | 1.208 | 97.259 | | | |
| 17 | 0.205 | 1.078 | 98.337 | | | |
| 18 | 0.174 | 0.917 | 99.254 | | | |
| 19 | 0.142 | 0.746 | 100.000 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

Table 9.24 presents the rotated component matrix results showing the factor loadings of the project delivery strategy measuring variables categorised according to the principal components. The varimax rotated component matrix helped in achieving a simple robust structure and results easier identify and interpret (Field, 2009; Tengan, 2018). The variables loadings in each principal component extracted were strong recording values above 0.5 except the integrated project delivery system which had no loading. Similarly, the principal components extracted had more than one variable on them which suggests reasonable results devoid of complicated structures (Field, 2009). The Cronbach's alpha reliability and internal consistency test were also assessed to ascertain the suitability of the items in each of the principal components. However, variables with cross loadings were not considered. Hence, Table 9.25 presents the Cronbach's alpha values of component 1, 2, and 3 recording 0.932, 0.820, and 0.766 respectively.

The three principal component factors extracted were named considering the interrelationships and loadings of the variables/items between them. Component one (1) was named *tendering and contractual strategies*, while component two (2) was named *integrated project delivery*. Similarly, component three (3) was named *procurement strategies*.

Principal component factor 1 (tendering and contractual strategies) comprised eleven variables with their loadings namely, Usage of the selective tendering method (0.833), Usage of negotiated

tendering method (0.812), Usage of targeted procurement method (0.772), Usage of lump sum contracts (0.691), Usage of cost-reimbursable contracts (0.684), Usage of open tendering method (0.666), Traditional project delivery system (Design-Bid-Build) (0.657), Usage of multiple criteria selection method (0.656), Usage of private sector funds (0.626), Design and build systems (0.579), and Construction management/general contractor method (0.562).

Similarly, principal component factor 2 (integrated project delivery) comprised four variables with their loadings namely, Collaboration of project participants (0.758), Early involvement of stakeholders (0.747), Client needs assessment (0.713), Delivery methods with a single contracting point (0.697). Additionally, component 3 (procurement strategies) comprised three variables with their loadings namely, Public-private partnerships (0.732), Turnkey system (0.724), and Usage of government budgetary allocations (0.659). The loadings explain the influence of variables on the extracted principal components/factors.

**Table 9. 24**:Rotated component matrix for PDS

| Code | Variable | Component | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| **PDS13** | Usage of the selective tendering method | 0.833 | | |
| **PDS12** | Usage of negotiated tendering method | 0.812 | | |
| **PDS14** | Usage of targeted procurement method | 0.772 | | |
| **PDS15** | Usage of lump sum contracts | 0.691 | | |
| **PDS16** | Usage of cost-reimbursable contracts | 0.684 | | |
| **PDS11** | Usage of open tendering method | 0.666 | | |
| **PDS2** | Traditional project delivery system (Design-Bid-Build) | 0.657 | | |
| **PDS17** | Usage of multiple criteria selection method | 0.656 | | |
| **PDS19** | Usage of private sector funds | 0.626 | | |
| **PDS3** | Design and build system | 0.579 | | |
| **PDS4** | Construction management/general contractor method | 0.562 | | |
| **PDS9** | Collaboration of project participants | | 0.758 | |
| **PDS10** | Early involvement of stakeholders | | 0.747 | |
| **PDS1** | Client needs assessment | | 0.713 | |
| **PDS8** | Delivery methods with a single contracting point | | 0.697 | |

| | | | | |
|---|---|---|---|---|
| **PDS7** | Public-private partnerships | | | 0.732 |
| **PDS6** | Turnkey system | | | 0.724 |
| **PDS18** | Usage of government budgetary allocations | | | 0.659 |
| **PDS5** | Integrated project delivery system | | | |

**Table 9. 25**:Cronbach's alpha for PDS principal components

| Principal Component | Cronbach's Alpha | Number of items |
|---|---|---|
| **1** | 0.932 | 11 |
| **2** | 0.820 | 4 |
| **3** | 0.766 | 3 |

### *9.2.1.5 EFA for project management techniques (PMT)*

Tables 9.26 to 9.30 present the results of the EFA for project management techniques influencing sustainable building construction for project delivery in South Africa. Twelve (12) PMT measuring variables were analysed with EFA. Principal component analysis (PCA) and the varimax method were used for extraction and rotation respectively. Table 9.26 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.** KMO value was 0.912 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity result showed statistical significance value of 0.001 (<0.05).

**Table 9. 26**:KMO and Bartlett's test for project management techniques variables (PMT)

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.912 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 3232.174 |
| | df | 66 |
| | Sig. | <0.001 |

Table 9.27 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 27**:Communalities for PMT

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **PMT1** | Appropriate project management methodology | 1.000 | 0.718 |
| **PMT2** | Scope management techniques | 1.000 | 0.790 |
| **PMT3** | Integration management techniques | 1.000 | 0.828 |
| **PMT4** | Exploratory techniques (meeting, brainstorming etc.) | 1.000 | 0.647 |
| **PMT5** | Procurement management techniques | 1.000 | 0.725 |
| **PMT6** | Time management techniques | 1.000 | 0.796 |
| **PMT7** | Cost management techniques | 1.000 | 0.800 |
| **PMT8** | Quality management techniques | 1.000 | 0.789 |
| **PMT9** | Risk management techniques | 1.000 | 0.780 |
| **PMT10** | Stakeholder management techniques | 1.000 | 0.736 |
| **PMT11** | Communication management techniques | 1.000 | 0.766 |
| **PMT12** | Environmental management system | 1.000 | 0.763 |

Table 9.28 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering Kaiser's criterion, two principal component factors achieved values greater than one and were extracted with a cumulative percentage variance of 76.15 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018). The principal component one (1) accounted for 66.04% of the total variance explained while component two (2) accounted for 10.10%.

**Table 9. 28**: Total variance explained for PMT

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 7.925 | 66.043 | 66.043 | 7.925 | 66.043 | 66.043 |
| 2 | 1.212 | 10.103 | 76.146 | 1.212 | 10.103 | 76.146 |
| 3 | 0.513 | 4.275 | 80.421 | | | |
| 4 | 0.509 | 4.241 | 84.662 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 0.453 | 3.778 | 88.440 | | | |
| 6 | 0.330 | 2.751 | 91.192 | | | |
| 7 | 0.269 | 2.245 | 93.437 | | | |
| 8 | 0.224 | 1.867 | 95.304 | | | |
| 9 | 0.182 | 1.520 | 96.824 | | | |
| 10 | 0.166 | 1.386 | 98.210 | | | |
| 11 | 0.112 | 0.930 | 99.140 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

Table 9.29 presents the rotated component matrix results showing the factor loadings of the PMT measuring variables categorised according to the principal components. The varimax rotated component matrix helped in achieving a simple robust structure and the results were easier to identify and interpret (Field, 2009; Tengan, 2018). The variables loadings in each principal component extracted were strong recording values above 0.5. Similarly, the principal components extracted had more than one variable to them which suggests reasonable results devoid of complicated structures (Field, 2009).

**Table 9. 29**: Rotated component matrix for PMT

| Code | Variable | Component | |
|---|---|---|---|
| | | 1 | 2 |
| **PMT8** | Quality management techniques | 0.870 | |
| **PMT7** | Cost management techniques | 0.834 | |
| **PMT9** | Risk management techniques | 0.826 | |
| **PMT6** | Time management techniques | 0.819 | |
| **PMT12** | Environmental management system | 0.762 | |
| **PMT10** | Stakeholder management techniques | 0.711 | |
| **PMT11** | Communication management techniques | 0.677 | 0.555 |
| **PMT3** | Integration management techniques | | 0.851 |
| **PMT1** | Appropriate project management methodology | | 0.819 |
| **PMT2** | Scope management techniques | | 0.792 |
| **PMT4** | Exploratory techniques | | 0.756 |
| **PMT5** | Procurement management techniques | | 0.705 |

Table 9.30 presents the Cronbach's alpha values of component one (1) and two (2) recording 0.939 and 0.910 respectively. The Cronbach's alpha reliability and internal consistency test was assessed to ascertain the suitability of the items in each of the principal components. Variables with cross loadings were not considered.

**Table 9. 30**: Cronbach's alpha for PMT principal components

| Principal Component | Cronbach's Alpha | Number of items |
|---|---|---|
| **1** | 0.939 | 6 |
| **2** | 0.910 | 5 |

The two principal components extracted were named considering the interrelationships and loadings of the variables/items between them. Component one (1) was named *project schedule and control techniques* while component two (2) was named *project initiation and procurement techniques*.

Principal component factor 1 (project schedule and control techniques) comprised six variables with their loadings namely, Quality management techniques (0.870), Cost management techniques (0.834), Risk management techniques (0.826), Time management techniques (0.819), Environmental management system (0.762), and Stakeholder management techniques (0.711). Similarly, principal component factor 2 (project initiation and procurement techniques) comprised five variables with their loadings, namely, Integration management techniques (0.851), Appropriate project management methodology (0.819), Scope management techniques (0.792), Exploratory techniques (0.756), and Procurement management techniques (0.705). The loadings explain the influence of variables on the extracted principal components/factors.

#### *9.2.1.6 EFA for modern building techniques (MBT)*

Tables 9.31 to 9.33 present the results of the EFA for modern building techniques factors influencing sustainable building construction for project delivery in South Africa. Seven (7) MBT measuring variables were analysed with EFA. Principal component analysis (PCA) and varimax methods were used for extraction and rotation respectively. Table 9.31 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.**

KMO value was 0.906 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity result showed statistical significance value of 0.001 (<0.05).

**Table 9. 31**:KMO and Bartlett's test for modern building techniques variables (MBT)

| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.906 |
|---|---|---|
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1434.875 |
| | df | 21 |
| | Sig. | <0.001 |

Table 9.32 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 32**: Communalities for MBT

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **MBT1** | Building information management (BIM) | 1.000 | 0.702 |
| **MBT2** | Lean techniques | 1.000 | 0.687 |
| **MBT3** | Value engineering/management | 1.000 | 0.635 |
| **MBT4** | Industrialised building systems (IBS) | 1.000 | 0.805 |
| **MBT5** | Supply chain management systems | 1.000 | 0.691 |
| **MBT6** | Big data analytics | 1.000 | 0.725 |
| **MBT7** | Two-stage open-book procurement models | 1.000 | 0.649 |

Table 9.33 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering the Kaiser's criterion, only one principal component factors achieved values greater than one and were extracted and achieved the same percentage and cumulative percentage variance of 69.90 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018).

However, there was no rotation because only one component factor was extracted. Similarly, the Cronbach's alpha reliability and internal consistency test result were the same for descriptive

statistics in Table 9.7 which was 0.926. Moreover, the principal component extracted retained the name, *modern building techniques (MBT)*, considering there was no rotation. This indicates that all the MBT measuring variables will be considered for the structural equation modelling (SEM) analysis.

**Table 9. 33:** Total variance explained for MBT

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 4.893 | 69.904 | 69.904 | 4.893 | 69.904 | 69.904 |
| 2 | 0.622 | 8.882 | 78.785 | | | |
| 3 | 0.442 | 6.317 | 85.102 | | | |
| 4 | 0.334 | 4.774 | 89.876 | | | |
| 5 | 0.296 | 4.227 | 94.104 | | | |
| 6 | 0.227 | 3.240 | 97.344 | | | |
| 7 | 0.186 | 2.656 | 100.000 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

### *9.2.1.7 EFA for sustainable building construction implementation (SBCI)*

Tables 9.34 to 9.38 present the results of the EFA for sustainable building construction implementation features for project delivery in South Africa. Twenty-four (24) SBCI measuring variables were analysed with EFA. Principal component analysis (PCA) and varimax method were used for extraction and rotation respectively. Table 9.34 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.** KMO value was 0.959 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity result showed statistical significance value of 0.001 (<0.05).

**Table 9. 34**:KMO and Bartlett's test for SBCI

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.959 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 7699.136 |

| | | |
|---|---|---|
| | df | 276 |
| | Sig. | <0.001 |

Table 9.35 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 35**:Communalities for SBCI

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **SBCI1** | Sustainability indicators in project briefs | 1.000 | 0.786 |
| **SBCI2** | Sustainable and efficient designs | 1.000 | 0.866 |
| **SBCI3** | Sustainable structural materials | 1.000 | 0.873 |
| **SBCI4** | Minimisation of the use of non-renewable goods | 1.000 | 0.762 |
| **SBCI5** | Usage of biodegradable materials | 1.000 | 0.669 |
| **SBCI6** | Decrease in generating waste | 1.000 | 0.833 |
| **SBCI7** | Promotion of waste material recyclability | 1.000 | 0.851 |
| **SBCI8** | Usage of waste in making construction materials | 1.000 | 0.814 |
| **SBCI9** | Usage of materials with low carbon footprint | 1.000 | 0.795 |
| **SBCI10** | Decrease in the use of toxic materials | 1.000 | 0.658 |
| **SBCI11** | Protection of biodiversity and ecology | 1.000 | 0.690 |
| **SBCI12** | Energy consumption minimisation | 1.000 | 0.721 |
| **SBCI13** | Consideration of supplementary energy systems (solar etc.) | 1.000 | 0.746 |
| **SBCI14** | Usage of renewable resources | 1.000 | 0.752 |
| **SBCI15** | Consideration of the project's effect on air, soil, water etc. | 1.000 | 0.793 |
| **SBCI16** | Water usage minimisation | 1.000 | 0.762 |
| **SBCI17** | Green procurement | 1.000 | 0.772 |
| **SBCI18** | Usage of Smart appliances | 1.000 | 0.707 |
| **SBCI19** | Impact consideration on social background | 1.000 | 0.678 |
| **SBCI20** | Minimisation of pollution and greenhouse gas emission | 1.000 | 0.712 |
| **SBCI21** | Compliance with regulations on sustainable practices | 1.000 | 0.799 |
| **SBCI22** | Compliance with sustainability assessment measures | 1.000 | 0.792 |
| **SBCI23** | Improved use of construction resources | 1.000 | 0.758 |
| **SBCI24** | Diminished operational and utility costs in building | 1.000 | 0.754 |

Likewise, Table 9.36 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering Kaiser's criterion, two principal component factors achieved values greater than one and were extracted with a cumulative percentage variance of 76.440 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018). The principal component 1 accounted for 66.596% of the total variance explained, component 2 accounted for 5.453%, and component 3 accounted for 4.391%.

**Table 9. 36**:Total variance explained for SBCI

| **Component** | **Initial Eigenvalues** | | | **Extraction Sums of Squared Loadings** | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 15.983 | 66.596 | 66.596 | 15.983 | 66.596 | 66.596 |
| 2 | 1.309 | 5.453 | 72.049 | 1.309 | 5.453 | 72.049 |
| 3 | 1.054 | 4.391 | 76.440 | 1.054 | 4.391 | 76.440 |
| 4 | 0.758 | 3.158 | 79.598 | | | |
| 5 | 0.583 | 2.430 | 82.029 | | | |
| 6 | 0.492 | 2.051 | 84.080 | | | |
| 7 | 0.423 | 1.761 | 85.841 | | | |
| 8 | 0.397 | 1.655 | 87.496 | | | |
| 9 | 0.331 | 1.379 | 88.875 | | | |
| 10 | 0.294 | 1.223 | 90.099 | | | |
| 11 | 0.277 | 1.153 | 91.252 | | | |
| 12 | 0.262 | 1.092 | 92.344 | | | |
| 13 | 0.236 | 0.984 | 93.327 | | | |
| 14 | 0.220 | 0.917 | 94.244 | | | |
| 15 | 0.214 | 0.891 | 95.135 | | | |
| 16 | 0.189 | 0.787 | 95.922 | | | |
| 17 | 0.176 | 0.732 | 96.654 | | | |
| 18 | 0.161 | 0.672 | 97.326 | | | |
| 19 | 0.137 | 0.573 | 97.899 | | | |
| 20 | 0.115 | 0.480 | 98.378 | | | |
| 21 | 0.112 | 0.467 | 98.845 | | | |
| 22 | 0.101 | 0.421 | 99.266 | | | |
| 23 | 0.094 | 0.391 | 99.656 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 24 | 0.082 | 0.344 | 100.000 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

Table 9.37 presents the rotated component matrix results showing the factor loadings of the regulatory environment measuring variables categorised according to the principal components. The varimax rotated component matrix helped in achieving a simple robust structure and results easier identify and interpret (Field, 2009; Tengan, 2018). The variables loadings in each principal component extracted were strong recording values above 0.5. Similarly, the principal components extracted. had more than one variable on them which suggests reasonable results devoid of complicated structures (Field, 2009). The Cronbach's alpha reliability and internal consistency test was also assessed to ascertain the suitability of the items in each of the principal components. However, variables with cross loadings were not considered. Hence, Table 9.38 presents the Cronbach's alpha values of component 1, 2 and 3 recording 0.966, 0.931 and 0.913 respectively.

The three principal components extracted were named considering the interrelationships and loadings of the variables/items between them. Component one (1) was named *sustainable resource utilisation and compliance;* component 2 was named *sustainable waste minimisation and recycling,* and component 3 was named *sustainable designs and materials*.

Principal component factor 1 (sustainable resource utilisation and compliance) comprised twelve variables with their loadings namely, Improved use of construction resources (0.788), Compliance to regulations on sustainable practices (0.781), Diminished operational and utility costs in building (0.772), Compliance with sustainability assessment measures (0.772), Water usage minimization (0.755), Consideration of the project's effect on air, soil, water and others. (0.745), Impact consideration on social background (0.724), Minimisation of pollution and greenhouse gas emission (0.708), Energy consumption minimization (0.698), Green procurement (0.686), Usage of Smart appliances (0.656), and Decrease in the use of toxic materials (0.570).

Similarly, principal component factor 2 (sustainable waste minimisation and recycling) comprised five variables with their loadings namely, Promotion of waste material recyclability

(0.818), Decrease in generating waste (0.787), Usage of waste in making construction materials (0.783), Minimisation of the use of non-renewable goods (0.663), and Usage of biodegradable materials (0.623). Furthermore, principal component factor 3 (sustainable designs and materials) comprised three variables with their loadings namely, Sustainable and efficient designs (0.836), Sustainable structural materials (0.819), and Sustainability indicators in project briefs (0.748). The loadings explain the influence of variables on the extracted principal components/factors.

**Table 9. 37**: Rotated component matrix for SBCI

| Code | Variable | Component | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| **SBCI23** | Improved use of construction resources | 0.788 | | |
| **SBCI21** | Compliance with regulations on sustainable practices | 0.781 | | |
| **SBCI24** | Diminished operational and utility costs in building | 0.772 | | |
| **SBCI22** | Compliance with sustainability assessment measures | 0.772 | | |
| **SBCI16** | Water usage minimisation | 0.755 | | |
| **SBCI15** | Consideration of the project's effect on air, soil, water etc. | 0.745 | | |
| **SBCI19** | Impact consideration on social background | 0.724 | | |
| **SBCI20** | Minimisation of pollution and greenhouse gas emission | 0.708 | | |
| **SBCI12** | Energy consumption minimisation | 0.698 | | |
| **SBCI17** | Green procurement | 0.686 | | |
| **SBCI13** | Consideration of supplementary energy systems (solar etc.) | 0.674 | 0.505 | |
| **SBCI14** | Usage of renewable resources | 0.658 | 0.514 | |
| **SBCI18** | Usage of Smart appliances | 0.656 | | |
| **SBCI11** | Protection of biodiversity and ecology | 0.582 | 0.512 | |
| **SBCI10** | Decrease in the use of toxic materials | 0.570 | | |
| **SBCI7** | Promotion of waste material recyclability | | 0.818 | |
| **SBCI6** | Decrease in generating waste | | 0.787 | |
| **SBCI8** | Usage of waste in making construction materials | | 0.783 | |
| **SBCI9** | Usage of materials with low carbon footprint | 0.531 | 0.682 | |
| **SBCI4** | Minimisation of the use of non-renewable goods | | 0.663 | |
| **SBCI5** | Usage of biodegradable materials | | 0.623 | |
| **SBCI2** | Sustainable and efficient designs | | | 0.836 |
| **SBCI3** | Sustainable structural materials | | | 0.819 |

| | | | | |
|---|---|---|---|---|
| **SBCI1** | Sustainability indicators in project briefs | | | 0.748 |

**Table 9. 38**:Cronbach's alpha for SBCI principal components

| Principal Component | Cronbach's Alpha | Number of items |
|---|---|---|
| **1** | 0.966 | 12 |
| **2** | 0.931 | 5 |
| **3** | 0.913 | 3 |

### *9.2.1.8 EFA for integrated SBC project delivery (ISBCPD)*

Tables 9.39 to 9.41 present the results of the EFA for the outcome variables of integrated SBC project delivery. Ten (10) measuring variables were analysed with EFA. Principal component analysis (PCA) and varimax methods were used for extraction and rotation respectively. Table 9.39 indicates the results of Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity**.** KMO value was 0.924 surpassing the minimum acceptable threshold of 0.6 to continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Additionally, factorability was permitted as the Bartlett's test of sphericity result showed statistical significance value of 0.001 (<0.05).

**Table 9. 39**: KMO and Bartlett's test for ISBCPD outcomes

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure Sampling Adequacy | | 0.924 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 2777.195 |
| | df | 45 |
| | Sig. | <0.001 |

Table 9.40 presents the communalities results. All the extraction values surpassed the 0.5 threshold indicating suitability of data and the goodness of fit of the items in each component factors (Hair et al., 2013).

**Table 9. 40**:Communalities for ISBCPD outcomes

| Code | Variable | Initial | Extraction |
|---|---|---|---|
| **ISBCPD1** | Projects completion with no time overrun | 1.000 | 0.654 |
| **ISBCPD2** | Project completion with no cost overrun | 1.000 | 0.621 |

| | | | |
|---|---|---|---|
| **ISBCPD3** | Achievement of prescribed quality requirements | 1.000 | 0.756 |
| **ISBCPD4** | Construction stakeholders/Client Satisfaction | 1.000 | 0.749 |
| **ISBCPD5** | End-user satisfaction | 1.000 | 0.750 |
| **ISBCPD6** | Value for money | 1.000 | 0.763 |
| **ISBCPD7** | Environmental objectives met | 1.000 | 0.716 |
| **ISBCPD8** | Health safety and comfort | 1.000 | 0.743 |
| **ISBCPD9** | Construction innovation | 1.000 | 0.706 |
| **ISBCPD10** | Improvement in sustainability rating | 1.000 | 0.655 |

Table 9.41 presents the total variance explained and the individual eigenvalues of the measuring variables. Considering the Kaiser's criterion, only one principal component factors achieved values greater than one and were extracted and achieved the same percentage and cumulative percentage variance of 71.13 surpassing the recommended minimum threshold of 50% (Field, 2009; Tengan, 2018).

**Table 9. 41**: Total variance explained for ISBCPD outcomes

| **Component** | **Initial Eigenvalues** | | | **Extraction Sums of Squared Loadings** | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % Of Variance | Cumulative % |
| 1 | 7.113 | 71.130 | 71.130 | 7.113 | 71.130 | 71.130 |
| 2 | 0.871 | 8.713 | 79.843 | | | |
| 3 | 0.502 | 5.024 | 84.867 | | | |
| 4 | 0.331 | 3.309 | 88.177 | | | |
| 5 | 0.298 | 2.985 | 91.161 | | | |
| 6 | 0.257 | 2.572 | 93.734 | | | |
| 7 | 0.204 | 2.038 | 95.772 | | | |
| 8 | 0.172 | 1.717 | 97.489 | | | |
| 9 | 0.147 | 1.468 | 98.957 | | | |
| 10 | 0.104 | 1.043 | 100.000 | | | |
| **Extraction Method: Principal Component Analysis.** | | | | | | |

However, there was no rotation because only one component factor was extracted. Similarly, the Cronbach's alpha reliability and internal consistency test results were the same for descriptive statistics in Table 9.9 which was 0.954. Moreover, the principal component extracted retained

the name, *integrated project delivery (ISBCPD)*, considering there was no rotation. This indicates that all the ISBCPD outcome variables will be considered for the structural equation modelling (SEM) analysis.

## 9.3 Structural Equation Modelling Model Fit Measurement

This aims to determine how good the conceptual model fits the sampled data collected. Therefore, the selected variables in each latent construct from exploratory factor analysis were subjected to confirmatory factor analysis (CFA). The aim was to reveal the final measuring variables in each latent construct for the model. In other words, the variables that met the required criteria were used for the final model. Kline (2010) asserts that for the final model to be suitable, each of the latent constructs that make up the model should first pass the goodness of fit assessment test. Therefore, the latent constructs of the conceptual model of this study were assessed based on the criteria stipulated on Table 9.42 and the results discussed in the following subsections.

**Table 9. 42**: Benchmarks for fit indices

| **Model fit indices** | **Thresholds** | **References** |
|---|---|---|
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | Hair et al. (2010); Kline (2010) |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | Kline (2010) |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | Kline (2010); Collier (2020); |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | Hu and Bentler (1999); Hair et al. (2010) |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | Hu and Bentler (1999); Hair et al. (2010) |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | Hu and Bentler (1999); Hair et al. (2010) |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | Hu and Bentler (1999); Hair et al. (2010) |
| Cronbach's reliability | Good fit (≥ 0.70) | Hair et al. (2010); Collier (2020) |
| Composite reliability | Good fit (≥ 0.70) | Collier (2020) |
| Convergent reliability | Good fit: Average variance extracted (AVE) (>0.50) | Collier (2020) |
| Discriminatory validity | Square root of AVE greater than intercorrelations | Collier (2020) |

| | | |
|---|---|---|
| | between latent constructs | |

### 9.3.1 Model fit assessment for regulatory environment (RE)

This section discusses the confirmatory factor analysis (CFA) for the exogenous latent construct regulatory environment (RE). Initial number of variables in the model was 21 comprising 9 observed/endogenous variables and 10 unobserved/exogenous variables. However, the results from the initial measurement of the model were not satisfactory based on the acceptable criteria. Hence, the model was modified to enhance goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than 0.55 threshold (Tengan, 2018). Therefore, only RE9, RE10, RE11 and RE7 met the criteria and were chosen for further analysis. Also, these selected observer variables were so adequate that there was no need to apply modification indices approach like covariance of items with large error terms. Figure 9.1 portrays the modified regulatory environment (RE) measurement model.

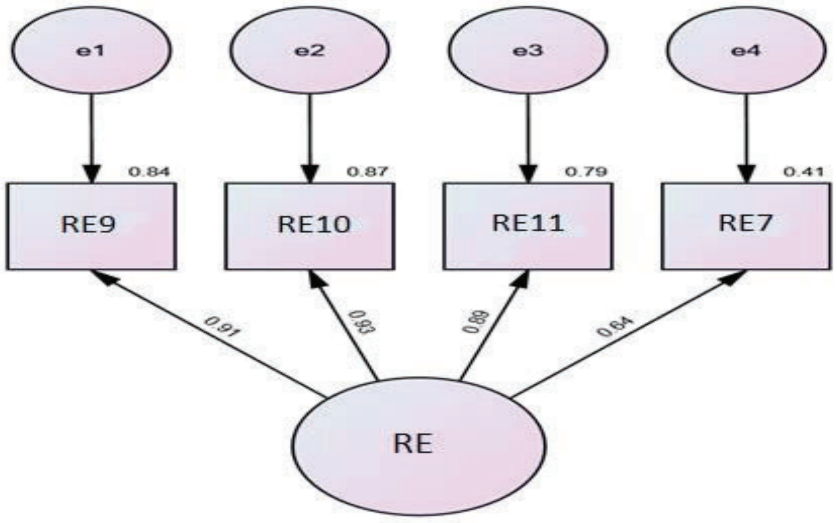


**Figure 9. 1:**Regulatory environment modified measurement model

Table 9.43 on the other hand presents the results and fit indices of the initial and modified RE model. The modified model achieved a good fit with P=0.550, $\chi^2$/df=0.598, SRMR=0.005, RMSEA=0.000, CFI = 1.000, IFI = 1.001, NFI = 0.999, and TLI = 1.003. Kline also affirmed that the degree of freedom (df) must be greater than zero (0) for an overall goodness of fit. Considering all these criteria, the RE measurement model was found suitable for the structural model analysis.

**Table 9. 43**: Hypothesised and modified model fit indices for regulatory environment (RE)

| **Model fit indices** | **Thresholds** | **Initial measurement** | **Modified model** |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.550 |
| Discrepancy ($\chi^2$) | - | 483,637 | 1.197 |
| Degrees of freedom (df) | - | 27 | 2 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 17.912 | **0.598** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.099 | **0.005** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.246 | **0.000** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.722 | **1.000** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.723 | **1.001** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.711 | **0.999** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.629 | **1.003** |

#### *9.3.1.1 Reliability assessment for RE model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the RE model also confirmed their suitability. Cronbach's alpha was used in the assessment. Equally, the standardised regression loadings were assessed with composite reliability criteria. The results were suitable, having Cronbach's alpha and composite reliability values of 0.904 and 0.912 respectively as shown in Table 9.44. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring variables (Pallant, 2020).

Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

#### *9.3.1.2 Convergent validity for RE model variables*

The convergent validity results further solidified the suitability of the modified RE model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.44 was 0.725 above the 0.5 threshold for suitability. This indicates that there is empirical evidence for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

**Table 9. 44**: Reliability and convergent validity of the RE model measurement variables

| Latent construct | Code | Standardised regression weight/loading | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | Convergent validity | |
|---|---|---|---|---|---|---|
| | | | | | Average variance extracted (AVE) (> 0.50) | Square root AVE |
| Regulatory environment (RE) | RE9 | 0.915 | 0.904 | 0.912 | 0.725 | 0.852 |
| | RE10 | 0.930 | | | | |
| | RE11 | 0.888 | | | | |
| | RE7 | 0.640 | | | | |

### 9.3.2 Model fit assessment for knowledge sharing (KS)

This section discusses the confirmatory factor analysis (CFA) for the exogenous latent construct knowledge sharing (KS). The initial number of variables in the model was 25 comprising 12 observed/endogenous variables and 13 unobserved/exogenous variables. However, the results from the initial measurement of the model were not satisfactory based on the acceptable criteria. Hence, the model was modified to enhance the goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than 0.55 threshold

(Tengan, 2018). Nonetheless, the standardised regression loadings of the observed variables were above 0.55. Similarly, modification indices were applied, large error terms assessed, and the items covaried to enhance the model fit. The measurement errors included e1 < --> e2, e1 <--> e3, e1 <--> e8, e2 <--> e3, e2 <--> e8, e2 <--> e9, e2 <--> e10, e3 <--> e4, e5 <--> e6, e5 <--> e9, e6 <--> e7, e6 <--> e8, e7 <--> e8, e8 <--> e9, e10 <--> e11, e10 <--> e12, and e11 <--> e12. Figure 9.2 portrays the modified knowledge sharing (KS) measurement model.

Table 9.45 on the other hand presents the results and fit indices of the initial and modified KS model. The modified model achieved a good fit with $\chi^2$/df=2.317, SRMR=0.015, RMSEA=0.069, CFI = 0.985, IFI = 0.985, NFI = 0.974, and TLI = 0.972. Considering these criteria, the KS measurement model was found suitable for the structural model analysis.

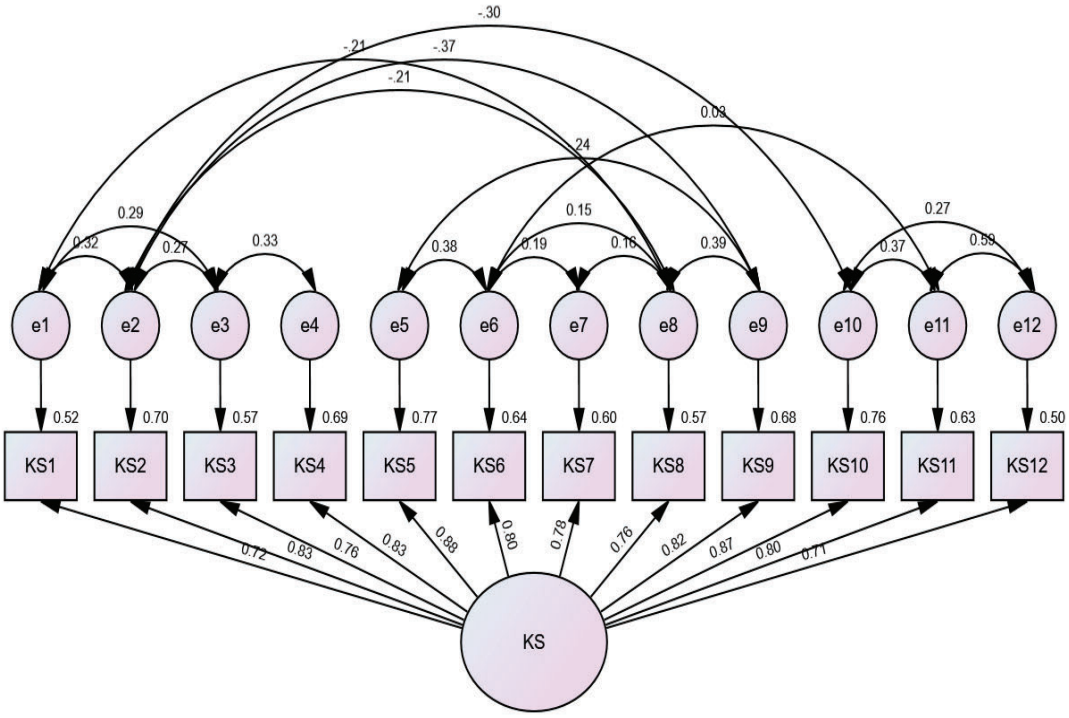


**Figure 9. 2:**Knowledge sharing modified measurement model

**Table 9. 45**:Hypothesised and modified model fit indices for knowledge sharing (KS)

| Model fit indices | Thresholds | Initial measurement | Modified model |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.000 |
| Discrepancy ($\chi^2$) | - | 486.985 | 83.400 |
| Degrees of freedom (df) | - | 54 | 36 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 9.018 | **2.317** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.036 | **0.015** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.169 | **0.069** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.861 | **0.985** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.862 | **0.985** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.847 | **0.974** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.831 | **0.972** |

#### *9.3.2.1 Reliability assessment for KS model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the knowledge sharing model also confirmed their suitability. Cronbach's alpha was used in the assessment. Equally, the standardised regression loadings were assessed with composite reliability criteria. Results were suitable, having Cronbach's alpha and composite reliability values of 0.956 and 0.954 respectively as shown in Table 9.46. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring variables (Pallant, 2020). Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

#### *9.3.2.2 Convergent validity for KS model variables*

The convergent validity results further solidified the suitability of the modified KS model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.46 was 0.637 above the 0.5 threshold for suitability. This indicates that there is empirical evidence

for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

**Table 9. 46**: Reliability and convergent validity of the KS model measurement variables

| Latent construct | Code | Standardised regression weight/loading | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | Convergent validity | |
|---|---|---|---|---|---|---|
| | | | | | Average variance extracted (AVE) (> 0.50) | Square root AVE |
| Knowledge sharing (KS) | KS1 | 0.721 | 0.956 | 0.954 | 0.637 | 0.798 |
| | KS2 | 0.834 | | | | |
| | KS3 | 0.758 | | | | |
| | KS4 | 0.830 | | | | |
| | KS5 | 0.878 | | | | |
| | KS6 | 0.801 | | | | |
| | KS7 | 0.775 | | | | |
| | KS8 | 0.756 | | | | |
| | KS9 | 0.823 | | | | |
| | KS10 | 0.874 | | | | |
| | KS11 | 0.796 | | | | |
| | KS12 | 0.708 | | | | |

### 9.3.3 Model fit assessment for corporate disposition (CD)

This section discusses the confirmatory factor analysis (CFA) for the exogenous latent construct corporate disposition (CD). Initial number of variables in the model was 27 comprising 13 observed/endogenous variables and 14 unobserved/exogenous variables. However, the results from the initial measurement of the model were not satisfactory based on the acceptable criteria. Hence, the model was modified to enhance the goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than 0.55 threshold (Tengan, 2018). However, the standardised regression loadings of the observed variables were

above 0.55. Likewise, modification indices were applied, large error terms assessed, and the items covaried to enhance the model fit. The measurement errors included e1 <--> e3, e1 <--> e8, e2 <--> e3, e4 <--> e5, e4 <--> e7, e4 <--> e10, e4 <--> e12, e5 <--> e6, e5 <--> e8, e5 <--> e9, e7 <--> e8, e7 <--> e10, e7 <--> e11, e8 <--> e9, e8 <--> e11, e10 <--> e11, e11 <--> e12, e11 <--> e13, and e12 <--> e13. Figure 9.3 portrays the modified corporate disposition (CD) measurement model.

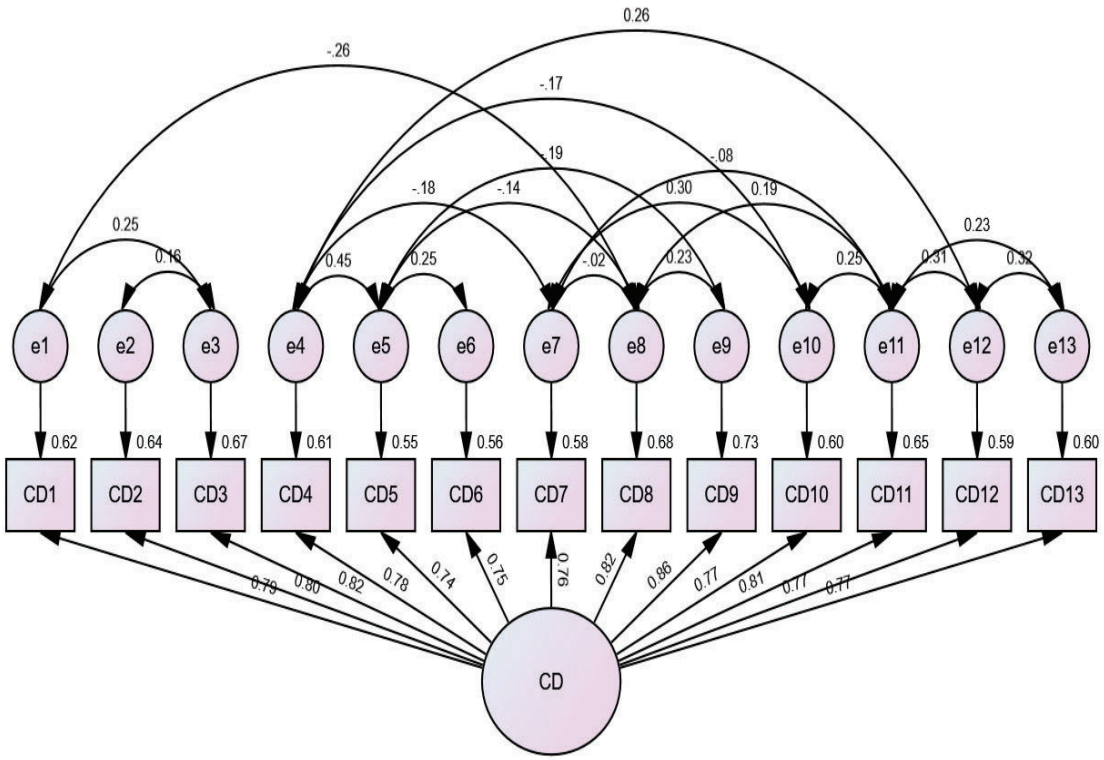


**Figure 9. 3:**Corporate disposition modified measurement model

Table 9.47 on the other hand presents the results and fit indices of the initial and modified CD model. The modified model achieved a good fit with $\chi^2/df=2.170$, SRMR=0.020, RMSEA=0.065, CFI = 0.983, IFI = 0.983, NFI = 0.969, and TLI = 0.971. Considering these criteria, the CD measurement model was found suitable for the structural model analysis.

**Table 9. 47:**Hypothesised and modified model fit indices for corporate disposition (CD)

| Model fit indices | Thresholds | Initial measurement | Modified model |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.000 |
| Discrepancy ($\chi^2$) | - | 447.619 | 99.833 |
| Degrees of freedom (df) | - | 65 | 46 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 6.886 | **2.170** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.037 | **0.020** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.145 | **0.065** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.878 | **0.983** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.878 | **0.983** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.861 | **0.969** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.854 | **0.971** |

#### *9.3.3.1 Reliability assessment for CD model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the corporate disposition model also confirmed their suitability. Cronbach's alpha was used in the assessment. Similarly, the standardised regression loadings were assessed with composite reliability criteria. Results were suitable, having Cronbach's alpha and composite reliability values of 0.956 and 0.955 respectively as shown in Table 9.48. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring variables (Pallant, 2020). Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

#### *9.3.3.2 Convergent validity for CD model variables*

The convergent validity results further solidified the suitability of the modified CD model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.48 was 0.621 above the 0.5 threshold for suitability. This indicates that there is empirical evidence

for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

**Table 9. 48**: Reliability and convergent validity of the CD model measurement variables

| Latent construct | Code | Standardised regression weight/loading | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | Convergent validity | |
|---|---|---|---|---|---|---|
| | | | | | Average variance extracted (AVE) (>0.50) | Square root AVE |
| Corporate disposition (CD) | CD1 | 0.790 | 0.956 | 0.955 | 0.621 | 0.788 |
| | CD2 | 0.802 | | | | |
| | CD3 | 0.819 | | | | |
| | CD4 | 0.778 | | | | |
| | CD5 | 0.744 | | | | |
| | CD6 | 0.747 | | | | |
| | CD7 | 0.759 | | | | |
| | CD8 | 0.823 | | | | |
| | CD9 | 0.856 | | | | |
| | CD10 | 0.773 | | | | |
| | CD11 | 0.806 | | | | |
| | CD12 | 0.770 | | | | |
| | CD13 | 0.772 | | | | |

### 9.3.4 Model fit assessment for project delivery strategies (PDS)

This section discusses the confirmatory factor analysis (CFA) for the exogenous latent construct project delivery strategies (PDS). Initial number of variables in the model was 37 comprising 18 observed/endogenous variables and 19 unobserved/exogenous variables. But the results from the initial measurement of the model were not satisfactory based on the acceptable thresholds. Thus, the model was modified to enhance the goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than 0.55 threshold (Tengan,

2018). However, the standardised regression loadings of the observed variables were above 0.55 except for PDS1 (0.515), PDS7 (0.546), and PDS8 (0.527) which were first removed. Similarly, modification indices were applied, large error terms assessed, and the items covaried to enhance the model fit.

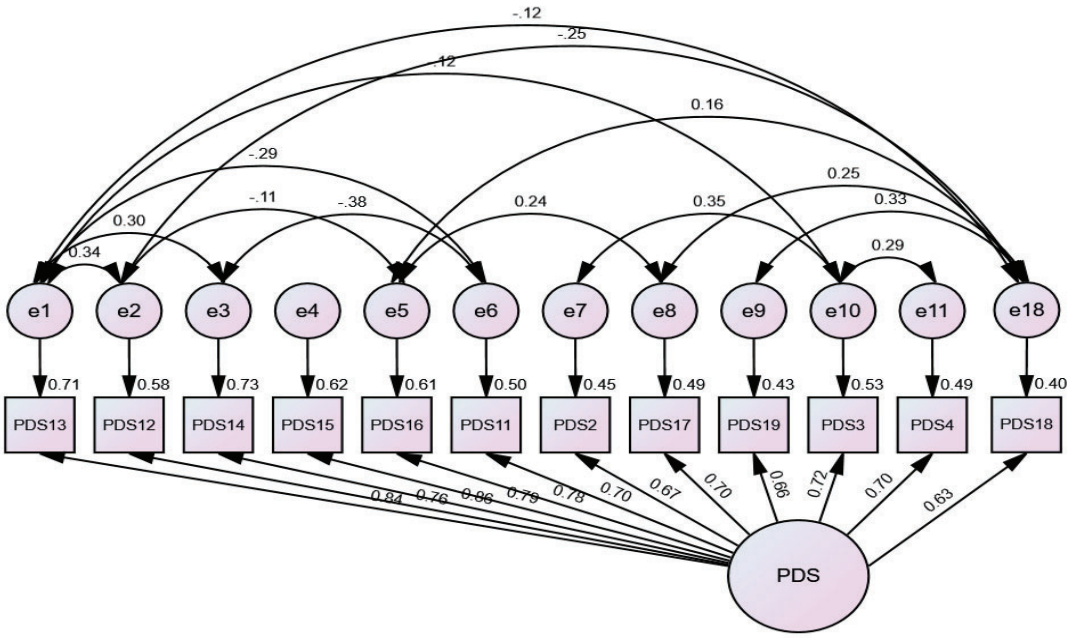


**Figure 9. 4**:Project delivery strategies modified measurement model

However, after covarying the measurement errors, variables PDS6, PDS9, and PDS10 were found unsuitable. They were separated from others with very low values close to the 0.55 threshold, and not passing the convergent validity test (Gefen et al., 2000), hence, were removed. The rest of the measuring indicators were found suitable after covariance of the measurement errors. The measurement errors included e1 <--> e2, e1 <--> e3, e1 <--> e6, e1 <--> e10, e1 <--> e18, e2 <--> e5, e2 <--> e18, e3 <--> e6, e5 <--> e8, e5 <--> e18, e7 <--> e10, e8 <--> e18, e9 <--> e18, and e10 <--> e11. Figure 9.4 portrays the modified project delivery strategies (PDS) measurement model.

**Table 9. 49**:Hypothesised and modified model fit indices for project delivery strategies (PDS)

| Model fit indices | Thresholds | Initial measurement | Modified model |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.000 |
| Discrepancy ($\chi^2$) | - | 1028.588 | 78.001 |
| Degrees of freedom (df) | - | 135 | 40 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 7.619 | 1.950 |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.074 | **0.028** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.154 | **0.058** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.736 | **0.983** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.738 | **0.983** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.710 | **0.967** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.701 | **0.972** |

Additionally, Table 9.49 presents the results and fit indices of the initial and modified CD model. The modified model achieved a good fit with $\chi^2$/df=1.950, SRMR=0.028, RMSEA=0.058, CFI = 0.983, IFI = 0.983, NFI = 0.967, and TLI = 0.972. Considering these criteria, the PDS measurement model was found suitable for the structural model analysis.

#### *9.3.4.1 Reliability assessment for PDS model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the project delivery strategies model also confirmed their suitability. Cronbach's alpha was used in the assessment. Similarly, the standardised regression loadings were assessed with composite reliability criteria. Results were suitable, having Cronbach's alpha and composite reliability values of 0.934 and 0.935 respectively as shown in Table 9.50. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring variables (Pallant, 2020). Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

**Table 9. 50**:Reliability and convergent validity of the PDS model measurement variables

| Latent construct | Code | Standardised regression weight/loading | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | Convergent validity | |
|---|---|---|---|---|---|---|
| | | | | | Average variance extracted (AVE) (>0.50) | Square root AVE |
| Project delivery strategies (PDS) | PDS13 | 0.845 | 0.934 | 0.935 | 0.545 | 0.739 |
| | PDS12 | 0.764 | | | | |
| | PDS14 | 0.855 | | | | |
| | PDS15 | 0.788 | | | | |
| | PDS16 | 0.781 | | | | |
| | PDS11 | 0.704 | | | | |
| | PDS2 | 0.669 | | | | |
| | PDS17 | 0.700 | | | | |
| | PDS19 | 0.659 | | | | |
| | PDS3 | 0.725 | | | | |
| | PDS4 | 0.701 | | | | |
| | PDS18 | 0.633 | | | | |

#### *9.3.4.2 Convergent validity for PDS model variables*

The convergent validity results further solidified the suitability of the modified PDS model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.50 was 0.545 above the 0.5 threshold for suitability. This indicates that there is empirical evidence for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

### 9.3.5 Model fit assessment for project management techniques (PMT)

This section discusses the confirmatory factor analysis (CFA) for the exogenous latent construct project management techniques (PMT). Initial number of variables in the model was 23

comprising 11 observed/endogenous variables and 12 unobserved/exogenous variables. Conversely, the results from the initial measurement of the model were not satisfactory based on the acceptable criteria. Thus, the model was modified to enhance the goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than 0.55 threshold (Tengan, 2018). However, the standardised regression loadings of the observed variables were above 0.55.

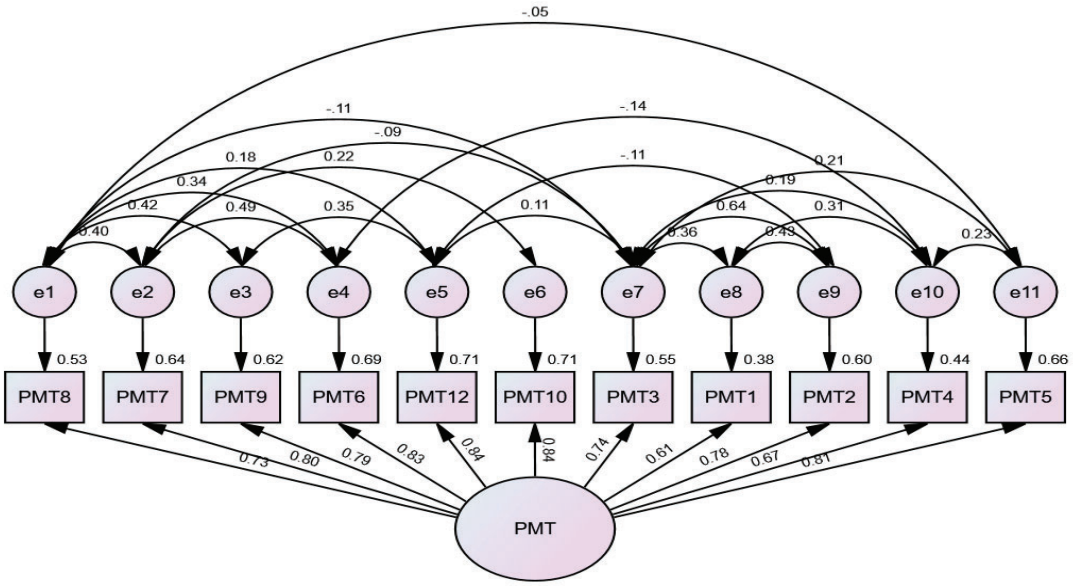


**Figure 9. 5**:Project management techniques modified measurement model

Similarly, modification indices were applied, large error terms assessed, and the items covaried to enhance the model fit. The measurement errors included e1 <--> e2, e1 <--> e3, e1 <--> e4, e1 <--> e5, e1 <--> e7, e1 <--> e11, e2 <--> e4, e2 <--> e6, e2 <--> e7, e3 <--> e5, e4 <--> e10, e5 <--> e7, e5 <--> e9, e7 <--> e8, e7 <--> e9, e7 <--> e10, e7 <--> e11, e8 <--> e9, e8 <--> e10, and e10 <--> e11. Figure 9.5 portrays the modified project management techniques (PMT) measurement model.

Moreover, Table 9.51 presents the results and fit indices of the initial and modified PMT model. The modified model achieved a good fit with $\chi^2$/df=2.810, SRMR=0.020, RMSEA=0.080, CFI = 0.984, IFI = 0.985, NFI = 0.976, and TLI = 0.964. Considering these criteria, the PMT measurement model was found suitable for the structural model analysis.

**Table 9. 51**: Hypothesised and modified model fit indices for project management techniques

| **Model fit indices** | **Thresholds** | **Initial measurement** | **Modified model** |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.000 |
| Discrepancy ($\chi^2$) | - | 629.170 | 67.441 |
| Degrees of freedom (df) | - | 44 | 24 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 14.299 | **2.810** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.052 | **0.020** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.218 | **0.080** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.790 | **0.984** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.791 | **0.985** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.779 | **0.976** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.738 | **0.964** |

#### *9.3.5.1 Reliability assessment for PMT model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the project management techniques model also confirmed their suitability. Cronbach's alpha was used in the assessment. Similarly, the standardised regression loadings were assessed with composite reliability criteria. Results were suitable, having Cronbach's alpha and composite reliability values of 0.945 and 0.946 respectively. as shown in Table 9.52. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring variables (Pallant, 2020). Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

#### *9.3.5.2 Convergent validity for PMT model variables*

The convergent validity results further solidified the suitability of the modified PMT model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.52 was 0.618 above the 0.5 threshold for suitability. This indicates that there is empirical evidence for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

**Table 9. 52**:Reliability and convergent validity of the PMT model measurement variables

| Latent construct | Code | Standardised regression weight/loading | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | Convergent validity | |
|---|---|---|---|---|---|---|
| | | | | | Average variance extracted (AVE) (>0.50) | Square root AVE |
| Project management techniques (PMT) | PMT8 | 0.728 | 0.945 | 0.946 | 0.618 | 0.786 |
| | PMT7 | 0.803 | | | | |
| | PMT9 | 0.790 | | | | |
| | PMT6 | 0.829 | | | | |
| | PMT12 | 0.841 | | | | |
| | PMT10 | 0.843 | | | | |
| | PMT3 | 0.745 | | | | |
| | PMT1 | 0.613 | | | | |
| | PMT2 | 0.777 | | | | |
| | PMT4 | 0.666 | | | | |
| | PMT5 | 0.812 | | | | |

### 9.3.6 Model fit assessment for modern building techniques (MBT)

This section discusses the confirmatory factor analysis (CFA) for the exogenous latent construct modern building techniques (PMT). Initial number of variables in the model was 15 comprising 7 observed/endogenous variables and 8 unobserved/exogenous variables. However, the results

from the initial measurement of the model were not satisfactory based on the acceptable criteria. Hence, the model was modified to enhance the goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than 0.55 threshold (Tengan, 2018). However, the standardised regression loadings of the observed variables were above 0.55.

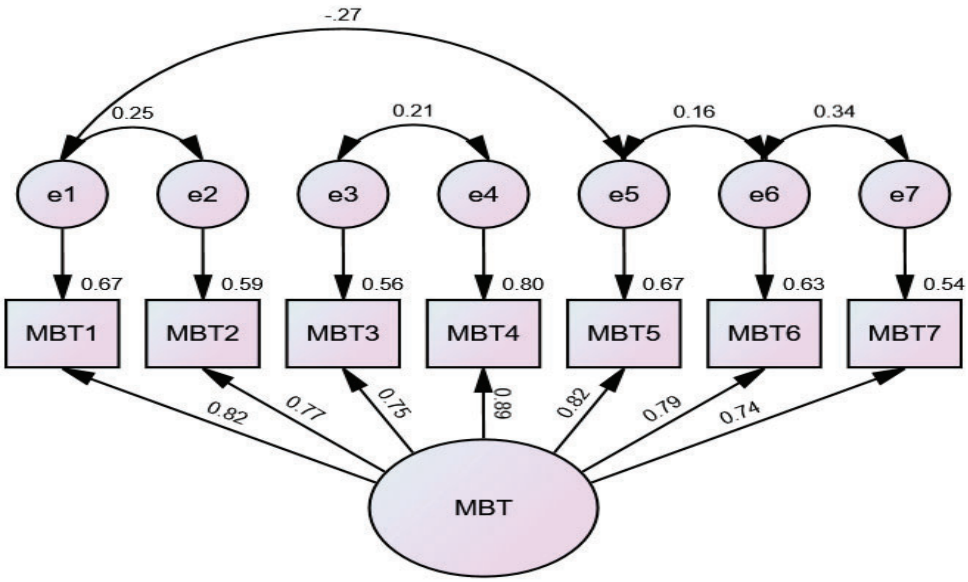


**Figure 9. 6**:Modern building techniques modified measurement model

Similarly, modification indices were applied, large error terms assessed, and the items covaried to enhance the model fit. The measurement errors included e1 <--> e2, e1 <--> e5, e3 <--> e4, e5 <--> e6, and e6 <--> e7. Figure 9.6 portrays the modified modern building techniques (MBT) measurement model.

Moreover, Table 9.53 presents the results and fit indices of the initial and modified MBT model. The modified model achieved a good fit with $\chi^2/df=2.804$, SRMR=0.017, RMSEA=0.080, CFI = 0.989, IFI = 0.989, NFI = 0.983, and TLI = 0.974. Considering these criteria, the MBT measurement model was found suitable for the structural model analysis.

**Table 9. 53:**Hypothesised and modified model fit indices for modern building techniques (MBT)

| Model fit indices | Thresholds | Initial measurement | Modified model |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.003 |
| Discrepancy ($\chi^2$) | - | 108.307 | 25.237 |
| Degrees of freedom (df) | - | 14 | 9 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 7.736 | **2.804** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.033 | **0.017** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.155 | **0.080** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.934 | **0.989** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.934 | **0.989** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.925 | **0.983** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.901 | **0.974** |

#### *9.3.6.1 Reliability assessment for MBT model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the modern building techniques model also confirmed their suitability. Cronbach's alpha was used in the assessment. Similarly, the standardised regression loadings were assessed with composite reliability criteria. The results were suitable, having Cronbach's alpha and composite reliability values of 0.926 and 0.925 respectively as shown in Table 9.54. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring variables (Pallant, 2020). Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

#### *9.3.6.2 Convergent validity for MBT model variables*

The convergent validity results further solidified the suitability of the modified MBT model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.54 was 0.638 above the 0.5 threshold for suitability. This indicates that there is empirical evidence

for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

**Table 9. 54**:Reliability and convergent validity of the MBT model measurement variables

| Latent construct | Code | Standardised regression weight/loading | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | ConveREnt validity | |
|---|---|---|---|---|---|---|
| | | | | | Average variance extracted (AVE) (>0.50) | Square root AVE |
| Modern building techniques (MBT) | MBT1 | 0.820 | 0.926 | 0.925 | 0.638 | 0.799 |
| | MBT2 | 0.770 | | | | |
| | MBT3 | 0.747 | | | | |
| | MBT4 | 0.893 | | | | |
| | MBT5 | 0.820 | | | | |
| | MBT6 | 0.795 | | | | |
| | MBT7 | 0.736 | | | | |

### 9.3.7 Model fit assessment for sustainable building construction features (SBCI)

This section discusses the confirmatory factor analysis (CFA) for the endogenous latent construct sustainable building construction implementation features (SBCI). Initial number of variables in the model was 41 comprising 20 observed/endogenous variables and 21 unobserved/exogenous variables. Conversely, the results from the initial measurement of the model were not satisfactory based on the acceptable criteria. Therefore, the model was modified to enhance the goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than 0.55 threshold (Tengan, 2018). Nonetheless, the standardised regression loadings of the observed variables were all above 0.55.

Similarly, modification indices were applied, large error terms assessed, and the items covaried to enhance the model fit. The measurement errors included e1 <--> e3, e1 <--> e4, e1 <--> e7, e1 <--> e15, e2 <--> e4, e2 <--> e8, e2 <--> e14, e2 <--> e15, e2 <--> e16, e3 <--> e4, e3 <--> e7,

e3 <--> e13, e3 <--> e17, e4 <--> e8, e5 <--> e9, e5 <--> e17, e6 <--> e7, e6 <--> e9, e7 <--> e17, e8 <--> e15, e9 <--> e11, e9 <--> e20, e13 <--> e14, e13 <--> e15, e13 <--> e16, e14 <--> e15, e14 <--> e16, e14 <--> e17, e15 <--> e16, e16 <--> e18, e16 <--> e19, e17 <--> e19, e18 <--> e19, e18 <--> e20, and e19 <--> e20.

Figure 9.7 depicts the modified sustainable building construction implementation features (SBCI) measurement model.

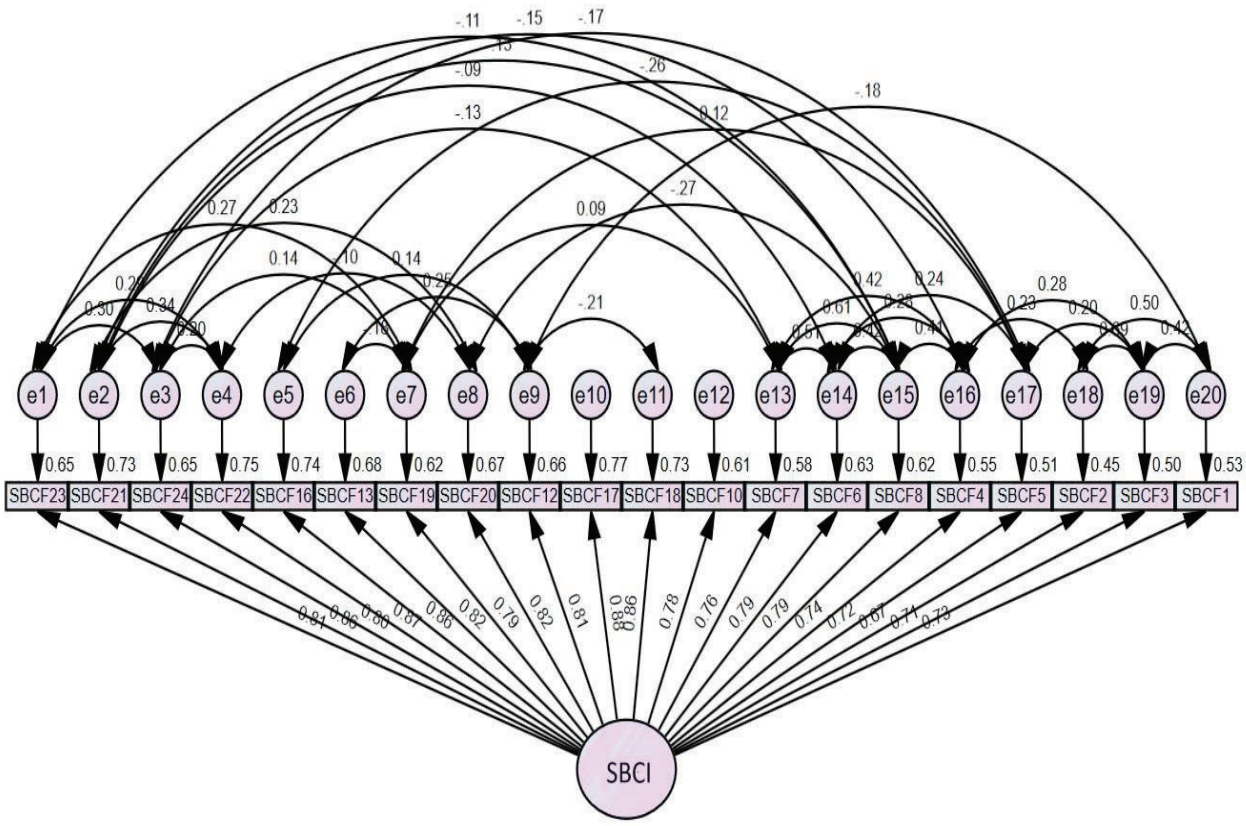


**Figure 9. 7**:Sustainable building construction features modified measurement model

Moreover, Table 9.55 presents the results and fit indices of the initial and modified SBCI model. The modified model achieved a good fit with $\chi^2/df=2.632$, SRMR=0.024, RMSEA=0.076, CFI = 0.963, IFI = 0.964, NFI = 0.943, and TLI = 0.948. Considering these criteria, the SBCI measurement model was found suitable for the structural model analysis.

**Table 9. 55**:Hypothesised and modified model fit indices for SBCI

| Model fit indices | Thresholds | Initial measurement | Modified model |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.000 |
| Discrepancy ($\chi^2$) | - | 1385.153 | 352.657 |
| Degrees of freedom (df) | - | 170 | 134 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 8.148 | **2.632** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.042 | **0.024** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.160 | **0.076** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.797 | **0.963** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.798 | **0.964** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.776 | **0.943** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.773 | **0.948** |

#### *9.3.7.1 Reliability assessment for SBCI model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the SBCI model also confirmed their suitability. Cronbach's alpha was used in the assessment. Similarly, the standardised regression loadings were assessed with composite reliability criteria. Results were suitable, having Cronbach's alpha and composite reliability values of 0.972 and 0.972 respectively as shown in Table 9.56. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring variables (Pallant, 2020). Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

#### *9.3.7.2 Convergent validity for SBCI model variables*

The convergent validity results further solidified the suitability of the modified SBCI model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.56 was 0.632 above the 0.5 threshold for suitability. This indicates that there is empirical evidence

for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

**Table 9. 56:**Reliabiity and convergent validity of the SBCI model measurement variables

| **Latent construct** | **Code** | **Standardised regression weight/loading** | **Cronbach's alpha (≥ 0.70)** | **Composite reliability (≥ 0.70)** | **Convergent validity** | |
|---|---|---|---|---|---|---|
| | | | | | **Average variance extracted (AVE) (>0.50)** | **Square root AVE** |
| Sustainable building construction implementation (SBCI) | SBCI23 | 0.809 | 0.972 | 0.972 | 0.632 | 0.795 |
| | SBCI21 | 0.856 | | | | |
| | SBCI24 | 0.804 | | | | |
| | SBCI22 | 0.866 | | | | |
| | SBCI16 | 0.860 | | | | |
| | SBCI13 | 0.822 | | | | |
| | SBCI19 | 0.790 | | | | |
| | SBCI20 | 0.816 | | | | |
| | SBCI12 | 0.813 | | | | |
| | SBCI17 | 0.878 | | | | |
| | SBCI18 | 0.856 | | | | |
| | SBCI10 | 0.784 | | | | |
| | SBCI7 | 0.761 | | | | |
| | SBCI6 | 0.793 | | | | |
| | SBCI8 | 0.786 | | | | |
| | SBCI4 | 0.740 | | | | |
| | SBCI5 | 0.717 | | | | |
| | SBCI2 | 0.671 | | | | |
| | SBCI3 | 0.707 | | | | |
| | SBCI1 | 0.728 | | | | |

### 9.3.8 Model fit assessment for integrated SBC project delivery (ISBCPD)

This section discusses the confirmatory factor analysis (CFA) for the endogenous latent construct integrated SBC project delivery outcomes variables. Initial number of variables in the model was 21 comprising 10 observed/endogenous variables and 11 unobserved/exogenous variables. Conversely, the results from the initial measurement of the model were not satisfactory based the acceptable criteria. Consequently, the model was modified to enhance the goodness of fit. The modification started with examining and ensuring that all observed variables loadings were not less than the 0.55 threshold (Tengan, 2018). Nonetheless, the standardised regression loadings of the observed variables were all above 0.55.

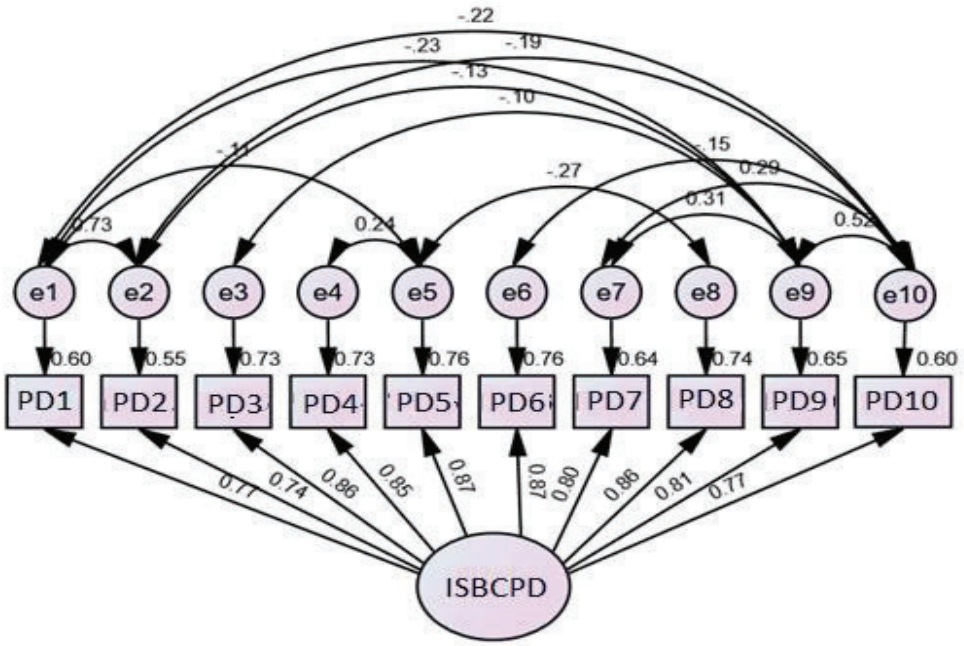


**Figure 9. 8**: ISBCPD outcomes modified measurement model

Similarly, modification indices were applied, large error terms assessed, and the items covaried to enhance the model fit. The measurement errors included e1 <--> e2, e1 <--> e5, e1 <--> e9, e1 <--> e10, e2 <--> e9, e2 <--> e10, e3 <--> e9, e4 <--> e5, e5 <--> e8, e6 <--> e10, e7 <--> e9, e7

<--> e10, and e9 <--> e10. Figure 9.8 depicts the modified ISBCPD outcomes measurement model.

Moreover, Table 9.57 presents the results and fit indices of the initial and modified ISBCPD model. The modified model achieved a good fit with $\chi^2$/df=2.413, SRMR=0.011, RMSEA=0.071, CFI = 0.989, IFI = 0.989, NFI = 0.981, and TLI = 0.977. Considering these criteria, the ISBCPD measurement model was found suitable for the structural model analysis.

**Table 9. 57**: Hypothesised and modified model fit indices for ISBCPD measurement variables

| **Model fit indices** | **Thresholds** | **Initial measurement** | **Modified model** |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | 0.000 |
| Discrepancy ($\chi^2$) | - | 464.894 | 53.094 |
| Degrees of freedom (df) | - | 35 | 22 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | 13.283 | 2.413 |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | 0.038 | **0.011** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | 0.209 | **0.071** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.845 | **0.989** |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.846 | **0.989** |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.835 | **0.981** |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.801 | **0.977** |

#### *9.3.8.1 Reliability assessment for ISBCPD model variables*

The reliability analysis of the modified selected measurement (observed/endogenous) variables for the ISBCPD model also confirmed their suitability. Cronbach's alpha was used in the assessment. Similarly, the standardised regression loadings were assessed with composite reliability criteria. Results were suitable, having Cronbach's alpha and composite reliability values of 0.954 and 0.954 respectively as shown in Table 9.58. The Cronbach's value higher than the 0.7 threshold suggests high reliability and internal consistency of the measuring

variables (Pallant, 2020). Similarly, the composite reliability value greater than the 0.7 threshold suggests that the construct was consistent, predictable, and dependable (Salkind, 2012).

**Table 9. 58**: Reliability and convergent validity of the ISBCPD model measurement variables

| Latent construct | Code | Standardised regression weight/loading | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | Convergent validity | |
|---|---|---|---|---|---|---|
| | | | | | Average variance extracted (AVE) (>0.50) | Square root AVE |
| Integrated SBC project delivery (ISBCPD) | ISBCPD1 | 0.775 | 0.954 | 0.954 | 0.676 | 0.822 |
| | ISBCPD2 | 0.740 | | | | |
| | ISBCPD3 | 0.857 | | | | |
| | ISBCPD4 | 0.853 | | | | |
| | ISBCPD5 | 0.871 | | | | |
| | ISBCPD6 | 0.871 | | | | |
| | ISBCPD7 | 0.802 | | | | |
| | ISBCPD8 | 0.858 | | | | |
| | ISBCPD9 | 0.807 | | | | |
| | ISBCPD10 | 0.775 | | | | |

#### *9.3.8.2 Convergent validity for ISBCPD model variables*

The convergent validity results further solidified the suitability of the modified ISBCPD model measurement variables. Thus, the value of the average variance extracted as shown in Table 9.58 was 0.676 above the 0.5 threshold for suitability. This indicates that there is empirical evidence for convergent validity (Bagozzi and Yi, 2012) as the underlying latent construct explains more than half of the variance in the belonging indicators.

Generally, Table 9.59 presents the summary of the reliability and convergent validity results of the latent constructs of the integrated sustainable building construction (ISBC) model.

**Table 9. 59**: Summary of the reliability and convergent validity of the model measurement variables

| Latent construct | Cronbach's alpha (≥ 0.70) | Composite reliability (≥ 0.70) | Convergent validity | |
|---|---|---|---|---|
| | | | Average variance extracted (AVE) (>0.50) | Square root AVE |
| Regulatory environment (RE) | 0.904 | 0.912 | 0.725 | 0.852 |
| Knowledge sharing (KS) | 0.956 | 0.954 | 0.637 | 0.798 |
| Corporate disposition (CD) | 0.956 | 0.955 | 0.621 | 0.788 |
| Project delivery strategies (PDS) | 0.934 | 0.935 | 0.545 | 0.739 |
| Project management techniques (PMT) | 0.945 | 0.946 | 0.618 | 0.786 |
| Modern building techniques (MBT) | 0.926 | 0.925 | 0.638 | 0.799 |
| Sustainable building construction features (SBCI) | 0.972 | 0.972 | 0.632 | 0.795 |
| Integrated SBC Project delivery (ISBCPD) outcomes | 0.954 | 0.954 | 0.676 | 0.822 |

### 9.3.9 Overall CFA for integrated sustainable building construction model

Table 9.60 presents confirmatory factor analysis (CFA) results for the integrated sustainable building construction model for project delivery in South Africa. The number of variables in the model was 186 comprising 89 observed/endogenous variables and 97 unobserved/exogenous variables. The results from the initial measurement of the model were satisfactory based on Chi-square, SRMR, RMSEA thresholds which were the most revered (Kline, 2010, Collier, 2020). All the standardised regression loadings were above 0.55 and none was less than 0.6 indicating a good fit (Tengan, 2018).

**Table 9. 60:**CFA fit indices for ISBC model

| Model fit indices | Thresholds | Achieved fit indices |
|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 |
| Discrepancy ($\chi^2$) | - | 8669.789 |
| Degrees of freedom (df) | - | 3617 |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | **2.397** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | **0.049** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | **0.071** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.823 |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.824 |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.732 |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.808 |

However, the Hu and Bentler (1999) thresholds (CFI, IFI, NFI, and IFI) were not met by the model. Also, covariance of items with measurement errors were not able to be improved. Nevertheless, the overall model was deemed acceptable fit based on Marsh, Hau, and Wen (2004), and Kline's (2010) positions. Marsh et al. (2004) have argued against the rigorous Hu and Bentler (1999) criteria in using multiple indices. Affirming that using a complex model, will be difficult in achieving a good model fit compared to a more simplistic model if all model fit indices are considered. Marsh et al. (2004) and Kline (2010) also affirm that a good model fit does not mean that every part of the model fits well. According to Kline (2010) a so-called model fit can still poorly explain the relationships in a model.

Therefore, the robust integrated sustainable building construction (ISBC) model with $\chi^2$/df=2.397, SRMR=0.049, and RMSEA=0.071 was deemed suitable for structural model analysis and obtaining the path significance of each association. Figure 9.9 portrays the confirmatory (CFA) path diagram for the ISBC model.

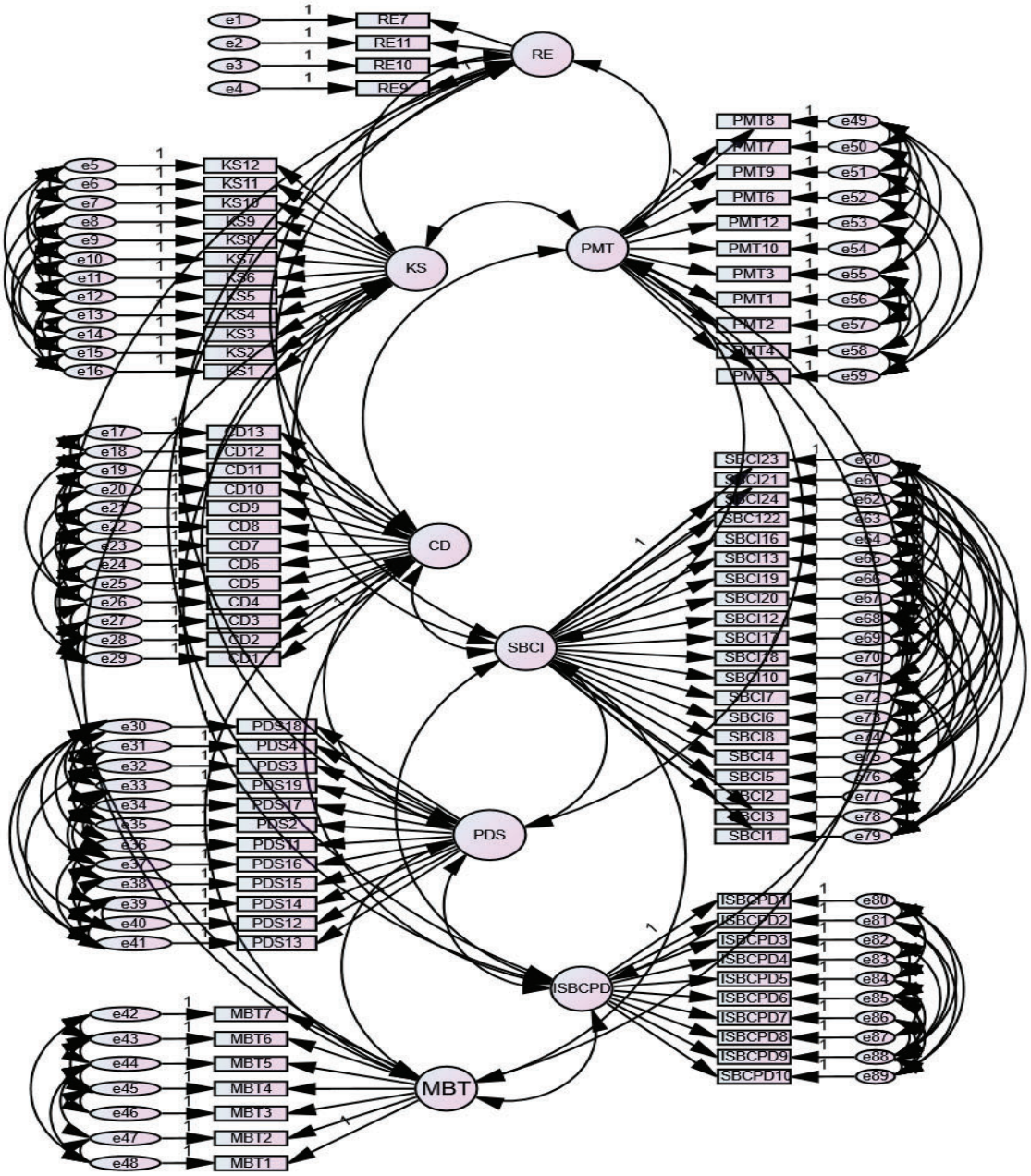


**Figure 9. 9**:Confirmatory factor analysis (CFA) path diagram for ISBC model

### 9.3.10 Discriminatory validity of the integrated sustainable building construction (ISBC) model

The discriminatory validity of the latent constructs in the ISBC model further solidifies the suitability of the model. The aim of discriminant validity is to reveal how distinct and unrelated the measurements of two latent constructs are (Fornell and Larcker, 1981). Hence, the square root of the average variance extracted (AVE) for each latent construct should be greater than the intercorrelation value of the constructs. Table 9.61 shows that all the square root of AVE met the discriminatory validity criteria and were greater than the values underneath.

**Table 9. 61**: Square root of AVE and the correlation of the constructs

| | RE | KS | CD | PDS | PMT | MBT | SBC | ISBCPD |
|---|---|---|---|---|---|---|---|---|
| **RE** | **0.852** | | | | | | | |
| **KS** | 0.589 | **0.798** | | | | | | |
| **CD** | 0.515 | 0.791 | **0.788** | | | | | |
| **PDS** | 0.220 | 0.474 | 0.440 | **0.739** | | | | |
| **PMT** | 0.386 | 0.613 | 0.672 | 0.526 | **0.786** | | | |
| **MBT** | 0.351 | 0.525 | 0.553 | 0.659 | 0.665 | **0.799** | | |
| **SBCI** | 0.392 | 0.599 | 0.658 | 0.411 | 0.668 | 0.711 | **0.795** | |
| **ISBCPD** | 0.328 | 0.582 | 0.607 | 0.437 | 0.696 | 0.611 | 0.663 | 0.822 |

## 9.4 Full Structural Model Assessment and Hypothesis Testing

The integrated sustainable building construction (ISBC) model was subjected to structural model assessment and hypothesis testing. This robust model was designed to determine the influence of sustainable building construction determinants (exogenous latent constructs) on sustainable building construction implementation (SBCI) and to determine the influence of SBCI (mediating latent construct) on integrated SBC project delivery (endogenous latent construct).

Like confirmatory factor analysis, the model achieved an acceptable fit with $\chi^2/df=2.397$, SRMR=0.049, and RMSEA=0.071 although it did not meet the Hu and Bentler (1999) criteria

for CFI, IFI, NFI and TLI. The model was deemed acceptable based on Marsh et al. (2004) and Kline (2010) assertions discussed in section 9.3.9. Table 9.62 presents the results of the fit indices for the ISBC model while Figure 9.10 presents the path diagram of the structural model.

**Table 9. 62**:Full structural model fit indices for ISBC model

| **Model fit indices** | **Thresholds** | **Achieved fit indices** | **Remarks** |
|---|---|---|---|
| Probability Value (P-Value) | P>0.05 | 0.000 | - |
| Discrepancy ($\chi^2$) | - | 8669.789 | - |
| Degrees of freedom (df) | - | 3617 | - |
| Chi-square ($x^2$/df) | Acceptable fit (< 5); Good fit (< 3) | **2.397** | **Good** |
| Standardised root means square residual (SRMR) | Good fit (≤ 0.05) | **0.049** | **Acceptable** |
| Root means square error of approximation (RMSEA) | Acceptable fit (≤ 0.08); Good fit (≤ 0.05) | **0.071** | **Acceptable** |
| Comparative fit index (CFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.822 | Weak |
| Increment fit index (IFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.824 | Weak |
| Normed fit index (NFI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.732 | Weak |
| Tucker-Lewis's index (TLI) | Acceptable fit (> 0.90); Good fit (> 0.95) | 0.808 | Weak |

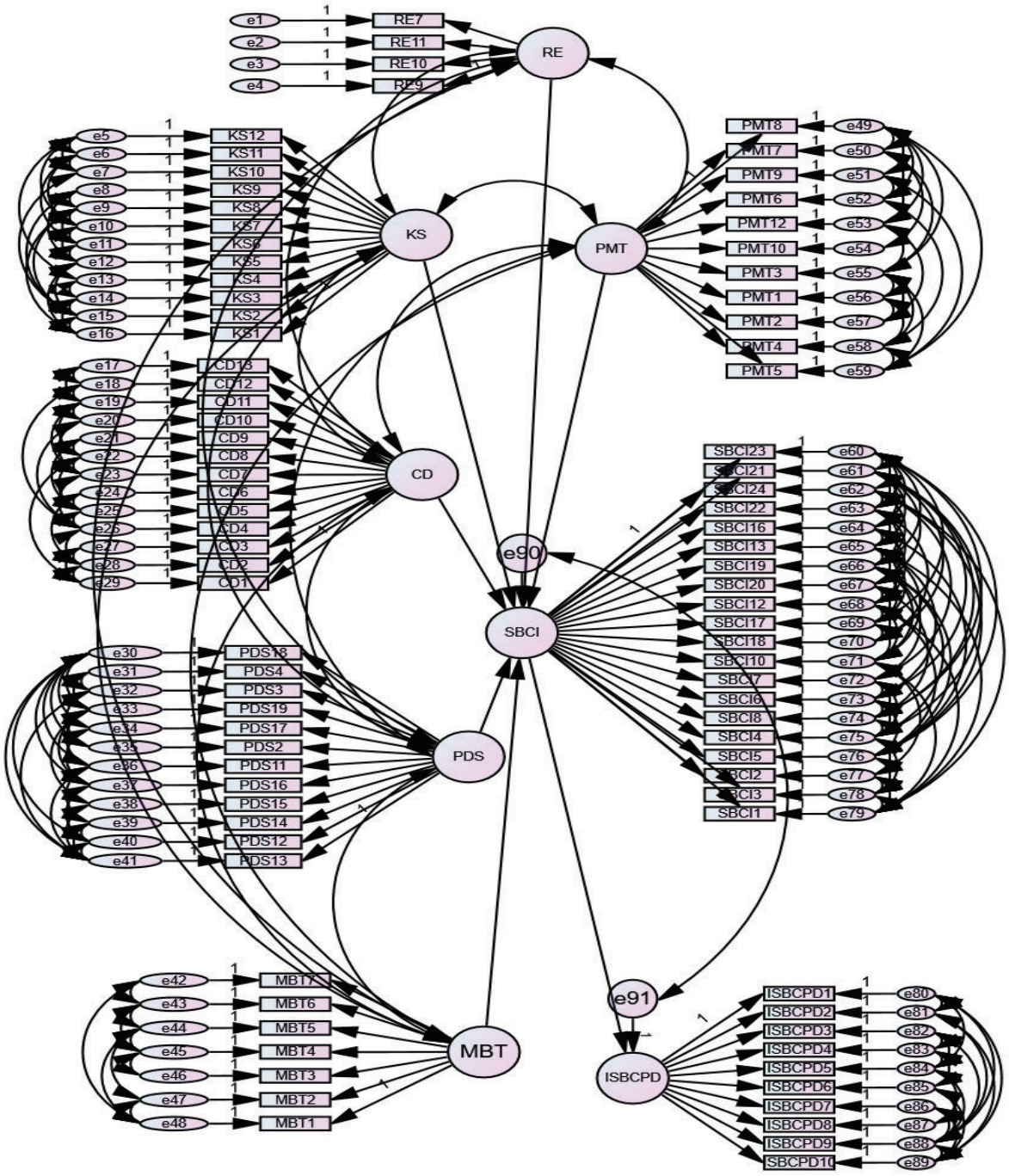


**Figure 9. 10**: Path diagram for the structural model of the ISBC

### 9.4.1 Hypothesis testing for the influence of SBC-determinants on SBC implementation for project delivery

This section presents the results of the hypothesis testing for the influence of the SBC - determinants (exogenous constructs) on SBC implementation. This was the first hypothesis (**H1**) of the study classified into *H11, H12, H13, H14*, *H15,* and *H16*. The hypotheses results are discussed in the following subsections and presented in Table 80. Nonetheless, the square multiple correlation for sustainable building construction implementation features (SBCI) was 0.634. This proves that 63.4% variance in SBCI is accounted by regulatory environment (RE), knowledge sharing (KS), corporate disposition (CD), project delivery strategies (PDS), project management techniques (PMT), and modern building techniques (MBT).

#### *9.4.1.1 Testing the influence of regulatory environment (RE) on sustainable building construction implementation (SBCI)*

Table 9.63 presents the results of the impact of regulatory environment (RE) on sustainable building construction implementation (SBCI) with hypothesis (**H11**). RE unique contribution was negative with standardised regression weight (b) of -0.034, critical ratio (t) value of – 0.780, and statistically insignificant (p = 0.435). Hence, ***H11*** was not supported.

#### *9.4.1.2 Testing the influence of knowledge sharing (KS) on sustainable building construction implementation (SBCI)*

Table 9.63 presents the results of the impact of knowledge sharing (KS) on sustainable building construction implementation (SBCI) with hypothesis (**H12**). KS unique contribution was positive and statistically significant (b = 0.153, t = 2.249, p = 0.025), hence, ***H12*** was supported.

#### *9.4.1.3 Testing the influence of corporate disposition (CD) on sustainable building construction implementation (SBCI)*

Table 9.63 presents the results of the impact of corporate disposition (CD) on sustainable building construction implementation (SBCI) with hypothesis (**H13**). CD unique contribution

was positive and statistically significant (b = 0.187, t = 2.729, p = 0.006), hence, ***H1₃*** was supported.

#### *9.4.1.4 Testing the influence of project delivery strategies (PDS) on sustainable building construction implementation (SBCI)*

Table 9.63 presents the results of the impact of project delivery strategies (PDS) on sustainable building construction implementation (SBCI) with hypothesis (**H1₄**). PDS unique contribution was negative but statistically significant (b = -0.135, t = -2.657, p = 0.008), hence, ***H1₄*** was supported.

#### *9.4.1.5 Testing the influence of project management techniques (PMT) on sustainable building construction implementation (SBCI)*

Table 9.63 presents the results of the impact of project management techniques (PMT) on sustainable building construction implementation (SBCI) with hypothesis (**H1₅**). PMT unique contribution was positive and statistically significant (b = 0.287, t = 4.717, p = 0.000), hence, ***H1₅*** was supported.

#### *9.4.1.6 Testing the influence of modern building techniques (MBT) on sustainable building construction implementation (SBCI)*

Table 9.63 presents the results of the impact of modern building techniques (MBT) on sustainable building construction implementation (SBCI) with hypothesis (**H1₆**). MBT unique contribution was positive and statistically significant (b = 0.418, t = 6.506, p = 0.000). Hence, ***H1₆*** was supported.

### 9.4.2 Hypothesis testing for the influence of SBC implementation on integrated SBC project delivery (ISBCPD) outcomes

This section presents the influence of SBC implementation (also serving as a mediating construct) on integrated SBC project delivery outcomes (endogenous construct). This was the

second major hypothesis (**H2**). Table 9.63 presents the results of the impact of sustainable building construction implementation (SBCI) on ISBCPD outcomes with hypothesis (**H2**). SBCI unique contribution was positive and statistically significant (b = 0.929, t = 10.596, p = 0.000). Hence, ***H2*** was supported. Similarly, the square multiple correlation was 0.363 for ISBCPD outcomes. This confirms that 36.3% variance in ISBCPD is accounted by sustainable building construction implementation (SBCI).

**Table 9. 63**:Hypothesised relationship results for the ISBC model

| Major Hypothesis | | Hypothesised Relationship | Standardised regression weights (b) | t-value | p-value | Decision | | Squared multiple correlation | |
|---|---|---|---|---|---|---|---|---|---|
| **H1** | $H1_1$ | RE → SBCI | -0.034 | -0.780 | 0.435 | Weak | **H1** | SBCI | 0.634 |
| | $H1_2$ | KS → SBCI | 0.153 | 2.249 | **0.025** | **Supported** | | | |
| | $H1_3$ | CD → SBCI | 0.187 | 2.729 | **0.006** | **Supported** | | | |
| | $H1_4$ | PDS → SBCI | -0.135 | -2.657 | **0.008** | **Supported** | | | |
| | $H1_5$ | PMT → SBCI | 0.287 | 4.717 | **0.000** | **Supported** | | | |
| | $H1_6$ | MBT → SBCI | 0.418 | 6.506 | **0.000** | **Supported** | | | |
| **H2** | H2 | SBCI → ISBCPD | 0.929 | 10.596 | **0.000** | **Supported** | **H2** | ISBCPD | 0.363 |

Finally, Figure 9.11 portrays the integrated sustainable building construction (ISBC) model to answer the hypotheses testing. Hence, expressing unique contributions of the influencing constructs as well as the variances explained by them.

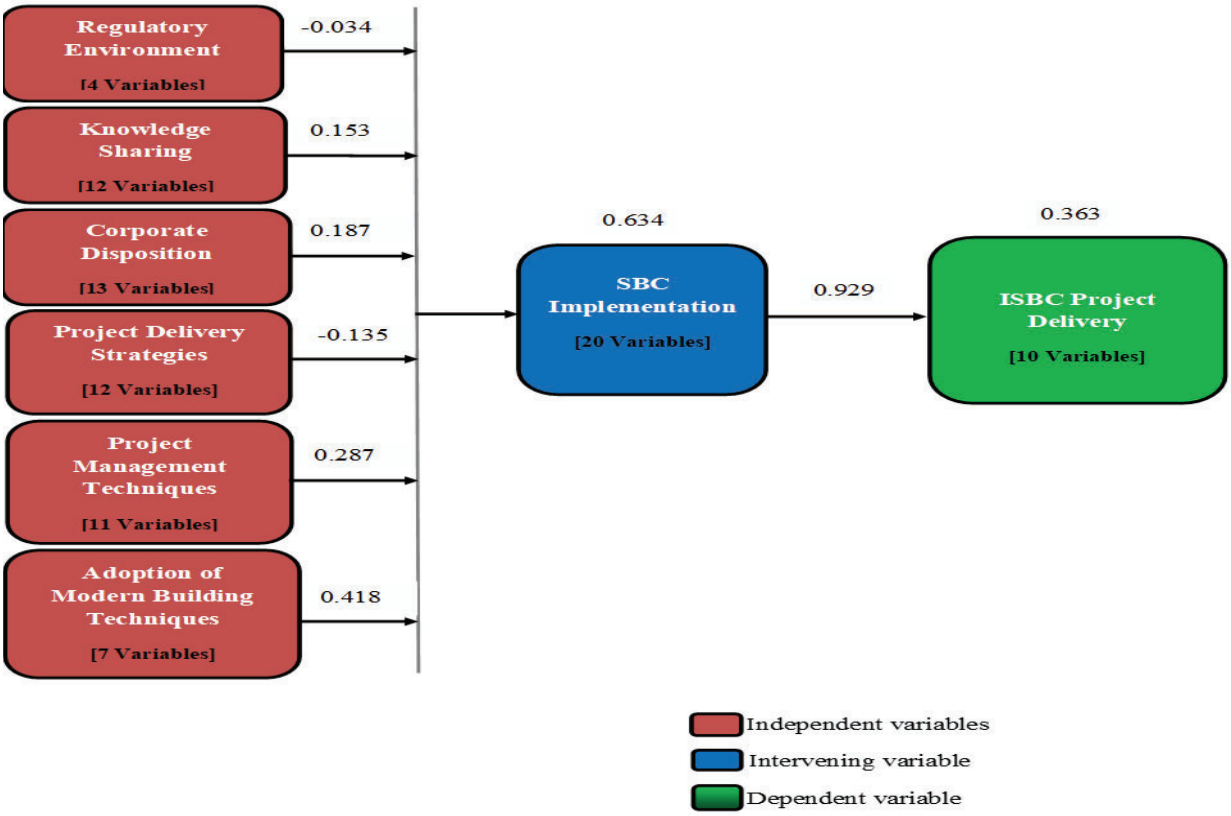


**Figure 9. 11**:Final ISBC model indicating unique contributions and variances explained

## 9.5 Chapter Conclusion

This chapter presented the results of the analysis from the questionnaire collected data. Descriptive and inferential statistics were observed. Descriptive statistics included the presentation of the demographical data with frequencies. It also included the description of the latent constructs of the ISBC model with mean and standard deviation as outputs. Inferential statistics accommodated exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and the structural model analysis.

The EFA helped in refining the data and establishing the reliability of the measuring variables. CFA helped in validating the suitability of the measuring model and confirming the items that

actually measure the latent constructs. Reliability checks including Cronbach's and composite reliability were done to ensure internal consistency and dependability of the measuring variables. Similarly, convergent validity was observed to ensure that each underlying latent construct explains more than half of the variance in the belonging indicators. Additionally, discriminatory validity was checked to ensure that measurements of the latent constructs are distinct and unrelated.

Structural analysis on the other hand, helped in determining the direct relationships and the significance of the hypothesis testing in the model. Three major hypotheses (HI, H2, and H3) were tested that resulted to a total of 13 hypotheses. **HI** sought to determine the influence of sustainable building construction (SBC) determinants (exogenous latent constructs) on SBC implementation features. Hence, HI was separated into six sub-hypotheses ($HI_1$, $H1_2$, $H1_3$, $H1_4$, $H1_5$, and $H1_6$). Although *$HI_1$* (RE influence on SBCI) was insignificant, the rest of the hypotheses were significant. Exogenous variables KS, CD, PMT and MBT had a positive impact on SBCI while PDS had a negative impact.

Similarly, **H2** sought to establish the influence of sustainable building construction implementation SBCI, (intervening/mediating construct) on integrated SBC project delivery, ISBCPD) outcomes (endogenous construct), and the result was positive and statistically significant.

The integrated sustainable building construction (ISBC) model for project delivery in South Africa was robust with many measuring variables and latent constructs. Although the CFI, IFI, NFI, and TLI cut off values were not met, the ISBC model achieved an acceptable fit with $\chi^2/df=2.397$, SRMR=0.049, and RMSEA=0.071. These three criteria were the most preferred in literature compared to the other indices (Marsh et al., 2004). Moreover, the model adequately explained the relationships in it, and was confirmed to have an acceptable fit based on Marsh et al. (2004) and Kline (2010) positions that a good model does not mean every part of it fits well especially if the model was robust. Chapter ten discusses the findings of this study in detail relating them with the secondary data from the literature.

# CHAPTER TEN

# DISCUSSION OF FINDINGS

## 10.0 Introduction

This chapter discusses the findings of the study while relating them with literature as applicable. The discussion centres on the objectives of the study. The study conducted in South Africa aimed to establish the predominant factors defining effective implementation of sustainable building construction (SBC); evaluate the impact of SBC-determinants on SBC implementation; evaluate the impact of SBC implementation on integrated SBC project delivery; develop an integrated sustainable building construction model for project delivery in South Africa; and validate the developed model for SBC regarding the goodness of fit.

## 10.1 Discussion of Descriptive Statistics Results

### 10.1.1 Predominant factors defining effective implementation of sustainable building construction (SBC) for project delivery in South Africa

#### *10.1.1.1 Regulatory environment*

Results from descriptive statistics showed that the predominant regulatory environment factors defining effective implementation of SBC for project delivery in South Africa included the Green Building Council of South Africa (GBCSA) standards, National environmental management regulations, Department of public works green building policy, Compulsory sustainable building certification, and Compulsory enforcement of sustainable construction laws. Respectively, they were the top five ranked in descending order out of eleven variables.

The finding on *GBCSA standards* being the top ranked suggests that the Built Environment professionals in South Africa highly appreciate the initiatives of the council in ensuring sustainable building construction implementation (GBCSA, 2017; Hoffman et al., 2020). The

findings on *national environmental management regulations*, and *department of public works green building policy* are consistent with Abonginije et al. (2020) who affirmed that the two are among the prime factors for implementing green building practices in South Africa.

Moreover, the findings on *compulsory sustainable building certification*, and *compulsory enforcement of sustainable construction laws* are consistent with Wang et al. (2018) avowing that legislation regarding building green should be mandatory if green specifications should be adopted.

#### *10.1.1.2 Knowledge sharing*

Results from descriptive statistics showed that the predominant knowledge sharing factors defining effective implementation of SBC for project delivery in South Africa included Mentoring younger professionals in sustainable practices, Public awareness of environmental issues, Awareness creation of green building products, Education on sustainable practices among staff, and Educational and training programs upgrade. Respectively, they were the top five ranked in descending order out of twelve variables.

Mentoring young professionals and public awareness were both ranked first. The finding on *mentoring younger professionals in sustainable practices*, aligns with Saeed et al. (2009) who proposed youth mentoring as a key strategic move towards sustainability and promoting social integrity. Similarly, the result on *public awareness on environmental issues* concurs with Wang et al. (2018) that suggested the creation of public awareness on environmental issues as critical for adopting sustainable practices. Besides, according to Korkmaz et al. (2009), the rise in environmental awareness among the public was a significant facilitator in moving towards green building in the USA.

The finding on *awareness creation of green building products* agrees with Qian and Chan (2010), and Kalua (2015), who affirmed it to be a predominant approach for improving green building in developing countries.

The finding regarding *education on sustainable practices among staff* as a predominant factor aligns with Ahn et al. (2013). Ahn et al. (2013) assert that it is essential to educate and train workers and subcontractors in construction projects for complete understanding and integration of sustainability consideration into their daily practice, hence improving their modus operandi toward sustainability.

Likewise, the finding on *educational and training programs upgrade* validates Arif et al. (2009a) claim that the lack of sufficient educational programs at school and college levels to promote green are barriers to sustainable construction. This expresses that *education and training programs upgrade* is a critical approach to promoting sustainable building construction in South Africa. According to Manoliadis et al. (2006), education and training in sustainable construction ideas and strategies are presumably the primary methods for facilitating and adopting sustainable construction practices.

#### *10.1.1.3 Corporate disposition*

Results from descriptive statistics showed that the predominant corporate disposition factors defining effective implementation of SBC for project delivery in South Africa included Top Management support, Availability of competent personnel, Availability of finance for the project operation, Good project management culture, and Stakeholders' involvement and commitment. Respectively, they were the top five ranked in descending order out of thirteen variables.

The finding on *top management support* concurs with many scholars who affirmed that top management support/commitment is essentially required if organisations will adopt sustainable building construction (Aktas and Ozorhon, 2015; Ametepey et al., 2015; Wong et al., 2016; Darko et al., 2017; Yas and Jaafer, 2020; Iqbal et al., 2021).

The finding on *availability of competent personnel* confirms many scholars' findings that incompetence is a significant barrier in adopting sustainable practices (AlSanad, 2015; Ametepey et al., 2015; Durdyev et al., 2018a). Similarly, *availability of finance for the project operation* being among the predominant factors indicates that financial capability is critical for

implementing SBC (Serpell et al., 2013; Darko et al., 2017; Susanti et al, 2019; Karji et al., 2020).

The finding on *good project management culture*, as a predominant factor supports Andelin et al's (2015) position that corporate culture which alludes to the practices, behaviours and convictions of an organisation influences sustainable building construction. On the other hand, the finding on *stakeholders' involvement and commitment* being a predominant factor confirms many authors positions suggesting that the lack of it is a critical barrier to sustainable building construction (Hwang and Tan, 2012; Ochieng et al., 2014; Saad, 2016; Osuizugbo et al., 2020; Aghimien et al., 2021; Marsh et al., 2021).

#### *10.1.1.4 Project delivery strategies*

Results from descriptive statistics showed that the predominant project delivery strategies defining effective implementation of SBC in South Africa included Early involvement of stakeholders, Collaboration of project participants, Client needs' assessment, Integrated project delivery system, and Public-private partnerships. Respectively, they were the top five ranked in descending order out of nineteen variables.

The findings on *early involvement of stakeholders*, and *collaboration of project participants* correspond with several scholars' assertion that delivery methods that encourage the early involvement of stakeholders, and the collaboration of project participants are crucial for effective project delivery (Kent and Bercerik-Gerber, 2010; Aknar, 2016; Garcia et al., 2016; Akiner and Akiner, 2018; Hashem et al., 2018; Gunhan, 2019; Olanike et al., 2020).

The finding on *client needs assessment* aligns with Gunhan (2019) that it is essential to establish the priorities of the client and project participants in any undertaking. Similarly, the findings on *integrated project delivery* (IPD) as predominant factor is consistent with Aknar (2016). Aknar (2016) assets that IPD, is a new delivery system that supports collaborative innovation and decision making, early involvement of key participants, early goal definition, intensified planning, open communication, appropriate technology, organisation and leadership, mutual

respect and trust, and mutual benefit and reward. These traits, therefore, are relevant for delivery of sustainable building construction projects.

Furthermore, the finding on public-private partnerships corresponds with Akomea-Frimpong et al. (2023), Dolla and Laishram (2020) and Hueskes et al. (2017), that suggested a connection between PPPs and sustainable infrastructure development. However, Hueskes et al. (2017) suggested that PPPs can be utilised for weak conceptualisation of sustainability as opposed to strong conceptualisation of sustainability.

#### *10.1.1.5 Project management techniques*

Results from descriptive statistics showed that the predominant project management techniques defining effective implementation of SBC for project delivery in South Africa included Quality management techniques, Cost management techniques, Stakeholder management techniques, Risk management techniques, and Time management techniques. Respectively, they were the top five ranked in descending order out of twelve variables.

The findings on *quality management techniques* aligns with Patanakul et al. (2010) who affirmed that it is very crucial in achieving project management deliverables and project objectives. Similarly, the findings on *cost management techniques* provides evidence on how critical cost is to project undertaking especially SBC, that are perceived to have hight cost (Osuizugbo et al., 2020; Marsh et al., 2021).

The findings on *stakeholder management techniques* as a predominant factor provides evidence on the criticality of managing stakeholders interest and participation in a project (Patanakul et al., 2010; Chou and Yang, 2012; PMI, 2021).

The finding on *risk management techniques* provides proof on the need for risk analysis and expert judgement regarding SBC projects (Cetindamar et al., 2012; PMI, 2021). Moreover, the finding on *time management techniques* validates how crucial they are in planning and scheduling of projects time and activities toward achieving specific project objectives (Kerzner and Kerzner, 2017; Emere et al., 2019).

Generally, the predominant project management techniques identified in this study align with project success outcomes such as time, cost, quality, stakeholders/client satisfaction etc. (Emere et al., 2019).

#### *10.1.1.6 Modern building techniques*

Results from descriptive statistics showed that the predominant modern building techniques defining effective implementation of SBC for project delivery in South Africa included Value engineering/management, Industrialised building systems (IBS), Lean techniques, and Building information management (BIM). Respectively, they were the top four ranked in descending order out of seven variables.

The finding on *value engineering/management* aligns with Wao et al. (2016), who recommended value engineering as a potential tool for improving sustainability outcomes due to its focus on performance, quality improvements and cost saving. Several scholars also affirm that value engineering has a connection with sustainable construction (Mahadik, 2015; Wao et al., 2016; Gunarathne et al., 2022; Kineber et al., 2022).

The findings on *industrialised building systems* corresponds with (Yunus and Yang, 2011), who asserted that IBS has the potential to promote sustainable deliverables. According to Yunus and Yang (2011, IBS can control the manufacturing environment better, reduce waste, use energy-efficient building materials, and stabilise work conditions (Yunus and Yang, 2011). Similarly, Jaillon et al. (2009) indicated that an IBS deployment typically results in a 52% reduction in waste. Furthermore, it was affirmed that IBS can adapt modern and smart building energy systems (mechanical, electrical, fire safety, etc.) that are renowned for their outstanding environmental performance (Jaillon and Poon, 2009; Saleh and Alalouch, 2020).

The finding on lean techniques validates Ogunbiyi et al. (2014)'s proposition that lean construction is one of the strategies for improving sustainable construction. Likewise, Hussin et al. (2013) proposed that using lean techniques among other advanced methods like value engineering, IBS, and BIM can improve sustainable construction project performance.

Furthermore, the finding on BIM as a predominant factor determining SBC project delivery in South Africa is consistent with Bynum et al. (2013), and Mollaoglu-Korkmaz et al. (2013) that identified BIM as crucial to meeting sustainable project performance objectives by the virtue of its models.

## 10.2 Discussion of Inferential Statistics Results

This section discusses the processes adopted for establishing the final measuring instruments for the integrated sustainable building construction (ISBC) model for project delivery in South Africa. However, a detailed presentation and discourse were done in chapter ten.

### 10.2.1 Exploratory factor analysis (EFA)

EFA helped in producing fewer linear combinations of the original variables that reflect most of the variability in the correlation pattern through principal component analysis (Pallant, 2020). Hence, the eight latent constructs of the proposed ISBC model were subjected to EFA. The proposed model was made of six primary endogenous latent constructs, one primary endogenous latent construct (serving also as a mediating construct) and one secondary latent construct. Thus, the latent constructs included regulatory environment (RE) with eleven variables, knowledge sharing (KS) with twelve variables, corporate disposition (CD) with thirteen variables, project delivery strategies (PDS) with nineteen variables, project management techniques (PMT) with twelve variables, modern building techniques (MBT) with seven variables, SBC implementation with twenty-four variables, and integrated SBC project delivery (ISBCPD) with ten variables. Hence, these variables were used for elicitation of data from the structured questionnaire. The responses from 281 respondents were found suitable for all the necessary analyses of the study (Neuman, 2014; Leedy and Ormrod, 2016; Tengan, 2018; Ametepey, 2019; Pallant, 2020).

Regarding EFA, the suitability of the collected data was further assessed with the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett's test of sphericity (significance level). Hence, all the latent constructs met the criteria. For KMO, the values of the latent constructs ranged from 0.889 to 0.959 surpassing the minimum acceptable threshold of 0.6 to

continue with factor analysis (Tabachnick and Fidell, 2013; Pallant, 2020). Similarly, factorability was permitted as the Bartlett's test of sphericity results for all the latent constructs achieved values less than the set 0.05 significance level (Pallant, 2020).

Additionally, principal component analysis was used for extraction while varimax with Kaiser normalisation was used for rotation in the EFA. After extraction, each measuring variables of the latent constructs achieved communality value above 0.50. Besides, the average communality value of the variables in each latent construct was above 0.60 at the initial iteration indicating suitability (Field, 2009; Hair et al., 2013). However, there were variables with cross loading after rotation which can cause problems in the analysis and results' interpretation. These variables were removed from further analysis, hence, not included for confirmatory factor analysis. Under RE, integrating environmental studies in construction (RE8), and laws ensuring the sustainability of resources (RE5) were eliminated. Under PMT, "communication management techniques (PMT11)" was removed. Under SBCI, consideration of supplementary energy systems (SBCI13), usage of renewable resources (SBCI14), protection of biodiversity and ecology (SBCI11), and the usage of materials with low carbon footprint (SBCI9) were removed. Under, PDS, integrated project delivery system (PDS5) had no loading after rotation. Therefore, it was removed.

Furthermore, the selected variables internal consistency and reliability were assessed for each of the latent constructs. All met the criteria as they recorded Cronbach's alpha values above the 0.70 threshold (Pallant, 2020). Considering all the necessary prechecks, extractions and rotations, the selected variables were regarded as principal in underlying integrated sustainable building construction for project delivery in South Africa.

### 10.2.2 Confirmatory factor analysis (CFA)

The selected variables in each construct after EFA were subjected to CFA to assess the best fit for the model. All necessary checks, inter alia Cronbach alpha reliability, composite reliability, convergent validity and discriminatory validity were done. The variables that passed the CFA test recorded Cronbach's alpha reliability values ranging from 0.904 to 0.972 while composite

reliability values ranged from 0.912 to 0.972 as shown in Table 66. Hence, the results of the Cronbach's alpha confirmed a very good internal consistency and reliability of the measuring variables of the constructs exceeding the 0.7 threshold (Pallant, 2020). Similarly, the results of the composite validity confirmed that the constructs were consistent, predictable, and dependable (Salkind, 2012; Collier, 2020).

Additionally, the average variance explained (AVE) values which ranged from 0.545 to 0.725 exceeding the 0.5 threshold for suitability (Bagozzi and Yi, 2012) as shown in Table 76. Therefore, confirming empirical evidence for convergent validity as each of the underlying latent constructs explains more than half of the variance in the belonging indicators (Bagozzi and Yi, 2012; Collier, 2020). Furthermore, the discriminatory validity results as shown in Table 78 solidified the suitability of the latent constructs for the integrated sustainable building construction (ISBC) model. Hence, the latent constructs were distinct and unrelated as each had values greater than intercorrelation value between other constructs (Fornell and Larcker, 1981).

### 10.2.3 Full structural model and measurement instrument

The full structural model assessments started with CFA and concluded with the hypothesis testing of the relationships between the model. The CFA established the measurement models confirming their reliability and validity. The measurement model assessment established how well the latent constructs were measured by the observed variables (Kline, 2010; Collier, 2020). Hence, the final measurement models of ISBC comprised of six exogenous latent constructs, a primary endogenous construct, and a secondary endogenous construct. The exogenous latent constructs comprised *regulatory environment (RE)* with four measuring variables, *knowledge sharing (KS)* with twelve variables, *corporate disposition (CD)* with thirteen variables, *project delivery strategies (PDS)* with twelve variables, *project management techniques (PMT)* with eleven variables, and *modern building techniques (MBT)* with seven variables. Similarly, *sustainable building construction implementation (SBCI)*, the intervening/mediating construct, comprised twenty variables, while *integrated SBC project delivery* endogenous construct comprised ten variables.

Conversely, the structural model established the direct relationships between each exogenous latent construct and endogenous latent constructs (Collier, 2020). The results of these relationships are fully discussed and interpreted in the next section.

## 10.3 Discussion of the Full Structural Model Hypothesised Results

### 10.3.1 Influence of SBC-determinants on SBC implementation for project delivery

This section discusses the influence of the exogenous constructs such as regulatory environment, knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques on SBC implementation features.

#### *10.3.1.1 Influence of regulatory environment (RE) on SBC implementation for project delivery*

According to the findings of this study, the relationship between regulatory environment (RE) and SBC implementation was statistically insignificant at 5% significance level with p-value of 0.435. This finding contradicts Wang et al. (2018)'s assertion that regulatory environment factors like legal framework, regulations, policies, code, and specifications to guide all the stakeholders including that government officials are a fundamental guarantee for the successful adoption of green specifications. Wang et al. (2018) further asserted that the lack of regulatory environment factors are critical barriers to sustainable construction. The finding also contradicts Manoliadis et al. (2006) and Serpell et al. (2013) who posited that regulatory environment factors such as policies and incentives from government are facilitators of sustainable construction. This position is predominant in literature findings.

Similarly, the results of the structural model testing showed a negative regression weight of -0.034. This, therefore, indicates that an increase in the measuring variables of regulatory environment will negatively impact SBC implementation. However, it is noteworthy that the four variables that made up the final measurement model for RE predominantly comprised compulsory instruments instead of voluntary. They included compulsory sustainable building assessment (RE9), compulsory enforcement of sustainable construction laws (RE10), compulsory sustainable building certification (RE11), and incentives for the companies that are building sustainably (RE7). This finding

contradicts several authors/scholars' position that policies and regulations should be mandatory for fruitful implementation of green procurement and sustainable building construction (Walker et al., 2008; Diabat and Govindan, 2011; Yang and Zhang, 2012; Zhai, 2014; Wang et al., 2018). Therefore, the regression weight finding of this study on RE may suggest that applying force or coercion is not the way forward for effective implementation of sustainable building construction. This is consistent with the findings of Lee and Yik (2004).

According to Lee and Yik (2004), despite the widespread use of regulatory control, many believe that it is more cost-effective to promote voluntary commitments to address environmental problems associated with sustainable construction. They also revealed that many scholars appreciate the choice of a well-articulated policy mix that included both voluntary and regulatory instruments (Lee and Yik, 2004). Similarly, Komives and Jackson (2014) proposed voluntary sustainability standard system as a contribution to sustainable development and its related objectives. Therefore, even though the study's main finding indicated a statistically weak related, it may be emphasised that the regulatory environment and SBC implementation for project delivery are related.

#### *10.3.1.2 Influence of knowledge sharing (KS) on SBC implementation for project delivery*

The findings of this study showed a significant relationship between knowledge sharing (KS) and SBC implementation at 5% significance level with p-value of 0.025. Therefore, the supposition that KS influences SBC implementation was approved. Likewise, the analysis of the structural model revealed a positive standardised regression weight of 0.153. This positive contribution indicates that an increase in knowledge sharing will result to an increase in the implementation of sustainable building construction (SBC). Consequently, it can be stated that knowledge sharing is beneficial to SBC implementation in the South African construction industry.

Wang et al. (2018) asserted that the creation of public awareness on environmental issues as critical for adopting sustainable practices. For Korkmaz et al. (2009), the rise in environmental awareness among the public was a significant facilitator in moving towards green building in the USA. Saeed et al. (2009) affirmed that mentoring of youths (young professionals) is a key

strategic move towards sustainability and promoting social integrity. Similarly, Manoliadis et al. (2006), Ahn et al. (2013) and others avow that education and training in sustainable construction ideas and strategies are presumably the primary methods for facilitating and adopting sustainable construction practices. Arif et al. (2009a) proposed sound research and development including educational program upgrade at schools. This suggests that a sound information hub/repository is required in educational institutions.

Furthermore, Abidin and Powmya (2014), asserted reaching out to people through media, advertisements, seminars, and training are very critical ways to promote green construction. Besides, Liu et al. (2012), suggested that government and companies should play a role by publicising the merits of green/sustainable buildings to the citizens and guiding them to circumvent high-carbon lifestyles. Additionally, knowledge sharing should extend to creating awareness of green building products (Qian and Chan, 2010, and Kalua, 2015) for improvement of SBC implementation in the developing countries such as South Africa. Therefore, the findings of this study confirm that knowledge sharing can significantly improve SBC implementation for project delivery in South Africa.

#### *10.3.1.3 Influence of corporate disposition (CD) on SBC implementation for project delivery*

The findings of this study showed a significant relationship between corporate disposition (CD) and SBC implementation at 5% significance level with p-value of 0.006. Therefore, the proposition that CD influences SBC implementation was approved. Likewise, the analysis of the structural model revealed a positive standardised regression weight of 0.187. This positive contribution indicates that an increase in good corporate disposition will result to an increase in the implementation of sustainable building construction (SBC). Consequently, the findings of this study prove that good corporate disposition is advantageous to SBC implementation in the South African construction industry. For example, many scholars affirmed that top management support is critical for SBC implementation (Aktas and Ozorhon, 2015; Ametepey et al., 2015; Wong et al., 2016; Darko et al., 2017; Yas and Jaafer, 2020; Iqbal et al., 2021).

Additionally, Duplessis (2007) asserted that institutions including government, academics, research, professional bodies, and construction firms, must accept sustainable development concepts as an integral part of their operations in order to create an environment that is supportive of sustainable construction. This will ensure that the corporate bodies maintain an image (values), visions, culture (behavioural, convictions, practices), and responsibility that upholds sustainable principles (Yang and Zhang, 2012; Andelin et al., 2015; Tarver and Brock, 2021).

Similarly, increase in competent personnel, finance for the project operation, good project management culture, and stakeholders' involvement and commitment within construction organisations were affirmed to facilitate SBC implementation (Andelin et al., 2015; Saad, 2016; Darko et al., 2017; Durdyev et al., 2018a; Ochieng et al., 2019; Karji et al., 2020; Aghimien et al., 2021; Marsh et al., 2021). Therefore, the findings of this study confirm that corporate disposition can significantly improve SBC implementation for project delivery in South Africa.

#### *10.3.1.4 Influence of project delivery strategies (PDS) on SBC implementation*

The findings of this study revealed a significant relationship between project delivery strategies (PDS) and SBC implementation at 5% significance level with a p-value of 0.008. Therefore, the supposition that PDS influences SBC implementation was accepted. This is consistent with many studies that affirmed that project's performance including that of SBC depends on the project delivery strategy (Gad et al., 2015; Kantola and Saari, 2016; Mehany et al., 2017; Hashem et al., 2018).

Similarly, the structural model analysis showed a negative standardised regression weight of -0.135. This negative contribution indicates that an increase the measuring variables of PDS will result to a decrease in the implementation of sustainable building construction (SBC). However, it is noteworthy, that the final measurement model for PDS was dominated with the traditional delivery and procurement strategies as opposed to integrated/newer delivery strategies. The newer delivery and procurement strategies were removed (considering the model indices results) to give the model a best fit and provide findings that are easy to interpret. These included early

involvement of stakeholders (PDS10), Collaboration of project participants (PDS9), Integrated project delivery system (PDS5), Public-private partnerships (PDS7) and the like, that were identified as the predominant project delivery strategies defining effective implementation of SBC in South Africa.

Therefore, the findings on PDS provide evidence that the choice of project delivery strategy has an impact on project undertaking including SBC implementation (DBIA, 2018; Kantola and Saari, 2016). Kantola and Saari (2016), explored the most effective delivery system for nearly-zero-energy building (nZEB) projects that use low energy, primarily generated from renewable sources. The authors declined the usage of traditional delivery method (Design-bid-build) and indicated that because nZEB projects have a multiparty contracting system, an integrated project delivery (IPD) system with a competitive procedure on negotiations or a competitive dialogue procurement technique would work well (Kantola and Saari, 2016). Gunhan (2019) also found that traditional project delivery method was not favoured as opposed to integrated project delivery and design and build.

Consequently, it can be stated that even though project delivery strategies (PDS) and SBC implementation had statistically significant relationship; and the choice of delivery strategy can have a negative or positive impact on SBC implementation.

#### *10.3.1.5 Influence of project management techniques (PMT) on SBC implementation for project delivery*

The findings of this study disclosed a significant relationship between project management techniques and SBC implementation at 5% significance level with p-value of 0.000. Therefore, the proposition that PMT influences SBC implementation was accepted. Likewise, the analysis of the structural model showed a positive standardised regression weight of 0.287. This positive contribution indicates that an increase in the use of project management techniques will result to an increase in the effective implementation of sustainable building construction (SBC) for project delivery. This finding provides evidence that there is a link between project management and sustainability (Wu and Low, 2010; Hwang and Ng, 2013; Sadaba et al., 2015).

Hwang and Ng (2013) affirmed that the cost, risks, and long period required for planning and designing green buildings demand adequate project management knowledge, skills and techniques to mitigate the challenges. Some fundamental knowledge areas were mentioned. They included "schedule management and planning, stakeholder management, communication management, cost management, and human resources management" (Abdelkhalik and Azmy, 2022:6).

Similarly, Patah (2010) and Horine (2013) acclaimed that project management, and its techniques are essential for achieving project efficiency and effectiveness, hence getting more done with fewer resources. For example, the use of cost management techniques can mitigate cost challenges associated with SBC that are perceived to have higher costs (Osuizugbo et al., 2020; Marsh et al., 2021). Besides, the use of risk management techniques can provide analysis and expert judgement regarding SBC projects (Cetindamar et al., 2012; PMI, 2021). Furthermore, Darus et al. (2009) recommended environmental management system in project management as critical for the effective implementation of sustainable building practices.

Considering the findings of this study it can be stated that PMT is advantageous to SBC implementation in the South African construction industry.

#### *10.3.1.6 Influence of modern building techniques (MBT) on SBC implementation for project delivery*

The findings of this study showed a significant relationship between modern building techniques (MBT) and SBC implementation at 5% significance level with p-value of 0.000. Therefore, the supposition that MBT influences SBC implementation was approved. Similarly, the analysis of the structural model revealed a positive standardised regression weight of 0.418. This positive contribution indicates that an increase in the adoption of modern building techniques will result to an increase in the implementation of sustainable building construction (SBC). These findings consolidate Hussin et al. (2013)'s proposition that using modern/advanced building techniques such as BIM, value engineering, lean techniques, industrialised building system, and supply chain management are essential for improving sustainable building construction.

Gultekin et al. (2013) revealed that the integration of BIM contributes to the level of green building systems in sustainable projects. Likewise, Ogunbiyi et al. (2014) proposed that using lean techniques is a very important strategy for improving sustainable construction. Also, Yunus and Yang (2011) avowed that the use of industrialised building systems has the potential to promote and achieve sustainable objectives like reducing waste, using energy-efficient building materials, stabilising work conditions and the like. Furthermore, Wao et al. (2016) recommended value engineering as a key tool for improving sustainability. Besides, Rachwan et al. (2016) avowed that value engineering not only improves quality and cost savings but also positively affects the environment and global green building.

Therefore, the findings of this study validate the supposition from extant literature that adoption of modern building techniques (MBT) have a positive impact on SBC implementation. The findings also confirm that MBT is essential for facilitating SBC implementation in the South African construction industry.

### 10.3.2 Influence of SBC implementation on integrated SBC project delivery (ISBCPD)

The integrated SBC project delivery outcomes in this study included Project completion with no time overrun, Project completion with no cost overrun, Achievement of prescribed quality requirements, Construction stakeholders/Client Satisfaction, End-user satisfaction, Value for money, Environmental objectives met, Health safety and comfort, Construction innovation, and Improvement in sustainability rating.

The findings on this study revealed a significant relationship between SBC implementation and integrated SBC project delivery outcomes at 5% significance level with p-value of 0.000. Therefore, the proposition that SBC implementation influence project delivery outcomes was accepted. Equally, the analysis of the structural model showed a positive standardised regression weight of 0.929. This positive contribution indicates that an increase in the implementation of SBC features/practices will result to an increase in the achievement of project delivery objectives/success outcomes. This position aligns with Olanipekun et al. (2017) who affirmed

that effective implementation of sustainable building construction (SBC) is linked with project delivery performance success.

SBC implementation provides value for money via its focus on reducing the rate of energy consumption during construction and the entire life of the building, considering the materials used, building components, construction technologies, and energy-related design concepts (Abd Jamil and Fathi, 2016; Ismail et al., 2017; Oke et al., 2017; Balasubramanian and Shukla, 2017). Besides, the embrace of technologies that helps in the improve use of construction resources, waste reduction, design and performance efficiency facilitates the attainment of cost, quality objectives, improvement in sustainability rating etc (Bynum et al., 2013; Malinauskaite et al., 2017; Olanipekun et al., 2017; Gunhan, 2019; Willar et al., 2020). Similarly, SBC features like sustainable and efficient designs, and sustainable structural materials not only decrease the adverse environment effects of building activities but also contributes to construction innovation and the attainment of health and safety objectives (Efthymiou et al., 2010; Wang and Adeli, 2014). Also, the use of smart appliances not only add to efficient utilisation of energy but also innovation, end user satisfaction, and comfort (Ko et al., 2012; Olanipekun et al., 2017; Willar et al., 2020).

Consequently, the findings of this study validate the supposition that SBC implementation impact integrated SBC project delivery outcomes.

### 10.3.4 Degree to which the hypothesised integrated sustainable building construction model fit into the sample data

The SEM findings of this study revealed that five out of the six identified exogenous latent constructs had a statistically significant direct influence on sustainable building construction implementation in the South African construction industry. They included knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques. Only regulatory environment had a statistically insignificant influence on sustainable building construction. Notably, the six exogenous latent constructs unanimously explained 63.4% of the variance in the sustainable building construction implementation

features. Therefore, the findings provided enough evidence to uphold the postulation that effective implementation of sustainable building construction is directly influenced by the identified exogenous constructs. The findings further confirmed the multifaceted of the determinants of effective implementation of sustainable building construction (Häkkinen and Belloni, 2011; Darko et al., 2017; Oguntona et al., 2019; Dosumu and Aigbavboa, 2021; Marsh et al., 2021; Illeperuma and Abeynayake, 2022).

Similarly, the findings of this study revealed that sustainable building construction implementation features had a statistically significant direct positive influence on integrated SBC project delivery outcomes. Besides, it explained 36.3% of the variance in project success outcomes. The findings, therefore, confirmed the supposition that effective implementation of sustainable building construction directly influences project delivery/success outcomes which is consistent with the views from literature (Olanipekun et al., 2017).

Generally, the integrated sustainable building construction model for South Africa was robust. It ascertained the influence of sustainable building construction (SBC) determinants on SBC implementation features. It also determined the influence of SBC implementation on integrate SBC project delivery (ISBCPD) success outcomes. All the necessary measures were observed including modification indices to ensure the goodness of fit of the model. Although the model was complex, it adequately measured what it was intended to measure, explained the relationships clearly, and achieved acceptable fit based on Marsh et al. (2004) and Kline (2010) assessment criteria.

## 10.4 Implications of the Findings

Sustainable building construction (SBC) is an innovative approach that is expected to transform the construction industry activities globally and in South Africa. However, there have been several bottlenecks in its implementation for project delivery. The present study succeeded in developing an integrated sustainable building construction (ISBC) model for project delivery in South Africa. The findings confirmed that SBC for project delivery in South Africa is a multi-

faceted model. The study revealed statistically significant influence of knowledge sharing, corporate disposition, choice of project delivery strategies, project management techniques, and modern building techniques on SBC implementation. These constructs' noteworthy influence suggests that they should be given priority to attain high levels of efficacy and efficiency when implementing SBC. Consequently, the consciousness of these influential determinants by the construction stakeholders and built environment organisations will help curb unsustainable practices in the construction industry.

Similarly, the study confirmed SBC implementation positive influence on integrated SBC project delivery outcomes through the contributions of SBC determinants. This suggests that the implementation of these constructs will guarantee not only the accomplishment of time, cost, and quality objectives but also enhancements in sustainability rating, innovative construction, environmental goal achievement, health, safety, and comfort, end-user satisfaction, value for money, and satisfaction from clients and construction stakeholders.

Evidence from the findings suggest that the enforcement of knowledge-sharing improves public awareness of sustainable principles, ensures adequate knowledge management in the construction sector, and improves the knowledge, skills, experience, competence, and capacity of the relevant personnel for SBC. Also, the study revealed that enforcing a good corporate disposition will guarantee support from upper management, a positive culture of project management, the involvement and commitment of stakeholders, a dedication to innovative building construction, environmental, protection as a social obligation and so on.

Additionally, the findings of this study shed light on the best project delivery strategies for SBC. Traditional approaches were found to have a negative impact as opposed to approaches that appreciates early involvement of stakeholders, collaboration of project participants, integrated project delivery system, and public-private partnerships. Therefore, these approaches were found to be essential in lessening the impact of inadequate procurement/delivery techniques, which have been recognised as a major obstacle to building sustainably and completing projects in developing countries like South Africa. Similarly, the results on project management techniques

(PMT) indicate that SBC project delivery is positively impacted by the appropriate use of pertinent techniques in line with the management of quality, cost, time, stakeholders, risk, procurement, scope, integration, and so on.

Moreover, the adoption of modern building techniques like value engineering/management, industrialised building systems, lean techniques, BIM, and the like, as revealed in this study, are critical for SBC implementation and actualisation of project success outcomes. Findings also revealed that features like sustainable/efficient designs, sustainable structural materials, energy consumption minimisation, consideration of supplementary energy systems, usage of renewable resources, compliance with sustainability assessment measures, promotion of waste material recyclability, compliance with regulations on sustainable practices, and so forth, are critical deliverables for sustainable building construction in South Africa. Therefore, the study recommends adequately considering and prioritising the revealed critical features to implement SBC project delivery effectively. Besides, knowledge of the variables associated with the critical features will enable decision-makers within construction organisations to direct improvement initiatives from this study appropriately. It will mitigate the reluctance to shift from the conventional methods and poor knowledge sharing among the public/clients on the essence of SBC.

Although the findings of the study provide indications that the respondents are knowledgeable of the features of SBC adoption, the built environment organisations should be continually kept abreast of the benefits of SBC to the environment, economy, and society. The findings on sustainable and efficient designs and waste minimisation further confirm that modern building techniques applicable to these features, such as BIM, industrialised building systems, value engineering/management, and lean techniques, should be embraced and prioritised in South Africa. The study, therefore, recommends effective enforcement and mobilisation of resources to support technological changes. Also, social acceptance of cutting-edge and innovative technologies can be achieved by deploying awareness programs by professional bodies in the built environment. Similarly, information technological specialists can collaborate with the built environment professional bodies to curb the technological barriers identified from the literature

regarding cost. This can give clients and users the desired value for money in implementing SBC.

Additionally, energy efficiency programs and systems and renewable energy sources like solar should be implemented and prioritised to reduce the overreliance on conventional electricity in South Africa. Moreover, sustainable materials should be prioritised in the South African construction industry. The embrace of sustainable materials with increased performance qualities can lessen the frequency and intensity of maintenance and repair tasks, leading to improved long-term productivity and increasing longevity and durability (Adebowale and Agumba, 2023).

Conversely, the findings on regulatory environment not being statistically significant added to an ongoing debate whether SBC legislation should be made compulsory or not. Although the findings suggest that compulsion may not be the ideal, compliance to such standards and policies, like the GBCSA and DPW green building policies, are well encouraged. This will help mitigate unsustainable practices in the built environment. The government should also be a driving force in implementing sustainable practices which will facilitate the actualisation of sustainable development goals. Likewise, the provision of financial incentives to organisations prioritising SBC is advised.

With the insights from the value and findings of this study, the SA construction industry can contribute immensely towards achieving sustainable development goals by aligning its construction activities with sustainability initiatives. Furthermore, the general results can serve as a support tool for identifying the most significant determinants and implementation features to enhance the decision of built environment professionals and stakeholders to adopt SBC.

## 10.5 Chapter Conclusion

This chapter discussed the results of the findings of this study and related them with literature studies. The study established the predominant determinants defining sustainable building construction (SBC) in the South African construction industry. It also established the influence of SBC determinants on SBC implementation. The statistically significant determinants included

knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques while regulatory environment was not.

Similarly, it also established the significance and positive contribution of SBC implementation on integrated SBC project delivery outcomes. SBC implementation was statistically significant. Additionally, the extent to which the hypothesised integrated sustainable building construction model fit the sample data/identified factors was expounded. Furthermore, the implication of the findings were discussed.

The next chapter presents a discourse on the achievements of the objectives of the study along with conclusions, contributions to the body of knowledge, policy, and practice, as well as suggestions for additional research.

# CHAPTER ELEVEN

# CONCLUSIONS AND RECOMMENDATIONS

## 11.0 Introduction

This chapter presents conclusions based on the discussion of the findings regarding the research objectives which included to firstly establish the predominant factors defining effective implementation of sustainable building construction (SBC) for project delivery in South Africa; secondly evaluates the impact of SBC determinants on SBC implementation in South Africa; thirdly it evaluates the impact of SBC implementation on integrated SBC project delivery outcomes; fourthly the development of an integrated SBC model for project delivery in South Africa; lastly it validates the developed model regarding the goodness of fit. Additionally, it discusses the study's contribution to practice and the body of knowledge and recommends possible initiatives to improve the adoption of sustainable building construction and practices in South Africa. Furthermore, it states the limitations of the study and recommendations for further research.

## 11.1 Summary of the Achieved Research Objectives

### 11.1.1 Objective 1

The first objective of the study was to establish the predominant factors defining effective implementation of sustainable building construction (SBC) for project delivery in South Africa. Firstly, the literature review was used to identify these factors which were categorised under latent constructs namely, regulatory environment, knowledge sharing, corporate disposition, project delivery strategy, project management techniques, and modern building techniques. Secondly the factors were used to elicit the relevant data through a structured questionnaire circulated among the Built Environment professionals in South Africa. Descriptive statistics with

mean and standard deviation were used as outputs. The predominantly ranked defining factors were stated in their descending order.

Results showed that for *regulatory environment*, the predominant factors out of eleven variables included the Green Building Council of South Africa (GBCSA) standards, National environmental management regulations, Department of public works green building policy, Compulsory sustainable building certification, and Compulsory enforcement of sustainable construction laws.

For *knowledge sharing*, the predominant factors out of twelve variables included Mentoring younger professionals in sustainable practices, Public awareness of environmental issues, Awareness creation of green building products, Education on sustainable practices among staff, and Educational and training programs upgraded.

Regarding *corporate disposition*, the predominant factors out of thirteen variables included Top management support, Availability of competent personnel, Availability of finance for the project operation, Good project management culture, and Stakeholders' involvement and commitment.

Regarding *project delivery strategies*, the predominant factors out of nineteen variables included Early involvement of stakeholders, Collaboration of project participants, Client needs assessment, Integrated project delivery systems, and Public-private partnerships.

For *project management techniques*, the predominant factors out of twelve variables included Quality management techniques, Cost management techniques, Stakeholder management techniques, Risk management techniques, and Time management techniques.

Regarding *modern building techniques*, the predominant factors out of seven variables included Value engineering/management, Industrialised building systems (IBS), Lean techniques, and Building information management (BIM).

Therefore, the findings of the study established the predominant factors defining effective implementation of sustainable building construction (SBC) for project delivery in South Africa.

### 11.1.2 Objective 2

The second objective was to evaluate the impact of sustainable building construction (SBC) determinants on SBC implementation in South Africa. The findings provided statistical evidence that there is a significant relationship between the two. Five out of the six identified exogenous latent constructs had a statistically significant direct influence on SBC implementation in South Africa. They included knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques. Only regulatory environment had a statistically insignificant influence on sustainable building construction. Nevertheless, the six exogenous latent constructs unitedly explained 63.4% of the variance in the SBC implementation features as shown in Table 9.63 by the squared multiple correlation of the inferences. Therefore, the findings provided sufficient evidence to uphold the postulation that effective implementation of sustainable building construction (SBC) is directly influenced by the identified exogenous latent constructs (SBC determinants).

### 11.1.3 Objective 3

The third objective was to evaluate the impact of sustainable building construction (SBC) implementation on integrated SBC project delivery (ISBCPD) outcomes in South Africa. The findings provided statistical evidence that there is a significant relationship between the two. Similarly, the findings of this study revealed that sustainable building construction implementation had a statistically significant direct positive influence on project success outcomes. Additionally, it explained 36.3% of the variance in ISBCPD as shown in Table 9.63 by the squared multiple correlation of the inference. The findings, therefore, confirmed the supposition that effective implementation of sustainable building construction directly influences ISBCPD.

### 11.1.4 Objective 4

The fourth objective of the study was to develop an integrated sustainable building construction (ISBC) model for South Africa. Relevant theories and models concerning sustainable building

construction were reviewed. The literature review helped in the identification of gaps in knowledge and the formulation of the main constructs of the conceptual model of the study. The conceptual model comprised of six exogenous latent constructs which included regulatory environment (RE), knowledge sharing (KS), corporate disposition (CD), choice of project delivery strategies (PDS), project management techniques (PMT), and adoption of modern building techniques (MBT). PDS, PMT, and MBT were the gaps in knowledge regarding sustainable building construction. Similarly, the model contained a mediating latent construct termed sustainable building construction implementation (SBCI) and endogenous latent constructs called integrated SBC project delivery (ISBCPD). Generally, the constructs of the model were underpinned by literature studies. The model resulted to seven hypotheses summarised under two major hypotheses which were confirmed using structural equation modelling (SEM) analysis in Chapter nine.

### 11.1.5 Objective 5

The fifth and final objective of the study was to determine the validity of the integrated sustainable building construction (ISBC) model for project delivery in South Africa. Rigorous processes were adhered to ensuring that the data collection and analysis were adequate. Structured questionnaire was used to elicit data. Exploratory factor analysis was used to refine the variables with SPSS version 29 software. Similarly, SEM analysis through Amos software version 29 was done to confirm the constructs/variables in the model and establish the relationships between the various constructs in the model. The ISBC model was very robust. It ascertained the influence of sustainable building construction (SBC) determinants on SBC implementation. It also determined the influence of SBC implementation on integrated SBC project delivery. All the necessary measures were observed including modification indices to ensure the goodness of fit of the model. Although the model was complex, it adequately measured what it intended to measure, explained the relationships clearly, and achieved acceptable fit based on the criteria for complex model portrayed in literature studies.

## 11.2 Research Contribution and Value

### 11.2.1 Integrated sustainable building construction model

The current study's most notable contribution is the design and validation of the integrated sustainable building construction (ISBC) model for project delivery in South Africa. The model revealed statistically significant influence of knowledge sharing, corporate disposition, choice of project delivery strategies, project management techniques, and modern building techniques on SBC implementation. It also revealed the statistically significant influence of SBC implementation on integrated SBC project delivery (ISBCPD) outcomes. The study revealed and validated the influence of the identified gaps in knowledge (choice of project delivery strategies, project management techniques, and adoption of modern building techniques) in predicting effective implementation of sustainable building construction for project delivery in South Africa. The developed and validated integrated sustainable building construction (ISBC) model was underpropped by the resilience and institutional theory. The combined theories underscored the exogenous latent constructs which included regulatory environment, knowledge sharing, corporate disposition, project delivery strategies, and modern building techniques that were hypothesised in the ISBC for project delivery in South Africa.

### 11.2.2 Contribution and value to theory

The findings of the structural equation model (SEM) analysis revealed that sustainable building construction for project delivery in South Africa is a multi-factor model. No similar study of this magnitude was identified by the researcher within South Africa. Similarly, there is very scanty theoretical information regarding the factors that will most significantly impact sustainable building construction (SBC) in the developing nation's setting. Besides, none has statistically confirmed the extent of influence of the determining factors of SBC implementation. Only that many had majored on establishing barriers and suggesting possible drivers of sustainable/green building. Hence, a wholistic approach of establishing a robust model for sustainable building construction (SBC) for successful project delivery has not been done. This indicates a novel approach contribution to the body of knowledge.

Additionally, the SEM results of the current study justified the theory that effective implementation of SBC towards achieving project delivery success outcomes is a by-product of multifaceted construct. Likewise, the SEM findings confirmed the theoretical base that regulatory environment, knowledge sharing, corporate disposition, choice of project delivery strategies, project management techniques, and adoption of modern building techniques determine SBC. Furthermore, the findings confirmed that the latent variables had significant contribution towards implementing SBC for project delivery success in South Africa.

### 11.2.3 Contribution and value to methodology

To the best of the researcher's knowledge, this is one of the recent studies in SBC research that incorporated exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and structural model analysis. The current study used EFA to explore the factors and to produce fewer linear combinations of the original variables that reflect most of the variability in the correlation pattern through principal component analysis. CFA on the other hand, helped in confirming the specific hypotheses or theories concerning the structure of the set of variables CFA was also essential for determining the variables in each latent construct, the best fit for the model before performing the main SEM analysis. The extent/strength of the relationship of the factors in the integrated sustainable building construction model were tested and brought to light by the SEM analysis. Additionally, high internal reliability values were achieved by the questionnaire instrument. Hence, the reliability values could be used as thresholds to validate instruments in similar studies or applied in other contexts.

### 11.2.4 Contribution and value to practice

Many practical contributions have stemmed from this study. The structural equation modelling results indicate that knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques statistically influence SBC implementation. Knowledge of the variables associated with these key influencing constructs will enable decision-makers within construction organisations to direct improvement initiatives from this study appropriately. Also, the significant impact of the constructs indicates that they

are to be prioritised to achieve high efficiency and effectiveness in implementing sustainable building construction.

Similarly, results indicate that through the contributions of SBC determinants, SBC implementation directly impact integrated SBC project delivery outcomes. In other words, these constructs will ensure the achievement of not only the time, cost, and quality objectives but also improvement in sustainability rating, construction innovation, meeting environmental objectives, health safety and comfort, end-user satisfaction, value for money, and client and construction stakeholders' satisfaction.

Additionally, the findings of this study suggest that the enforcement of knowledge-sharing inter-alia improves public awareness of sustainable principles, ensures adequate knowledge management in the construction sector, and improves the knowledge, skills, experience, competence, and capacity of the relevant personnel for SBC. Also, enforcing good corporate disposition will ensure top management support, good project management culture, stakeholders' involvement and commitment, commitment to innovative construction, social responsibility to protect the environment, and the like. Besides, the current study's results provide insight into the suitable project delivery strategies for sustainable building construction (SBC). Hence, these strategies can mitigate the poor procurement/delivery strategies identified as one of the prevalent challenges regarding building sustainably and project delivery in South Africa and developing nations. Likewise, the findings about project management techniques (PMT) suggest that adequate utilisation of the relevant techniques in alignment with the management of quality, cost, time, stakeholders, risk, procurement, scope, integration, and so forth, are favourable for SBC project delivery. Moreover, the adoption of modern building techniques like value engineering/management, industrialised building systems, lean techniques, BIM, and the like, as revealed in this study, are essential for effectively implementing SBC and actualisation of project success outcomes.

Furthermore, the study reveals that the use of sustainable, efficient designs, sustainable structural materials, energy consumption minimisation, consideration of supplementary energy systems, usage of renewable resources, compliance with sustainability assessment measures, promotion of

waste material recyclability, compliance with regulations on sustainable practices, and so forth, are critical implementation features to be adhered to for sustainable building construction in South Africa.

The revelations from the current study's findings are valuable, especially for construction sectors in South Africa and developing nations. Therefore, the contributions from the current study's findings, when carefully considered, will improve sustainable building construction (SBC) implementation and project delivery success.

## 11.3 Recommendations

### 11.3.1 Integrated sustainable building construction model

The current study used a six-factor construct to conceptualise the effective implementation of sustainable building construction for project delivery in the South African construction industry. The constructs include regulatory environment, knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques. The model determined the influence of the constructs on SBC implementation and project success outcomes and tested the effect of SBC implementation as a meditating construct on integrated SBC project delivery outcomes. Although the model is robust and achieved what it intended to measure, the study recommends its validation in the broader population. Similarly, the study suggests integrating other constructs from the literature that may be significant with the existing constructs in predicting the effective implementation of sustainable building construction for project delivery in South Africa.

### 11.3.2 Theoretical recommendation

Theoretically, there is a limited view and narrow conceptualisation of SBC. Also, there has yet to be any consensus on what defines the effective implementation of SBC. Hence, the current study arrived at a functional definition and validated the determinants that guarantee the SBC implementation for successful project delivery. This was done by reviewing the extant literature, identifying and

developing a latent exogeneous six-factor ISBC model, and validating it with structural equation modelling (SEM) using Amos 29 software. The identified factors include regulatory environment, knowledge sharing, corporate disposition, project delivery strategies, project management techniques, and modern building techniques. Consequently, the study recommends that the developed multi-factor model form the basis regarding SBC implementation for project delivery success, especially in South Africa. Furthermore, knowledge sharing, corporate disposition, project management techniques, and modern building techniques should be prioritised for integration in further studies.

### 11.3.3 Methodological recommendation

The current study recommends that similar studies with larger samples and different sampling techniques, be done in the South African construction industry. This may provide different viewpoints concerning SBC implementation. Notably, this implies that additional time and financial resources may be required. Further research could investigate enhancing the existing model's fit to the indicator variables. Some of the indicators were developed specifically for South Africa. As a result, the model can be enhanced by considering other indicators, as there is no perfect model. Furthermore, structural equation modelling (SEM) is advised as an analysis technique for improved results and abstraction.

### 11.3.4 Practical recommendations

The are many recommendations for practice identified, considering the contributions and value of the current study. Firstly, this study recommends that Built Environment stakeholders and professionals adhere to the implementation features of sustainable building construction, considering the critical determinants revealed by the current research.

Secondly, all construction stakeholders are encouraged to be involved in driving sustainable building construction (SBC) forward. Similarly, top management support is highly recommended among construction organisations. In addition, it is recommended that construction companies become socially responsible toward building sustainably.

Thirdly, regulatory environment factors such as Green Building Council of South Africa (GBCSA) standards, National environmental management regulations, and Department of Public Works green building policy are recommended for defining SBC implementation in South Africa. However, based on the findings of the current study, applying force or coercion is not the way forward for the effective implementation of sustainable building construction. Hence, construction companies are to be allowed to do their activities or enter sustainable building projects voluntarily.

Fourthly, the current study revealed that project delivery strategies like early involvement of stakeholders, collaboration of project participants, client needs assessment, integrated project delivery system, and public-private partnerships are key facilitators to effective implementation of SBC for project delivery success in South Africa. This suggests that the traditional project delivery system, especially design-bid-build, and such delivery systems with a single contracting point may not be ideal. Therefore, the study recommends that the right choice of project delivery strategy is essential for actualising project success and implementing SBC effectively.

Fifthly, the study recommends the adoption of modern building and advanced techniques such as BIM, value engineering, lean techniques, industrialised building systems (IBS), sustainable supply chain management, and so on, to ensure that SBC implementation is a success in South Africa.

Sixthly, the South African construction industry, with the insights from the value and findings of this study, can contribute immensely towards the achievement of sustainable development goals by virtue of aligning its construction activities with sustainability initiatives.

Lastly, this study proposed an integrated sustainable building construction model for project delivery in South Africa. However, with the necessary adjustments to national contexts and distinctiveness, the model can be securely adopted to provide similar information and a guide for practice in other African and developing countries.

## 11.4 Limitations of the Study

There are some limitations to be considered when interpreting and generalising the findings of this research. To start with, the study was tailored to the South African construction industry. Therefore, replicating the study in other countries may show significant differences in the variations in the findings. However, it is noteworthy that this limitation does not invalidate the research findings and the possible application of the main findings in other developing countries. This is because many developing nations, especially in Africa, share similar practical and professional characteristics in the construction industry and encounter similar challenges.

Also, the sample size used, 281, although statistically adequate for the analysis, may be narrow. Given the complexity of the model examined in the present study, a larger sample, like 400 and above, may benefit the study. Nevertheless, this does not invalidate the findings of the present study.

Similarly, the study adopted a quantitative approach; hence, other methodological approaches, such as mixed methods, may benefit the findings in this study.

The study was limited using convenience sampling that may lack clear generalisability and can easily provide false data when proper care is not taken. However, the researcher considered several measures to ensure that the data collected was valid.

## 11.5 Suggestions for Further Research

The following suggestions for further research have been identified:

- Future studies could compare the findings from this research with studies in other developing countries, such as Nigeria, Ghana, and Malaysia, to provide a comprehensive picture of the developments in sustainable building construction (SBC) in similar contexts.
- More research should be done to examine factors that will facilitate the effective implementation of SBC using more than one category of a questionnaire to get

information from the respondents. Such studies' findings might show stronger correlations with the constructs than the ones found in this study.

- The current study's model did not cover all the drivers of sustainable building construction. Hence, future studies can include other drivers, such as leadership and market factors (demand, benefits, affordability, and so forth) in the model factor composition.
- Future research into why the regulatory environment was not found to have a significantly positive relationship with SBC implementation is recommended.
- Future studies are recommended to further validate the Integrated Sustainable Building Construction (ISBC) model developed in this study.

## 11.6 Chapter Conclusion

Sustainable building construction (SBC) is an invaluable approach to the growth of the South African construction industry and the global construction industry and is also a contributor to the actualisation of sustainable development goals. This study established the impact of SBC determinants on SBC implementation, as well as the impact of SBC implementation on project success outcomes. Subsequently, the systematic, deliberate, and efficient application of SBC will ensure the achievement of project success outcomes like client/stakeholders' satisfaction, improvement in sustainability ratings, construction innovation, value for money, attainment of time, cost, quality, health and safety, and environmental objectives.

To conclude, this chapter reviewed the research objectives and established how they were met. Similarly, the chapter made a lot of recommendations and suggestions, including significant contributions that add to existing knowledge. Additionally, the study's limitations were acknowledged. Furthermore, recommendations for future related studies were made.

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# APPENDICES

## APPENDIX A: QUESTIONNAIRE COVER LETTER

23 Pearse street

Faculty of Engineering and the Built Environment,

University of Johannesburg Doornfontein Campus,

Johannesburg, South Africa.

2094

Dear sir/ma

**INVITATION LETTER TO PARTICIPATE IN QUESTIONAIRE SURVEY**

**Chijioke Emmanuel Emere** is a registered PhD candidate in the Department of Construction Management and Quantity Surveying in the Faculty of Engineering and the Built Environment at the University of Johannesburg. This candidate's research project is supervised by **Professor Clinton Aigbavboa** (University of Johannesburg) and **Prof Wellington Didibhuku Thwala** (University of South Africa). This research focuses on developing an *integrated sustainable building construction (SBC) model for project delivery* in South Africa.

As part of this research, the candidate requires information on sustainable building construction project delivery in South Africa. This research will be based on the questionnaire survey, which

entails sustainable building construction experts responding to the questionnaire. The questionnaire will be distributed to all relevant professionals involved in the study.

The faculty would like to request that you participate in this study by giving the required information to the best of your knowledge. **Participation is voluntary. Hence, you are free to withdraw at any time without negative consequences. It should take about 10-15 Minutes to complete the questionnaire. The questionnaire completion/collection is due on 30th May 2023.**

You will be informed of your participation and when the research is concluded. You and your organization are assured of complete confidentiality, and should you wish to know the research findings, the faculty will be glad to share with you the summary of the results. Your participation will contribute to expanding knowledge in the sustainable construction domain, which is timely and very significant in this era of the 4$^{th}$ industrial revolution.

Yours faithfully,

**PROMOTER**

Prof. C.O. Aigbavboa (Ph.D)
Department of Construction Management and Quantity Surveying
Faculty of Engineering and the Built Environment
University of Johannesburg, South Africa
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Editor - Journal of Construction Project Management and Innovation (JCPMI)

## APPENDIX B:QUESTIONNAIRE ON SUSTAINABLE BUILDING CONSTRUCTION (SBC) AND PROJECT PERFORMANCE IN SOUTH AFRICA

### SECTION A: DEMOGRAPHICAL DATA

Please complete the following questionnaire by crossing (x) when answering the questions. Thank you very much for your time.

1. What is your highest educational qualification? [SBCQ1]

| | | | | | |
|---|---|---|---|---|---|
| National Diploma | | Honours/Btech | | Doctorate | |
| Bachelor's Degree | | Master's Degree | | | |

2. Kindly state your professional background [SBCQ2]

| | |
|---|---|
| Project Management | |
| Architecture | |
| Engineering | |
| Quantity Surveying | |
| Construction Management | |
| Town and Regional Planning | |
| Other (Please specify) | |

3. What type of sector do you currently work in? [SBCQ3]

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Consultant | | Contractor | | Government Agency | | Private Sector | |

4. What type of project works are you engaged with or were recently involved in? [SBCQ4]

| | |
|---|---|
| Building Construction Works | |
| Civil Engineering Works | |
| Mechanical Engineering Works | |
| Electrical Engineering Works | |
| Other (Please specify) | |

5. Please indicate your current project role [SBCQ5]

| | |
|---|---|
| Project Manager | |
| Construction Manager | |
| Project Engineer | |
| Principal Agent | |

| | |
|---|---|
| Quantity Surveyor | |
| Town Planner | |
| Other (Please Specify) | |

6. How long do you have experience in the construction industry? [SBCQ6]

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Less than 12 months | | 1-5 years | | 6-10 years | | 11-15 years | | 16-20 years | | 21-25 years | | 26-30 years | | More than 30 years | |

## SECTION B: FACTORS THAT WILL DETERMINE SUSTAINABLE BUILDING CONSTRUCTION FOR PROJECT DELIVERY SUCCESS

The term "sustainable building construction" (SBC) refers to building in an environmentally friendly and sustainable manner. It focuses on the construction of buildings in a way that protects the environment, the economy, and society. It also includes the use of alternative and recycled materials to achieve sustainability.

1. **REGULATORY ENVIRONMENT**: This includes laws, standards, policies, and regulations that influence the practice of sustainable building construction.

   To what extent does the following influence sustainable building construction (SBC) implementation in South Africa?

| ID | | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| RE1 | National Building Standards acts | | | | | |
| RE2 | Green Building Council of South Africa standards | | | | | |
| RE3 | Department of Public Works Green Building Policy | | | | | |
| RE4 | National Environmental Management regulations | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| RE5 | Laws ensuring the sustainability of resources | | | | | |
| RE6 | Government-a driving force more than the market | | | | | |
| RE7 | Incentives for the companies that are building sustainably | | | | | |
| RE8 | Integrating environmental studies in construction | | | | | |
| RE9 | Compulsory sustainable building assessment | | | | | |
| RE10 | Compulsory enforcement of sustainable construction laws | | | | | |
| RE11 | Compulsory sustainable building certification | | | | | |

2. **KNOWLEDGE SHARING**: This refers to the activity through which information, skills, or expertise can be acquired or exchanged among individuals, communities, or organisations to influence the practice of sustainable building construction.

   To what extent does the following influence the implementation of sustainable building construction (SBC) in South Africa?

| ID | | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| KS1 | Education on sustainable practices among staff | | | | | |
| KS2 | Mentoring younger professionals in sustainable practices | | | | | |
| KS3 | Educational and training programs upgrade | | | | | |
| KS4 | Sustainable building construction integration in professional certifications | | | | | |
| KS5 | Content of Sustainable building construction training | | | | | |
| KS6 | Information hub or repository for sustainable construction | | | | | |
| KS7 | Collaboration with foreign companies for knowledge transfer | | | | | |
| KS8 | Promoting local green products through research | | | | | |
| KS9 | Sustainable building materials awareness creation | | | | | |
| KS10 | Creating public awareness for sustainable practices | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| KS11 | Awareness creation of green building products | | | | | |
| KS12 | Public awareness of environmental issues | | | | | |

3. **CORPORATE DISPOSITION**: This includes an organisation's image, vision, culture, policy, capacity, and social responsibility that influence the practices of sustainable building construction.

   To what extent does the following influence sustainable building construction (SBC) implementation in South Africa?

| ID | | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| CD1 | Identification of organisational benefits of adopting sustainable building construction | | | | | |
| CD2 | Social responsibility to protect the environment | | | | | |
| CD3 | Top management support | | | | | |
| CD4 | Availability of competent personnel | | | | | |
| CD5 | Availability of finance for the project operation | | | | | |
| CD6 | Alternate funding systems consideration for sustainable building construction | | | | | |
| CD7 | Pressure from the competitor's corporate involvement | | | | | |
| CD8 | Good project management culture | | | | | |
| CD9 | Commitment to innovative construction | | | | | |
| CD10 | Quest for competitive advantage over counterparts | | | | | |
| CD11 | Good intra-organisational leadership | | | | | |
| CD12 | Stakeholders' involvement and commitment | | | | | |
| CD13 | Cultural change promotion for sustainability | | | | | |

4. **PROJECT DELIVERY STRATEGY**: This refers to the project delivery methods, procurement strategies, and contract forms that influence sustainable building construction practices.

   To what extent does the following influence the implementation of sustainable building construction (SBC) in South Africa?

| ID | | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| PDS1 | Client needs assessment | | | | | |
| PDS2 | Traditional project delivery system (Design-Bid-Build) | | | | | |
| PDS3 | Design and build system | | | | | |
| PDS4 | Construction management/general contractor method | | | | | |
| PDS5 | Integrated project delivery system | | | | | |
| PDS6 | Turnkey system | | | | | |
| PDS7 | Public-private partnerships | | | | | |
| PDS8 | Delivery methods with a single contracting point | | | | | |
| PDS9 | Collaboration of project participants | | | | | |
| PDS10 | Early involvement of stakeholders | | | | | |
| PDS11 | Usage of open tendering method | | | | | |
| PDS12 | Usage of negotiated tendering method | | | | | |
| PDS13 | Usage of the selective tendering method | | | | | |
| PDS14 | Usage of targeted procurement method | | | | | |
| PDS15 | Usage of lump sum contracts | | | | | |
| PDS16 | Usage of cost-reimbursable contracts | | | | | |
| PDS17 | Usage of multiple criteria selection method | | | | | |
| PDS18 | Usage of government budgetary allocations | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| PDS19 | Usage of private sector funds | | | | | |

5. **PROJECT MANAGEMENT TECHNIQUES**: This refers to the systematic procedures to produce specific project management deliverables for successful sustainable building construction.

   To what extent does the use of the following influence sustainable building construction (SBC) implementation in South Africa?

| ID | | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| PMT1 | Appropriate project management methodology | | | | | |
| PMT2 | Scope management techniques | | | | | |
| PMT3 | Integration management techniques | | | | | |
| PMT4 | Exploratory techniques (meeting, brainstorming etc.) | | | | | |
| PMT5 | Procurement management techniques | | | | | |
| PMT6 | Time management techniques | | | | | |
| PMT7 | Cost management techniques | | | | | |
| PMT8 | Quality management techniques | | | | | |
| PMT9 | Risk management techniques | | | | | |
| PMT10 | Stakeholder management techniques | | | | | |
| PMT11 | Communication management techniques | | | | | |
| PMT12 | Environmental management system | | | | | |

6. **ADOPTION OF MODERN BUILDING TECHNIQUES:** This refers to the newer and advanced methodologies that will facilitate sustainable building construction practices.

To what extent does the following influence sustainable building construction (SBC) implementation in South Africa?

| ID | | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| MBT1 | Building Information Management (BIM) | | | | | |
| MBT2 | Lean techniques | | | | | |
| MBT3 | Value Engineering/Management | | | | | |
| MBT4 | Industrialised Building Systems (IBS) | | | | | |
| MBT5 | Supply Chain Management systems | | | | | |
| MBT6 | Big data analytics | | | | | |
| MBT7 | Two-stage open-book procurement models | | | | | |

**SECTION C: SUSTAINABLE BUILDING CONSTRUCTION (SBC) FEATURES -** This refers to the expected deliverables for practising sustainable building construction.

To what extent is the following essential for sustainable building construction in South Africa?

| ID | | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| SBCI1 | Sustainability indicators in project briefs | | | | | |
| SBCI2 | Sustainable and efficient designs | | | | | |
| SBCI3 | Sustainable structural materials | | | | | |
| SBCI4 | Minimisation of the use of non-renewable goods | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| SBCI5 | Usage of biodegradable materials (e.g. bamboo etc.) | | | | | |
| SBCI6 | Decrease in generating waste | | | | | |
| SBCI7 | Promotion of waste material recyclability | | | | | |
| SBCI8 | Usage of waste in making construction materials | | | | | |
| SBCI9 | Usage of materials with low carbon footprint | | | | | |
| SBCI10 | Decrease in the use of toxic materials | | | | | |
| SBCI11 | Protection of biodiversity and ecology | | | | | |
| SBCI12 | Energy consumption minimisation | | | | | |
| SBCI13 | Consideration of supplementary energy systems (solar etc.) | | | | | |
| SBCI14 | Usage of renewable resources | | | | | |
| SBCI15 | Consideration of the project's effect on air, soil, water etc. | | | | | |
| SBCI16 | Water usage minimisation | | | | | |
| SBCI17 | Green procurement | | | | | |
| SBCI18 | Usage of Smart appliances | | | | | |
| SBCI19 | Impact consideration on social background | | | | | |
| SBCI20 | Minimisation of pollution and greenhouse gas emission | | | | | |
| SBCI21 | Compliance with regulations on sustainable practices | | | | | |
| SBCI22 | Compliance with sustainability assessment measures | | | | | |
| SBCI23 | Improved use of construction resources | | | | | |
| SBCI24 | Diminished operational and utility costs in building | | | | | |

**SECTION D: INTEGRATED SUSTAINABLE BUILDING CONSTRUCTION PROJECT DELIVERY-** This refers to the overall project delivery success outcomes based on performance efficiency and effectiveness in sustainable building construction.

To what extent will the following outcomes be achieved if sustainable building construction is effectively practised due to the six constructs (Regulatory environment, Knowledge sharing, Corporate disposition etc.) in South Africa?

| ID | Outcomes | No Extent | Low Extent | Moderate Extent | High Extent | Very High Extent |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| ISBCPD1 | Projects completion with no time overrun | | | | | |
| ISBCPD2 | Project completion with no cost overrun | | | | | |
| ISBCPD3 | Achievement of prescribed quality requirements | | | | | |
| ISBCPD4 | Construction stakeholders/Client Satisfaction | | | | | |
| ISBCPD5 | End-user satisfaction | | | | | |
| ISBCPD6 | Value for money | | | | | |
| ISBCPD7 | Environmental objectives met | | | | | |
| ISBCPD8 | Health safety and comfort | | | | | |
| ISBCPD9 | Construction innovation | | | | | |
| ISBCPD10 | Improvement in sustainability rating | | | | | |

**Thank you for completing the questionnaire. Kindly return it to me either by hand or email.**

Emere CE
PhD Candidate
University of Johannesburg
Phone: 0717484707; Email: cjmere2018@gmail.com

## APPENDIX C: PHD RESEARCH CONSENT FORM FOR RESPONDENTS

I have been requested to take part in the study. I know how I am involved in the research and what is expected of me. I understand that:

- I am participating in this research voluntarily and not by compulsion.
- I am free to distance myself from participating at any time without negative consequences.
- Information provided on the questionnaire is very clear.
- The questionnaire does not contain any leading questions.
- My response is based on my opinion.
- There will be no incentive or reward for my response.
- I am not required to enter any personal information on the questionnaire. Therefore, my responses will be kept private and anonymous.
- The information and outcomes could be used to present at conferences or publish in journals.
- The data will be used for academic purposes and may also be used in related studies in future.
- I will not receive individual results reports, but I can request feedback on the study's overall findings.
- If I have any questions or issues about the study or any of the questionnaire's items, I can get in touch with the researchers using the contact details provided in the introductory letter of the questionnaire.
- I have received the researchers' contact information on the participant information sheet.
- All my questions about the research have been answered, and I agree that my questionnaire responses can be used for the analysis.
- I have read the information mentioned above and agree to participate under the conditions stated. I understand everything and voluntarily consent to participate in this study.

**Signature / Initials _____Date: _____**

## APPENDIX D: ETHICS CLEARANCE CERTICATE

Faculty of Engineering and the Built Environment

# Ethics Approval Clearance Certificate

The following research project has been reviewed and approved by the Ethics and Plagiarism Committee (FEPC) of the Faculty of Engineering and the Built Environment at the University of Johannesburg.
The FEPC is not registered with the National Heath Ethics Research Council of South Africa.

**An Integrated Sustainable Building Construction Model for Project Delivery in South Africa**

| | |
|---|---|
| **Ethical Clearance Number** | UJ_FEBE_FEPC_00714 |
| **Name of Researcher** | Mr Chijioke Emmanuel Emere |
| **Name of Department or Organization** | Construction Management and Quantity Surveying |
| **Name of Principal Investigator** | Prof Clinton Aigbavboa |

| | |
|---|---|
| **Commencement Date** | Tuesday, November 8, 2022 |

Unless otherwise specified in the notes below, the ethics approval is considered valid for 12 months from the commencement date.

| | |
|---|---|
| Dr Zach Simpson | November 8, 2022 |
| Chair of the FEBE FEPC | Decision Date |

**Notes Below**

ProQuest Number: 31716907

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