Use of Technology Acceptance Model to Increase Green Building Technology Use in South Africa

by

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Abstract

Buildings impact the environment as they consume energy and emit greenhouse gases on a high scale. Through technology and design, efforts are expedited to lower the buildings' negative impact on the environment. In this study, how the Technology Acceptance Model would increase project teams' use of green building technologies in South Africa was explored. A descriptive research design was used to achieve the aim for this study. The mixed-methods research was used to collect data. A multiple case-study design was used, and qualitative data were collected from five case projects in Bloemfontein, Free State, South Africa. Quantitative data were collected from eighty-seven (87) construction project team personnel in the Free State, South Africa, using a survey questionnaire. The thematic analysis was used to analyse the qualitative data, and the descriptive analysis was used to analyse the quantitative data. The results were validated using a focus group. Based on this study, a need for more awareness and knowledge about green building technologies to increase adoption was reported.

In addition, the lack of skills, research, and development incentives limits the knowledge of the public about green building technologies. This slows down the industry's uptake, which limits the number of green buildings in society. However, using the Technology Acceptance Model indicates that the increased adoption of green building technologies offers a range of sustainability benefits that cannot be attained from traditional building technologies. Project teams need the perceived usefulness of green building technologies to be emphasised to them to increase the adoption rate. Concurrently, this entails that the project teams should understand the essentiality of green building technologies. These green building technologies have the potential for long-term energy savings, improved indoor air quality, and decreased environmental impact. Moreover, these benefits could lead project teams to embrace the green building technologies. The demonstration of the perceived ease of use should show that green building technologies can be integrated into the existing construction practices without requiring significant changes or additional training but can further eradicate concerns. Concurrently, the increase in awareness and education about green building technologies can enhance the perceived usefulness, making the project teams more confident in their benefits. Additionally, the transition to green building technologies can be made less intimidating through user-friendly technologies and supportive resources that increase the perceived ease of use factor. Implementing the Technology Acceptance Model results in increased uptake of

green building technologies, which leads to additional environmental, social, and economic benefits. Compared to conventional building technologies, green building technologies have components that enable innovation and sustainability. Ultimately, leveraging the core concepts of the Technology Acceptance Model could drive the wider adoption of green building technologies, facilitating a shift towards sustainability.

Keywords: Construction, Green buildings, Technology Acceptance Model, Sustainability, South Africa

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Contents

Declaration of Academic Integrity		**ii**
Abstract		**iii**
Acknowledgements		**v**
Contents		**vi**
List of Tables		**xi**
List of Figures		**xiv**
Definition of Key Terms		**xv**
List of Abbreviations		**xvii**
1.	**Chapter 1: Research Background**	**18**
1.1.	**INTRODUCTION**	18
1.2.	**STATEMENT OF THE PROBLEM**	20
1.3.	**PRIMARY AND SECONDARY RESEARCH QUESTIONS**	21
1.4.	**RESEARCH AIMS AND OBJECTIVES**	22
1.5.	**THE HYPOTHESES**	23
1.6.	**DELIMITATIONS AND ASSUMPTIONS OF THE STUDY**	23
1.7.	**SUMMARY OF RESEARCH DESIGN AND METHODOLOGY**	24
1.7.1.	**Design**	24
1.7.2.	**Sampling**	24
1.7.3.	**Instrument Design and Data Collection**	25
1.7.4.	**Data Analysis**	26
1.8.	**GAPS IN THE LITERATURE**	26
1.9.	**THE EXPECTED RESULTS AND IMPORTANCE OF THE STUDY**	27
1.10.	**SOCIAL IMPACT**	27
1.11.	**OUTLINE OF THE DISSERTATION**	28
1.12.	**CHAPTER SUMMARY**	29
2.	**Chapter 2: Review of Related Literature**	**30**
2.1.	**INTRODUCTION**	30
2.2.	**GREEN BUILDING TECHNOLOGIES**	30
2.2.1.	**Overview of Green Building Technologies**	30
2.2.2.	**Barriers to Implementation of GBTs**	31
2.2.3.	**Drivers of GBT Implementation**	34
2.2.4.	**The Use of GBTS in South Africa**	36

2.3.	**TECHNOLOGY ACCEPTANCE MODEL**	39
2.3.1.	**Overview of TAM**	39
2.4.	**PERCEPTION OF USEFULNESS OF GBTS**	41
2.4.1.	**Overview of Perceived Usefulness as a Concept**	41
2.4.2.	**Factors Influencing Perceived Usefulness of GBTs by Project Teams**	41
2.5.	**PERCEPTION OF EASE OF USE OF GBTS**	42
2.5.1.	**Overview of Ease of Use as a Concept**	42
2.5.2.	**Factors that Influence Ease of Use of GBTs by Project Teams**	43
2.6.	**ATTITUDE TOWARDS USE**	45
2.6.1.	**Overview of Attitude as a Concept**	45
2.6.2.	**Factors that Influencing the Attitude of Project Teams towards GBTs**	45
2.7.	**CHANGE OF BEHAVIOURAL INTENTION TOWARDS USE**	46
2.7.1.	**Overview of Behavioural Intention as a Concept**	46
2.7.2.	**Factors that Influence Behavioural Intentions of Project Teams Regarding GBTs**	47
2.8.	**ACTUAL USAGE OF TECHNOLOGY**	48
2.8.1.	**Overview of Actual Usage as a Concept**	48
2.8.2.	**Factors that Influence the Actual Usage of GBTs by Project Teams**	48
2.9.	**GAPS IN THE LITERATURE**	49
2.10.	**CHAPTER SUMMARY**	50
3.	**Chapter 3: Research Methodology**	**52**
3.1.	**INTRODUCTION**	52
3.2.	**APPLICATION OF THE RESEARCH ONION**	52
3.3.	**RESEARCH PHILOSOPHY**	56
3.4.	**RESEARCH APPROACH**	57
3.5.	**RESEARCH STRATEGY**	58
3.6.	**RESEARCH METHODS**	58
3.7.	**TIME HORIZON**	59
3.8.	**DATA COLLECTION METHODS**	60
3.8.1.	**Secondary Data Collection**	60
3.8.2.	**Primary Data**	60
3.9.	**DATA COLLECTION PROCEDURES**	61
3.9.1.	**Define the Population**	61
3.9.2.	**Sampling Method**	61
3.9.3.	**Sample Size**	62
3.9.4.	**Instrument Administration**	63
3.10.	**RELIABILITY AND VALIDITY**	64
3.10.1.	**RELIABILITY**	65

3.10.2. VALIDITY 65

3.11. ETHICAL CONSIDERATIONS 66

3.12. CHAPTER SUMMARY 66

4. Chapter 4: Qualitative Results and Analysis **68**

4.1. INTRODUCTION 68

4.2. INTERPRETATION OF FINDINGS FROM SEMI-STRUCTURED INTERVIEWS 68

4.2.1. Perceived Usefulness of Green Building Technologies by Project Teams 68

4.2.2. Perceived Ease of Use of Green Building Technologies by Project Teams 70

4.2.3. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies 71

4.2.4. Actual Usage of Green Building Technologies by Project Teams 72

4.2.5. Perceived Usefulness of Green Building Technologies by Project Teams 74

4.2.6. Perceived Ease of Use of Green Building Technologies by Project Teams 75

4.2.7. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies 77

4.2.8. Actual Usage of Green Building Technologies by Project Teams 78

4.2.9. Perceived Usefulness of Green Building Technologies by Project Teams 80

4.2.10. Perceived Ease of Use of Green Building Technologies by Project Teams 81

4.2.11. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies 83

4.2.12. Actual Usage of Green Building Technologies by Project Teams 84

4.2.13. Perceived Usefulness of Green Building Technologies by Project Teams 86

4.2.14. Perceived Ease of Use of Green Building Technologies by Project Teams 87

4.2.15. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies 89

4.2.16. Actual Usage of Green Building Technologies by Project Teams 90

4.2.17. Perceived Usefulness of Green Building Technologies by Project Teams 92

4.2.18. Perceived Ease of Use of Green Building Technologies by Project Teams 93

4.2.19. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies 94

4.2.20. Actual Usage of Green Building Technologies by Project Teams 95

4.3. INTERPRETATION OF FOCUS GROUP FINDINGS 97

4.3.1. Perceived Usefulness of Green Building Technologies by Project Teams 97

4.3.2. Perceived Ease of Use of Green Building Technologies by Project Teams 99

4.3.3. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies 100

4.4. HYPOTHESIS TESTING AND THEMATIC SYNTHESIS OF QUALITATIVE FINDINGS ON GBT ADOPTION USING TAM 104

4.4.1. Synthesis of Case Study Findings 104

4.4.2.	Thematic Analysis	104
4.4.3.	Cross-Case Comparison	105
4.4.4.	Hypothesis Evaluation	106
4.5.	**CHAPTER SUMMARY**	106
5.	**Chapter 5: Quantitative Results and Analysis**	**107**
5.1.	**INTRODUCTION**	107
5.2.	**SURVEY ANALYSIS**	107
5.3.	**RESPONSE RATE**	108
5.4.	**DEMOGRAPHIC INFORMATION**	109
5.4.1.	**Qualification**	109
5.4.2.	**Employment Status**	110
5.4.3.	**Types of Projects**	111
5.4.4.	**Job Title**	112
5.5.	**INTERPRETATION OF SURVEY QUESTIONNAIRE FINDINGS**	113
5.5.1.	**Perceived Usefulness of Green Building Technologies**	113
5.5.2.	**Key Indicators of the Usefulness of Green Building Technologies**	113
5.5.3.	**Perceived Ease of Use of Green Building Technologies**	114
5.5.4.	**Aspects Promoting Ease of Use of Green Building Technologies**	115
5.5.5.	**Attitude and behavioural intentions**	116
5.5.6.	**Various GBTs in the Construction Industry**	117
5.6.	**CHAPTER SUMMARY**	119
6.	**Chapter 6: Discussion**	**120**
6.1.	**INTRODUCTION**	120
6.2.	**INTEGRATED DATA ANALYSIS**	120
6.2.1.	**Perceived Usefulness of Green Building Technologies by Project Teams**	120
6.2.2.	**Perceived Ease of Use of Green Building Technologies by Project Teams**	121
6.2.3.	**Attitude and Behavioural Intentions of Project Teams towards GBTs**	122
6.2.4.	**Actual Usage of Green Building Technologies by Project Teams**	123
6.3.	**IMPLICATIONS OF INTERVIEW RESULTS**	123
6.4.	**IMPLICATIONS OF SURVEY RESULTS**	124
6.5.	**MODIFIED TECHNOLOGY ACCEPTANCE MODEL**	125
6.6.	**CHAPTER SUMMARY**	126
7.	**Chapter 7: Conclusions and Recommendations**	**128**
7.1.	**INTRODUCTION**	128
7.2.	**CONCLUSIONS**	128
7.3.	**CONCLUSION RELATED TO THE RESEARCH OBJECTIVES**	128

7.3.1. Objective 1: Identify the Project Team's Perceived Usefulness of Green Building Technologies 129

7.3.2. Objective 2: Evaluate the Ease of Use of Green Building Technologies by Project Teams 129

7.3.3. Objective 3: Assess the Attitude of Project Teams towards Green Building Technologies 129

7.3.4. Objective 4: Assess the Change in Behavioural Intentions of Project Teams Regarding the Use of Green Building Technologies 130

7.3.5. Objective 5: Propose how the Factors of the Technology Acceptance Model could be Implemented to Increase the Uptake of Green Building Technologies in South Africa 130

7.4. RECOMMENDATIONS FOR POLICY AND PRACTICE 131

7.5. FUTURE RESEARCH DIRECTIONS 131

7.6. CONTRIBUTION OF THE STUDY 132

7.7. CHAPTER SUMMARY 132

References 133

8. Appendices 139

APPENDIX A (RECRUITMENT LETTER FOR INTERVIEW) 140

APPENDIX B (COVER LETTER FOR SURVEY) 143

APPENDIX C (ETHICAL CLEARANCE) 152

List of Tables

Table 1.1: Research objectives and secondary questions 22
Table 2.1: Barriers to the use of GBTs 32
Table 2.2: Drivers of the use of GBTs 35
Table 2.3: Breakdown of literature reviewed in relation to research objectives 50
Table 3.1: Structural research layers for the study 53
Table 3.2: Research methods 63
Table 4.1: Factors affected by green building technologies in the construction industry 69
Table 4.2: Whole life-cycle costing factors associated with green building technologies in the construction industry 70
Table 4.3: Factors enabling the adoption of GBTs 71
Table 4.4: Ways to influence the use of GBTs 71
Table 4.5: Effect of GBTs on companies 71
Table 4.6: Benefits of GBTs to companies 72
Table 4.7: Types of GBTs in the construction industry 72
Table 4.8: Factors of overall performance of GBTs on construction projects 73
Table 4.9: Factors that influence GBT use in the construction industry 73
Table 4.10: Project team members who influence specifications 74
Table 4.11: Factors that promote the use of GBT in the construction industry 75
Table 4.12: Whole life-cycle costing factors 75
Table 4.13: Factors that lead to the introduction of GBTs 76
Table 4.14: Factors that lead to the incorporation of GBTs 77
Table 4.15: Effect of GBTs on companies 77
Table 4.16: Factors introduced by GBTs into companies 78
Table 4.17: Types of GBTs in the construction industry 78
Table 4.18: Effect of GBTs on overall performance in construction projects 79
Table 4.19: Factors that set standards 79
Table 4.20: Project team members who set specifications 80
Table 4.21: Factors that influence GBT use 81
Table 4.22: Whole life-cycle costing factors influenced by GBTs 81
Table 4.23: Factors that promoted GBT use in a firm 82
Table 4.24: Various ways to enable ease of use of GBTs by project teams 83

Table 4.25: Effect of GBTs on a company 83
Table 4.26: Factors introduced by GBTS into a company 84
Table 4.27: Types of GBTs 84
Table 4.28: Factors of overall performance improved by GBTs 85
Table 4.29: Factors that set the standards to increase use of GBTs 85
Table 4.30: Project team members who set specifications 86
Table 4.31: Factors that influence the usefulness of GBTs 87
Table 4.32: Whole life-cycle costing factors 87
Table 4.33: Factors that lead to the introduction of GBTs in a firm 88
Table 4.34: Factors that lead to the incorporation of GBTs in construction projects 89
Table 4.35: Effect of GBTs on a company 89
Table 4.36: Factors introduced by the use of GBTs 90
Table 4.37: Types of GBTs in the construction industry 90
Table 4.38: Factors that improve overall performance on construction projects by project teams 91
Table 4.39: Project team members who set specifications for GBTs 91
Table 4.40: Factors influenced by GBTs 92
Table 4.41: Whole life-cycle costing factors 93
Table 4.42: Factors that lead to the introduction of GBTs in firms 94
Table 4.43: Factors that lead to the incorporation of GBTs in construction projects 94
Table 4.44: Effect of GBTs on a company 95
Table 4.45: Factors influenced by GBTs 95
Table 4.46: Types of GBTs 96
Table 4.47: Factors that improve overall performance of GBTs on construction projects 96
Table 4.48: Factors that set the standards for the incorporation of GBTs 97
Table 4.49: Project team members who set specifications 97
Table 4.50: Factors affected by the use of GBTs in the construction industry 98
Table 4.51: Whole life-cycle costing factors introduced by GBTs 99
Table 4.52: Factors that lead to the introduction of GBTs in construction firms 99
Table 4.53: Factors that lead to the incorporation of GBTs in construction projects 100
Table 4.54: Effect of GBTs on a company 101
Table 4.55: Factors introduced by GBTs 101
Table 4.56: Types of GBTs 102
Table 4.57: Factors improved by GBTs 102

Table 4.58: Factors that set standards 103
Table 4.59: Project team members who set specifications 103
Table 5.1: Qualifications 110
Table 5.2: Employment status 111
Table 5.3: Types of projects 111
Table 5.4: Job title 112
Table 5.5: Project team perceptions of the usefulness of GBTs 113
Table 5.6: Key indicators of the usefulness of GBTs 114
Table 5.7: Project team perceptions of the ease of use of GBTs 115
Table 5.8: Analysis of the factors that promote the ease of use of GBTs 115
Table 5.9: Project team insights into the incorporation of GBTs 116
Table 5.10: Project team insights into the impact of various GBTs on the construction industry 117
Table 5.11: Hindrances to the implementation of GBTs 118

List of Figures

Figure 2.1: Technology Acceptance Model by Davis (1986).. **Error! Bookmark not defined.**
Figure 3.1: Research Onion 53
Figure 3.2: Research process 55
Figure 5.1: Illustration of data organisation in Excel 108
Figure 5.2: Pi chart showing response rate 109
Figure 6.1: Modified TAM for GBTs 126

Definition of Key Terms

Building: A structure with a roof and walls, such as commercial, residential and industrial buildings (Pevsner, 2023: 5).

Built environment: The built environment refers to all aspects encompassing the man-made and modified physical buildings we live in, including the infrastructure that enable the provision of water and electricity, and the roads, bridges, and transportation systems we use for travelling (Akinshipe & Aigbavboa, 2018: 10).

Construction: A process used by contractors to erect infrastructure that serves a particular purpose, such as houses, schools, hospitals, and public works (Sawney *et al*., 2020: 8).

Construction industry: The industrial branch that encompasses of the manufacturing and trade that relates to building, repairing, renovating, and maintaining infrastructures (Sekerin *et al*., 2018: 660).

Construction life cycle: The whole cycle of the construction process, from initiation to project planning, implementation to monitoring and project completion (Agbajor & Mewono, 2022: 15).

Developing Countries: Countries with a lower Human Development Index and less developed industrial base, characterised by poor infrastructure and lack of access to modern technologies (Owoha *et al*., 2022: 1630).

Energy efficiency: The reduction of energy usage to perform the same task or produce the same result (Drago & Gatto, 2021: 2108).

Environmentally friendly: Not negatively impactful towards the environment (Ndiweni, 2020: 30).

Green building technologies: The implementation of designs in buildings that use advanced technologies to minimise impact of construction on the environment throughout all life-cycle stages (Chan *et al*., 2018: 1070).

Green building: A structure that is environmentally responsible and resource-efficient throughout the project's life cycle, starting from planning to design, construction, operation, maintenance, renovation, and demolition (Agbajor & Mewono, 2022: 5).

Life-cycle costing: A process of analysing the cost related to the construction, operation, and maintenance of a construction project throughout its life (Ramafalo & Awuzie, 2019: 8).

Project team: A group of people who are involved in the construction process (Owoha *et al*., 2022: 1628).

Sustainability: Incorporating the needs of the current generation without hindering the needs of future generations (Akinshipe & Aigbaboa, 2018: 340).

List of Abbreviations

AEC	Architecture, Engineering, and Construction
AU	Actual Usage
BE	Built Environment
ERB	Environmentally Responsible Behaviour
GB	Green Building
GBCSA	Green Building Council of South Africa
GBT	Green Building Technology
GHG	Greenhouse Gas
POE	Post-Occupancy Evaluation
SDG	Sustainable Development Goals
TAM	Technology Acceptance Model

Chapter 1: Research Background

1.1. Introduction

The construction industry is an essential pillar of society, but it has limitations. It provides a vital role within the socio-economic development of South Africa, as it provides living and working environments for its people. In addition, the construction sector offers infrastructure, including schools, hospitals, and various vital facilities to provide goods and services for occupants (Owoha *et al*., 2022: 1630). However, the construction sector has a negative impact on the environment, economy, and society. For example, construction operations cause the generation of dust, solid waste, noise, wastewater, and smoke (Darko *et al*., 2017: 325). The construction industry is regarded as the leading contributor to massive energy consumption along with greenhouse gas (GHG) emissions (Drago & Gatto, 2021: 2110). The construction industry has contributed to the significant reduction of resources and biological diversity through extracting, manufacturing, and transporting of raw materials (Wang *et al*., 2018: 10). Darko (2017) stated that, if there is no remedy to the current situation regarding the efficiency of construction and building activities, then the energy consumption within the construction industry and GHG emissions will increase by more than 50% by 2050 (Darko *et al*., 2017: 325). Therefore, the stakeholders within the industry must ensure that the severe pollution caused by high energy consumption and GHG emissions from the built environment (BE) is reduced (Akinshipe & Aigbavboa, 2018: 20).

Developing countries like South Africa have an intensive use of resources, which results in pollution of land and air, degradation of land, and high levels of energy consumption, together with the destruction of the wild, which is home to animals. As a solution to this predicament, the introduction of green building (GB) was encouraged to mitigate and reduce the effects of global warming (Zhang *et al*., 2019: 5). The construction industry has adopted the concept of sustainability as it has become an international imperative within the Architecture, Engineering, and Construction (AEC) sector. Sustainability as an imperative is derived from the significant impact that the construction sector has on climate and the environment, as the aim of sustainability is to develop inter-dependence of economic growth, natural ecosystems, and the adverse effects of economic activities on the environment (Simpeh & Smallwood, 2018: 1832). Sustainability has led to the development of various concepts, as follows:

sustainable material, renewable energy, sustainable design, green business, sustainable architecture, green building, sustainable construction, and ecological building (Emuze *et a*l., 2015: 19). The effective application of these concepts will lead to a balance within the ecosystem and enable improvement in the environment (Watkins & Sunjka, 2020: 134).

Moreover, national indicators provide critical context regarding infrastructure and development challenges specific to South Africa. These indicators often hinder the adoption and implementation of GBTs due to provincial variations; therefore, this study narrows its scope from a national to a provincial focus (Wall, 2024, p. 195). The economic assessment of the Free State Province reveals a gradual recovery, which affects investments in innovative and environmentally sustainable construction technologies. As a result, the province continues to operate within a constrained sector, marked by budget limitations, skills shortages, and inconsistent project delivery capacity (Free State Provincial Treasury, 2024, p. 58). Such factors restrict the integration of advanced technologies into both public and private construction initiatives.

Additionally, national infrastructure quality assessments indicate that provinces with weaker project performance and less diversified construction markets are generally slower to adopt energy-efficient, water-saving, and environmentally responsive building systems (Wall, 2024, p. 64). These systemic constraints are particularly evident in the Free State, where green-building adoption remains uneven and is mostly limited to select institutional or privately funded projects. Concurrently, sectoral analyses note that education and public facilities in the province are under increasing pressure to implement sustainable building solutions in response to rising energy costs, operational inefficiencies, and climate resilience requirements (World Bank, 2025, p. 2). Collectively, these structural barriers and emerging sustainability imperatives highlight the importance of conducting a province-specific analysis of the extent of use, driving factors, and obstacles associated with GBT adoption in the Free State (Agbajor & Mewomo, 2024, p. 320).

GB is the process of designing and constructing buildings while employing resource- and environmentally conscious methods at every stage of a building's life cycle. (Agbajor & Mewono, 2022: 1). GB takes place from setting, design, construction, operation, maintenance, and renovation to deconstruction (Kong & He, 2021: 3). The introduction of GB plays a vital

role of sustainable development strategy within the construction sector (Hu *et al*., 2022: 112641). The application of GB assists in saving energy, decreasing waste, reducing GHG emissions, conserving natural resources, and improving water and air quality. In addition, GBs are more cost-effective to run and provide their occupants with improved health and productivity (McElroy & Rosenow, 2019: 615).

Using technologies to realise GB is called green building technology (or technologies) (GBTs). The GBTs can refer to technologies that are incorporated within the building design and construction to ensure the sustainability of the needed product (Atanda & Olukoya, 2019: 370). Over the past decades, adopting GBTs has provided several positive effects, including increased water efficiency, improvement of productivity, enhancement of human health and well-being, enhanced indoor environmental quality, and increased property value (Ejidike *et al*., 2022: 265). GBTs are the most fundamental and successful method for promoting GBs. The use of GBT in construction projects incorporates aspects of sustainability within their construction life cycles. The increase in the uptake of GBTs will enable the project teams in the construction industry to provide occupants with sustainable infrastructure that offers affordable and clean energy. This aspect relates to Sustainable Development Goal (SDG) 7, which is focused on affordable and clean energy (United Nations, 2022: 15). However, the use of GBTs in South Africa is still in the inception phase (Ndiweni, 2020: 3).

The world is in the process of technological advancement. Hence, there is an increase in the variety of technology uses in different industries. The use of technology has led to an enhancement of learning experiences, the fostering of collaborative activity, and an increase in creativity and activity. This fosters SDG 9 in the industry, innovation, and infrastructure (Suh & Prophet, 2018: 77). The aim of this study was to incorporate and administer the TAM factors that influence the use of GBT by project teams in the construction industry. The TAM factors are used in the study to ensure an increase in the uptake of GBT by project teams within the construction industry (Zhang *et al*., 2019: 5387).

1.2. Statement of the Problem

The South African construction sector must adapt to the transformation associated with various GBTs, the aim of which is to increase productivity on site, quality of work and efficiency.

GBTs provide the personnel of construction project teams with the means of reducing the impact by construction activities on the climate and the environment. Although studies have been conducted about the drivers and barriers of GBT, studies that foster the perception of GBT, the attitude, and behavioural intention of project teams to use GBT for projects have been neglected. The Technology Acceptance Model (TAM) is focused on administering the perceived usefulness and ease of use of technology, attitude, and behavioural intentions leading to the actual usage of the technology (Fussell & Truong, 2022: 249). Several studies explore technical, financial, and regulatory barriers affecting the adoption of GBTs within South Africa. Moreover, there are limited studies that focus on the perceived usefulness, perceived ease of use, attitude, and behavioural intention of project teams, and actual usage of GBTs (Akinshipe & Aigbavboa, 2018: 340). Despite the global momentum towards sustainable construction, the uptake of GBTs is relatively low in South Africa, which is caused mainly by the level of awareness and knowledge of GBTs among construction professionals, which hinders the progression. In addition, the lack of skills, research, and development incentives restricts the knowledge of stakeholders about GBT and slows the process of the implementation of GBT in South Africa. There are existing studies exploring cost, skills shortages, and regulatory constraints related to GBTs. This serves as a critical gap to explore models such as TAM (Fussell & Truong, 2022: 250). This is the problem to be resolved using TAM in this study.

1.3. Primary and Secondary Research Questions

The primary research question of this study was: How would adoption of the Technology Acceptance Model increase the use of green building technologies by project teams in South Africa?

To address the primary question, the following secondary questions were formulated to guide the research:

- How do project teams perceive the usefulness of green building technologies?
- How do project teams perceive the ease of use of green building technologies?
- What is the attitude of project teams towards green building technologies?

- What would change the behavioural intentions of project teams regarding green building technologies use?
- How would factors of the Technology Acceptance Model increase the usage of green building technologies in South Africa?

1.4. Research Aims and Objectives

In this study, how TAM would increase the use of GBTs by project teams in South Africa was explored. The following objectives were used to guide the study:

- Identify the project team's perception of the usefulness of green building technologies.
- Evaluate the ease of use of green building technologies by project teams.
- Assess the attitude of project teams towards green building technologies.
- Assess the change in behavioural intentions of project teams regarding green building technologies.
- Propose how the factors of the Technology Acceptance Model would be implemented to increase the uptake of green building technologies in South Africa.

Table 1.1: Research objectives and secondary questions

Secondary Research Questions	Research Objectives
How do project teams perceive the usefulness of green building technologies?	Identify the project team's perception of the usefulness of green building technologies.
How do project teams perceive the ease of use of green building technologies?	Evaluate the ease of use of green building technologies by project teams.
What is the attitude of project teams towards green building technologies?	Assess the attitude of project teams towards green building technologies.
What would change the behavioural intentions of project teams regarding green building technologies use?	Assess the change in behavioural intentions of project teams regarding green building technologies.
How would the factors of the technology acceptance model increase the actual usage of green building technologies in South Africa?	Propose how the factors of the Technology Acceptance Model would be implemented to increase the uptake of green building technologies in South Africa.

1.5. The Hypotheses

To achieve the research aim and objectives, the following hypotheses were formulated:

Hypothesis 1: Frequency of use affects the perceived usefulness of green building technologies by the project team.
Hypothesis 2: User satisfaction based on education affects a project team's perceived ease of use of green building technologies.
Hypothesis 3: Attitude significantly influences behavioural intention toward GBT adoption.

1.6. Delimitations and Assumptions of the Study

The delimitations refer to the boundaries that are set to place a research study within context, as a guideline for the study, ensuring that it is focused and manageable (Park & Park, 2020: 7). The delimitations of this study encompassed geographical location, professional fields, time frame, age group, and educational level. The geographical area that was focused on was South Africa (Ndiweni, 2020: 10). GBTs affect various construction professionals, and this study was focused on the influence of the design team regarding factors of TAM on the increase in the use of GBTs. In this study, it was necessary to focus on design professionals with experience of GBs and GBTs. Therefore, experience and educational level were delimited (Fussell & Truong, 2022: 252). This study was conducted within a short period. The delimitations were essential as they provided a direction that ensured focus on the research question and the insights into the influence of TAM on the increase of actual usage of GBTs (Zhang *et al*., 2019: 4). The following delimitations applied to this study:

- Five case studies were used to obtain qualitative data because of logistical constraints.
- Participants were sampled from the Free State, South Africa, to obtain various perspectives.
- The interviews were mostly conducted in vernacular languages, and the interpretation in English made the research longer than anticipated.
- There was a lack of participation from a few construction project team members.
- Rescheduling and cancelling of interview appointments caused a delay.

The study was cross-sectional. Therefore, the study was conducted in a short period. This limited the scope of the research and the ability to capture long-term changes within the built environment. In the study, it was assumed that there is a relationship between the GBTs used in the construction industry and project teams. Some of the assumptions made in the study were as follows:

- Project teams are more likely to accept and use the GBTs if they perceive that they help to achieve the milestones of a project, such as reducing GHG emissions, increasing water efficiency, improving productivity, and improving indoor environmental quality, and if project teams perceive GBTs to be easy to use and understand.
- The external factors, such as social norms and subjective norms, could influence the acceptance and use of GBTs.
- The attitude and behaviour of project teams towards GBTs impact the acceptance and use of GBTs.
- The behavioural intentions of project teams are a strong predictor of the use of GBTs.

1.7. Summary of Research Design and Methodology

In this section, the research design and methodology adopted for data collection and analysis is outlined.

1.7.1. Design

The purpose of this study aligned with a descriptive research design as it was to describe the influence of TAM on the use of GBTs. A pragmatist research philosophy was followed for the study to provide useful insights to stakeholders in the construction industry. The approach that suited the principles of this study was abductive to develop a hypothesis.

1.7.2. Sampling

Sampling is a vital aspect of research methodology, as it involves selecting the appropriate participants from the population being studied. The group of interest in this study comprised the members of the Green Building Council of South Africa (GBCSA). This non-profit

organisation promotes sustainable development within the construction industry (Pandey & Pandey, 2021: 25). The members of this organisation include architects, engineers, builders, developers, and other professionals involved in the design, construction, and operation of GBs. A non-random sampling method was used to divide the target population based on specific characteristics. The study focused on construction professionals who are actively involved throughout the project lifecycle for GBT projects. The criterion was based on the membership type, such as individual, corporate, or academic membership. This posed a baseline knowledge of GBTs and the capability of providing informed responses. To enhance the validity and reliability of the study, a purposive sampling method was used within the study to enable the selection of a representative sample of members from the organisation (Agbajor & Mewono, 2022: 15). The qualitative data were collected during semi-structured interviews. The interviews involved 48 participants: the road construction case study = 11; the commercial case study = 8; the township development case study = 9; the residential case study = 10; and the industrial case study = 10. The quantitative data were collected using survey questionnaires. A total of 87 project teams were surveyed within the GBCSA.

1.7.3. Instrument Design and Data Collection

The secondary data were collected from published sources, which included articles, journals, books, and periodicals. Regulated questions were used for the study to enable consistency in responses and enable a comparison across various populations to increase the reliability of the research (Darko *et al*., 2017: 325). A questionnaire is a set of structured questions that can be administered in writing, online, or during personal interviews. A well-structured questionnaire was developed and aligned with the research aim and objectives. The questionnaire was clear, concise, and easy to understand (Chan *et al*., 2018: 1079). The questionnaire was first pre-tested with a small sample subset to help identify ambiguities in the questions or instructions and correct them before administering the main sample. After refining the questions or instructions, the questionnaire was sent out to the sample size using an online survey that was reliable and valid because it was sent out to the council that caters to professionals with expert knowledge on GBs and GBTs (Patil *et al*., 2022: 1819). Open-ended semi-structured interviews and focus groups were used as the qualitative data collection instruments. A survey questionnaire was selected as the quantitative data collection instrument.

1.7.4. Data Analysis

Descriptive analysis using statistical tools and techniques was employed for this study to summarise and describe the data collected from the sample size. The data were collected using an online survey form that was distributed to the selected sample of council members, encompassing professionals with expert knowledge of GBTs (Alharahshe & Pius, 2020: 42). After the data were collected, they were cleaned to ensure accuracy and completeness. This included checking for missing outputs, outliers, and inconsistencies in the data. Integration was used between variables within the study. Descriptive statistics were used to summarise the data collected from the survey, and this incorporated measures of central tendency, measures of dispersion, and frequency. These enabled a general summary of the data to assist in identifying the potential patterns and trends (Pandey & Pandey, 2021: 10). Data visualisation was used to present the findings in graphs, charts, and tables to display the data clearly and concisely. The visuals assisted in communicating the key findings of the study to the audience (Pearse, 2019: 147). An inferential technique provided a platform on which to test the hypothesis of the study to enable judgment based on the observations made by professionals with expert knowledge of GBTs. The qualitative data were analysed using thematic analysis, and the quantitative data were analysed using descriptive statistical analysis.

1.8. Gaps in the Literature

The construction industry is the role-player that can enable sustainable development, as it is a leading contributor to environmental degradation. Moreover, the adoption of GBTs within South Africa is still slow-paced; this entails that the contribution of the construction industry to sustainable development is exceptionally minimal (Agbajor & Mewono, 2022: 7). Moreover, the design project teams have not extensively reviewed the benefits associated with GBTs. The driving factors of GBTs can be thoroughly examined by using TAM. TAM and its factors promote the use of technologies through the aspects covered in this study (Fussell & Truong, 2022: 250). There is literature that reveals substantial research based on the barriers and drivers, although there is a limited understanding of the behavioural factors affecting GBT adoption in South Africa. Therefore, the aim of the study was to identify the enablers that would promote the increase of the usage of GBTs in South Africa (Darko *et al.*, 2017: 37). The increase in the use of GBTs would be an effective method for both energy consumption and an essential

strategy within the built environment (Ge *et al*., 2020: 11). However, because of the lack of awareness and research development about the use of GBTs in South Africa, the attention of developers and sponsors has not been attracted in the industry (Akinshipe & Aigbavboa, 2018: 10). To fill this gap, the TAM and the influence of construction professionals on the adoption of GBTs was explored in this study. The research on adoption behaviour is rarely applied through TAM with regard to sustainable construction. In a study by Patil *et al*. (2022), technology was perceived as a software-based technique that was suggested for the evolution of green buildings for various conditions. Therefore, the TAM was proposed, as it has been assisting in developing GB adoption and implementation in developing countries (Patil *et al*., 2022: 1814).

1.9. The Expected Results and Importance of the Study

The relationship between TAM and the use of GBTs by project teams was explored in this study. The findings highlighted the subject matter of users' acceptance of technology. This plays a vital role in adopting and using GBTs. It is perceived that the behavioural intentions construct TAM factors such as perceived usefulness, ease of use, and attitude that will showcase the significant influence on the intentions to adopt GBTs (Darko et al., 2017: 330). The results of the study will provide essential implications for the industry, as strategies to improve users' acceptance of GBTs to enhance their adoption and use are discussed. Moreover, the importance of GBTs that are user-friendly and easy to use was highlighted in the study, which could improve acceptance and adoption (Chan et al., 2018: 1072). Furthermore, the aim of this study was to enhance the use of GBTs by project teams and improve productivity in construction projects, water efficiency, and indoor air quality for occupants using the infrastructure to be constructed. The results of this study will allow project teams to eliminate the negative aspects and amplify positive elements within the construction industry using GBTs. In addition, the results of this study add to the understanding of the factors that influence the use of GBTs. Therefore, the findings of this study could help in the design of strategies to increase the adoption and use of GBTs (Ashiq *et al*., 2019: 4).

1.10. Social Impact

The aim of this study was to address the following United Nations Sustainable Development Goals (SDGs):

SDG 7 – Affordable and clean energy

The use of GBTs in construction projects incorporates aspects of sustainability within their construction life cycles. An increase in the uptake of GBTs will enable project teams in the construction industry to provide occupants with sustainable infrastructure that offers affordable and clean energy (Agbajor & Mewono, 2022).

SDG 9 – Industry, innovation, and infrastructure

The world is in the process of technological advancement. Hence, there is an increase in the variety of technology uses in different industries. The use of GBTs will lead to an enhancement of learning experiences, the fostering of collaborative activity, and an increase in creativity and activity. The increased use of GBTs will provide stakeholders in construction with a platform on which to generate more technologies and infrastructure, which is to reduce the effects of the construction industry on climate change and global warming (Owoha *et al*., 2022).

SDG 11 – Sustainable cities and communities

The adoption of GBTs has provided several benefits, such as increased water efficiency, improved productivity, enhanced human health and well-being, improved indoor environmental quality, and higher property value. The incorporation of GBTs within South Africa will enable the construction industry to provide sustainable infrastructure that will lead to South Africa having sustainable cities and communities (United Nations, 2022).

1.11. Outline of the Dissertation

Chapter 1: Research Background

This first chapter serves as an introduction to the dissertation. It contains the background, research questions, aim, and objectives. It includes a brief overview of the research assumptions, the structure of the study, and the chapter summary.

Chapter 2: The Review of Related Literature

In this chapter, the factors of the Technology Acceptance Model are explored. Past studies are reviewed, analysed, considered, and used for guidance. The contrasting areas are analysed and discussed.

Chapter 3: Research Methodology

In this chapter, the methodology applied throughout the study to achieve the desired results is explained. The Research Onion is employed to discuss the research philosophy that underpinned the research strategy and methods.

Chapter 4: Qualitative Data Results and Analysis

The qualitative data are presented and discussed in this chapter. The outcomes are presented in the form of tables. The interpretation of the findings is discussed.

Chapter 5: Quantitative Data Results and Analysis

The quantitative data are presented and discussed in this chapter. The outcomes are presented in the form of graphs. The interpretation of the findings is discussed.

Chapter 6: Discussion

In this chapter, the qualitative and quantitative data about the aim and objectives of the study are expanded and integrated. The findings from the literature are also compared to provide valuable insights when concluding the study.

Chapter 7: Conclusion and Recommendations

In this final chapter, the findings of the study are consolidated, and sound insights are provided based on the research objectives. Critical factors related to the literature reviewed are highlighted.

1.12. Chapter Summary

This chapter contains a synopsis of the research background, problem statement, research questions, research aim and objectives, research delimitations, assumptions and limitations, and the significance of the study. In the next chapter, a scoping review of relevant literature that links TAM factors to the increased adoption of GBT by project teams is presented.

Chapter 2: Review of Related Literature

2.1. Introduction

In this chapter, a widely used theoretical framework to understand an individual's acceptance and use of technology is explored. TAM has been applied across various spectrums, including the adoption of GBTs in South Africa. An overview of TAM and its components is provided, and then various studies that have been conducted regarding the influence of TAM on the adoption of GBTs in South Africa are explored.

2.2. Green Building Technologies

2.2.1. Overview of Green Building Technologies

Green buildings are perceived globally as a fast-growing phenomenon that enables and provides instruments that drive the construction industry to sustainable development. GBTs are found in GBs, which are perceived as being sustainable buildings, the aim of which is to deliver buildings that are self-sustaining in terms of energy consumption (Chigwenya & Zhakata, 2020: 9). GBTs enhance the ability of GBs to restore and revitalise the environment together with a positive influence on people and their health because they are occupants of the buildings (Aziz & Beg, 2022: 163). The aim of GBTs is to eliminate the negative aspects that are aligned with the construction sector and to amplify the positive aspects by incorporating newer design ideas that encourage the use of natural and biodegradable materials, solar power, green insulation, cool roofs, SMART appliances, and other technologies which ensure that a building consumes lower energy, or is even a zero-energy building (Simpeh & Smallwood, 2018: 1827). The optimisation of energy efficiency and reduction of GHG emissions provided by GBTs are part of the AEC's activities. Hence, GBs are an ideal measure that could enable the construction industry to achieve an industry that enhances conservation with little or no ecological pollution (Filonchyk *et al*., 2024: 10). The use of advanced technologies and the promotion of green and sustainable building is essential for developing countries to achieve a built environment that is efficient and safe (Agbajor & Mewono, 2022: 11).

The green concept has transformed the design and techniques that construction professionals use in various construction phases (Al-Shetwi, 2022: 168). GBs mitigate the adverse effects of

a construction project on the environment, as they comprise techniques used to design, develop, build, and control a project in an environmentally friendly manner (Chigwenya & Zhakata, 2020: 8). The development of GBTs has improved the demand for sustainability. Therefore, as a way of adapting to the ever-growing demand, construction professionals must reconfigure their operational and execution methods to fit the new technology requirements (Akinshipe & Aigbavboa, 2018: 340). According to Ge *et al*. (2020), various studies have been conducted to assess the impact of certain GBTs on environmental loads, which provided results based on which it was concluded that appropriate GBTs contribute to the effective reduction of the operating energy consumption of buildings (Ge *et al.,* 2020: 2). The development of GBs contributes to the transformation of the built environment. Song *et al*. (2022) stated that GBTs enable the desired results for buildings to be achieved by developing them in a low-carbon, energy-efficient, comfortable, and healthy manner. In addition, the GBTs also enhance aspects such as planning and design, energy efficiency, indoor air quality, high-performance structure and material, green construction and industrialised building systems in the built environment (Song *et al*., 2022: 1505).

2.2.2. Barriers to Implementation of GBTs

The term "implementation barriers" refers to aspects that hinder the progression of a certain concept being applied in the respective field (Ramafalo & Awuzie, 2019: 484). The adoption of GBTs in South Africa is lacking, as few buildings encompass green technologies. In addition to the myriad problems faced in the construction sector, the level of awareness and knowledge of construction professionals based on GBTs is relatively low (Simpeh *et al*., 2023: 286; Chigwenya & Zhakata, 2020: 12; Agbajor & Mewono, 2022: 3). In many studies, it has been stated that the low level of awareness and knowledge within developing countries hinders the progression of GBTs. Jaffar (2022) also stated that the lack of understanding by the public is the most significant factor regarding the promotion of GBTs (Jaffar *et al*., 2022: 1554). In developing countries, green building councils encounter problems such as poverty, poor public health, unemployment, and lack of skills and education (Taherkhani, 2023: 28394). In addition, the lack of skills, research, and investment in development limits the public's knowledge about the technologies and slows down the industry's recovery, which prevents the BE from achieving its full potential for sustainable development (Simpeh *et al*., 2023: 287; Jaffar *et al*., 2022: 1554). Manna and Banerjee (2019) argued that, compared with traditional methods and materials, the materials and installation of GBTs are expensive. Hence, most developers do not

incorporate GBTs within their projects (Manna & Banerjee, 2019: 1984). Chigwenya and Zhakata (2020) stated that the implementation barriers associated with the adoption of GBTs include a lack of government policy, a general lack of information and understanding of the need for GB, and the unfavourable economic environment in Zimbabwe (Chigwenya & Zhakata, 2020: 8). Table 2.1 below shows the barriers to the use of GBTs.

Table 2.1: Barriers to the use of GBTs

Primary Barriers	Secondary Barriers	Sources
Government and policy-related barriers	Inconsistency of policies and regulations	(Ding *et al*., 2018; Shan & Hwang, 2018; Chan *et al*., 2018; Simpeh & Smallwood, 2020; Chigwenya & Zhakata, 2020; Kong & He, 2021)
	Inadequate subsidies for GBTs	(Agbajor & Mewono, 2022; Manna & Banerjee, 2019; Chan *et al*., 2018; Udeagha & Ngepah, 2022; Jaffar *et al*., 2022)
	Lack of training in green-building technologies	(Chigwenya & Zhakata, 2020; Chan *et al*., 2017; Simpeh *et al*., 2023; Manna & Banerjee, 2019; Atanda & Olukoya, 2019)
Knowledge and awareness-related barriers	Lack of awareness of existing subsidies	(Atanda & Olukoya, 2019; Owoha *et al*., 2022; Simpeh & Smallwood, 2020; Chigwenya & Zhakata, 2020; Jaffar *et al*., 2022)
	Inadequate awareness of, and education in, GBTs	(Jaffar *et a*l., 2022; Simpeh *et al*., 2023; Chan *et al*., 2018; Udeagha & Ngepah, 2022; Akinshipe & Aigbavboa, 2018)
	Lack of environmental awareness among developers and consultants	(Hu *et al*., 2022; Ge *et al*., 2020; Simpeh *et al*., 2023; Akinshipe & Aigbavboa, 2018; Chigwenya & Zhakata, 2020)
	Lack of information and databases for green building technologies	(Chan *et al*., 2018; Simpeh *et al*., 2023; Song *et al*., 2022; Chigwenya & Zhakata, 2020; Jaffar *et al*., 2022; Kong & He, 2021)
	Low market demand for clients	(Akinshipe & Aigbavboa, 2018; Simpeh *et al*., 2023; Chan *et al*., 2018; Manna &

Primary Barriers	Secondary Barriers	Sources
		Banerjee, 2019; Chan *et al*., 2017)
Barriers related to construction professionals	Lack of expertise in GBTs	(Simpeh & Smallwood, 2020; Chigwenya & Zhakata, 2020; Shan & Hwang, 2018; Agbajor & Mewono, 2022; Hu *et al*., 2022)
	Resistance to change by traditional construction professionals	(Chan *et al*., 2017: 10; Song *et al*., 2022; Ashiq *et al*., 2019; Akinshipe & Aigbavboa, 2018; Jaffar *et al*., 2022; Kong & He, 2021)
	Complexity of GBT implementation	(Simpeh & Smallwood, 2018; Ashiq *et al*., 2019; Oguntona *et al*., 2019; Simpeh *et al*., 2023)
	Inadequate time for practising green building technologies	(Aziz & Beg, 2022; Simpeh & Smallwood, 2018; Oguntona *et al*., 2019; Chigwenya & Zhakata, 2020; Jaffar *et al*., 2022)
	Resistance to change by the supply chain stakeholders	(Ding *et al*., 2018; Simpeh & Smallwood, 2020; Wang *et al*., 2018; Sekerin *et al*., 2018; Agbajor & Mewono, 2022; Kong & He, 2021)
	Inadequacy of GBT materials	(Manna & Banerjee, 2019: 1984; Chan *et al*., 2018; Simpeh & Smallwood, 2018; Udeagha & Ngepah, 2022; Chigwenya & Zhakata, 2020)
Economic and finance-related barriers	High cost of GBTs	(Darko *et al*., 2017; Chan *et al*., 2018; Simpeh *et al*., 2023; Wang *et al*., 2018; Jaffar *et al*., 2022)
	Inadequate financial support for the up-front cost	(Ndiweni, 2020; Owoha *et al*., 2022; Simpeh *et al*., 2023; Chan *et al*., 2018; Manna & Banerjee, 2019)
	Preference of the client for the instant payback benefits	(Agbajor & Mewono, 2022; Simpeh & Smallwood, 2018; Oguntona *et al*., 2019; Akinshipe & Aigbavboa, 2018; Jaffar *et al*., 2022)
	Uncertainties and Risks of the new green building technologies	(Park & Park, 2020; Chigwenya & Zhakata, 2020; Wang *et al*., 2018; Akinshipe

Primary Barriers	Secondary Barriers	Sources
		& Aigbavboa, 2018; Manna & Banerjee, 2019)

(Agbajor & Mewomo, 2024, p. 317)

2.2.3. Drivers of GBT Implementation

"Implementation drivers" refer to aspects that give reason to apply concepts in respective fields (Ramafalo & Awuzie, 2019: 486). The low level of implementation of GBTs poses a challenge that must be addressed to achieve a construction sector that is capable of being environmentally friendly and user-friendly. The adoption of GBTs provides a range of notable sustainability benefits that cannot be attained by using traditional building technologies. According to Chan *et al*. (2018), 30% - 80% of building energy consumption can be reduced by using GBTs (Chan *et al*., 2018: 1068). Darko (2017) stated that the implementation of GBTs offers environmental, social, and economic benefits for the construction industry by mitigating global warming and climate change, reduction of carbon dioxide emissions, protection of the ecosystem, the use of renewable natural resources, improving health, comfort, and well-being, and alleviating poverty (Darko *et al*., 2017: 35). Principles have been developed for GBTs that can be used to assess buildings for compliance with comfort, energy efficiency, green requirements, and protection of nature. In addition, GBTs enabled the background air and water pollution reduction, and improved the human living environment (Sekerin et al., 2018, p. 660).

GBs provide a platform that enables the integration of GBTs and other building components to reduce their impact on a project. Wang *et al.* (2018) argued that the transformation of traditional buildings to GBs requires the integration and innovation of different design specialties in the application of GBTs (Wang *et al*., 2018: 2). The GBTs can incorporate positive externalities that can be harvested within the BE by increasing the productivity of the workforce within the working environment, and energy efficiency with green design and environmentally friendly buildings (Chigwenya & Zhakata, 2020: 9; Simpeh *et al*., 2023: 290). The diffusion of GBTs assists in improving the profitability of construction enterprises, which ensures a competitive edge (Zhao *et al*., 2024: 6). Moreover, GBTs encompass recycling technology, purification technology, pollution control, ecological technology, and detection and evaluation technology aimed at protecting the environment (Wang *et al*., 2019: 10). Table 2.2 shows the drivers of the use of GBTs.

Table 2.2: Drivers of the use of GBTs

Primary Drivers	Secondary Drivers	Sources
Environment and industry-related drivers	Reduced environmental impact	(Agbajor & Mewono, 2022; Aziz & Beg, 2022; Ge *et a*l., 2020; Oguntona *et al*., 2019; Chigwenya & Zhakata, 2020)
	Conservation of non-renewable resources	(Chigwenya & Zhakata, 2020; Ding *et al*., 2018; Ashiq *et al*., 2019; Sekerin *et al*., 2018; Akinshipe & Aigbavboa, 2018)
	High return on investment	(Ejidike *et al*., 2022; Chan *et al*., 2018; Song *et al*., 2022; Sekerin *et al*., 2018; Hu *et al*., 2022)
	Environmental awareness	(Ge *et al*., 2020; Chigwenya & Zhakata, 2020; Watkins & Sunjka, 2020; Manna & Banerjee, 2019; McElroy & Rosenow, 2019)
	Setting standards for future design and construction	(Agbajor & Mewono, 2022; *Ge et al*., 2020; Simpeh & Smallwood, 2018; Udeagha & Ngepah, 2022; Akinshipe & Aigbavboa, 2018; McElroy & Rosenow, 2019)
	Facilitating a culture of sharing best practice	(Ashiq *et al.,* 2019; Chan *et al.,* 2018; Song *et a*l., 2022; Oguntona *et al*., 2019; Drago & Gatto, 2021)
	Provision of incentives by the government	(Watkins & Sunjka, 2020; Joyram *et al*., 2022; Wang *et al*., 2018; Sekerin *et al*., 2018; Manna & Banerjee, 2019; Kong & He, 2021; McElroy & Rosenow, 2019)
Economy and health-related drivers	Greater water efficiency	(Akinshipe & Aigbavboa, 2018; Aziz & Beg, 2022; Ge *et al*., 2020; Chan *et al*., 2018)
	Job creation	(Ashiq *et al*., 2019; Zhang *et al*., 2019; Joyram *et al*., 2022; Song *et al*., 2022; Simpeh & Smallwood, 2018; Sekerin *et al*., 2018; Chigwenya & Zhakata, 2020)
	Improved indoor environmental quality	(Drago & Gatto, 2021; Simpeh *et al*., 2023; Ge *et al*., 2020; Chan *et al*., 2018; Udeagha & Ngepah, 2022)
	Reduced use of construction materials in the economy	(Manna & Banerjee, 2019; Simpeh *et al*., 2023; Watkins & Sunjka, 2020; Simpeh & Smallwood, 2018; Chigwenya & Zhakata, 2020)

Primary Drivers	Secondary Drivers	Sources
	Reduced construction life-cycle cost	(Sekerin *et al.,* 2018; Simpeh & Smallwood, 2018; Song *et al*., 2022; Oguntona *et al*., 2019; Akinshipe & Aigbavboa, 2018)
	Greater energy efficiency	(Ge *et al*., 2020; Darko *et al*., 2017; Simpeh *et al*., 2023; Chan *et al*., 2018; Sekerin *et al*., 2018)
Company related drivers	Increased building value	(Darko *et al*., 2017; Ashiq *et al*., 2019; Chan *et al*., 2018; Sekerin *et al*., 2018; Manna & Banerjee, 2019; Simpeh & Smallwood, 2018)
	Enhanced public image	(Agbajor & Mewono, 2022; Ge *et al*., 2020; Song *et al*., 2022; Simpeh & Smallwood, 2018; Akinshipe & Aigbavboa, 2018; Chigwenya & Zhakata, 2020)
	Improved productivity of occupants	(Ge *et al*., 2020; Wang *et al*., 2018; Chan *et al*., 2017; Song *et al*., 2022; Manna & Banerjee, 2019)
	Technological advancements	(Zhang *et al*., 2019; Simpeh *et al*., 2023; Song *et al*., 2022; Ashiq *et al*., 2019; Agbajor & Mewono, 2022)
	Increased demand from clients	(Simpeh *et al*., 2023; Joyram *et al*., 2022; Simpeh & Smallwood, 2020; Oguntona *et al*., 2019; Chigwenya & Zhakata, 2020)
	Better workplace environment	(Atanda & Olukoya, 2019; Patil *et al*., 2022; Ge *et al*., 2020; Chan *et al*., 2018; Sekerin *et al*., 2018; Chigwenya & Zhakata, 2020)

(Patil, Boraste, & Minde, 2022, p. 1815)

2.2.4. The Use of GBTS in South Africa

The development of green projects has introduced a few GBTs including green roof technology, solar technology, and prefabricated concrete technology. Owing to the sustainability benefits of GB, promoting GBTs has been significant in several developing countries (Simpeh *et al*., 2023: 288; Chigwenya & Zhakata, 2020: 10; Atanda & Olukoya, 2019: 370). According to Chigwenya and Zhakata (2020), South Africa is leading the way in relation to the adoption of GBTs, as they have introduced green star ratings which improve the attractiveness of buildings and provide a platform that assists in facilitating sustainable development. As a result of South Africa's high potential for solar energy, solar power systems

are designed to use photovoltaic systems, as they significantly reduce the electricity bills and carbon footprint caused by the emission of GHG (Agbajor & Mewono, 2022: 15; Atanda & Olukoya, 2019: 370). In addition, solar power systems, sustainable materials, and SMART building orientations are used to optimise the use of natural daylight. The prominent GBTs used in South Africa are as follows: passive, design strategies, solar power systems, rainwater harvesting, sustainable material, and green building rating systems (Simpeh *et al*., 2023: 290; Akinshipe & Aigbavboa, 2018: 60). Compared with traditional building technologies, GBTs have components that make a breakthrough of innovation possible that has a positive outcome for the economy and environment (Chigwenya & Zhakata, 2020). However, an integrated management technique is required to manage all facets of GBs based on the use of various technologies (Agbajor & Mewono, 2022: 11; Simpeh & Smallwood, 2018: 1835). All construction stakeholders should be able to acquire the fundamental knowledge necessary to increase the effectiveness and adaptability of management systems. From the viewpoint of the occupants, improving their input is crucial since it has a direct bearing on how the successful GBs are implemented (Akinshipe & Aigbavboa, 2018: 30; Aziz & Beg, 2022: 167).

In South Africa, there has been a slow uptake in the use of GBTs. However, GBTs assist in addressing the matters of energy efficiency and environmental sustainability within the construction industry (Agbajor & Mewomo, 2024: 318). The popular GBTs in South Africa are regarded as being the following: passive design strategies, solar power systems, rainwater harvesting, sustainable material, and green-building rating systems (Simpeh *et al*., 2023: 290; Akinshipe & Aigbavboa, 2018: 60). Passive buildings are designed to incorporate insulation, shading devices, and innovative building orientations to enhance natural daylight and ventilation and minimise solar heat absorption and energy consumption (Energy, 2023: 3). Rainwater harvesting is designed to assist occupants in collecting rainwater and using it for various purposes within the building, such as cleaning, irrigation, and flushing systems. There is often a significant occurrence of drought in South Africa. Therefore, rainwater harvesting has been made a necessary part of GBTs. Project teams are gradually shifting away from using traditional, unsustainable materials such as concrete and glass. They opt for eco-friendly solutions such as bamboo, recycled metal and sustainably sourced timber (Emuze *et al*., 2015: 15; Simpeh & Smallwood, 2020: 12). Green-building rating systems are at the forefront of encouraging project teams to design and erect more GBs or sustainable buildings within South Africa. GBTs in South Africa help to reduce the country's carbon footprint by making a more

sustainable way of living and working possible by building more GBs (Agbajor & Mewono, 2022: 18; Watkins & Sunjka, 2020: 135).

The adoption of GBTs within the construction sector is shaped by a complex interplay of barriers and drivers, both of which assume a critical analytical function when it is broken down and explained through the TAM. Extensive research established that these factors do more than merely describe the external environment; they actively mediate the core TAM constructs namely, perceived usefulness and perceived ease of use which fundamentally influence the behavioural intentions of project teams towards GBT implementation (Simpeh et al., 2023; Chigwenya & Zhakata, 2020; Atanda & Olukoya, 2019). In the South African context, the strategic introduction of innovations such as green roof technology, solar power systems, and prefabricated concrete has been propelled by both national and provincial sustainability imperatives, yet the sector continues to grapple with significant barriers. These include inadequate technical expertise, limited awareness, elevated initial costs, and insufficient policy enforcement, all of which directly undermine users' perceptions of GBTs' utility and accessibility, thereby impeding widespread acceptance (Agbajor & Mewono, 2022; Simpeh & Smallwood, 2018).

Within the Free State province, these barriers are magnified by persistent constraints in sectoral capacity and inconsistent exposure to innovative practices. Such limitations accentuate the analytical relevance of TAM, as they diminish perceived ease of use and usefulness, leading to a reticence among project teams to embrace GBTs (Akinshipe & Aigbavboa, 2018; Aziz & Beg, 2022). However, the presence of robust drivers, including demonstrable long-term cost savings, enhanced building performance, and alignment with established sustainability objectives, serves to counterbalance these impediments. These drivers positively reinforce the TAM constructs, fostering a more receptive attitude towards innovation and increasing the likelihood of adoption (Simpeh et al., 2023; Atanda & Olukoya, 2019). Notably, the adoption of solar power systems and sustainable materials in South Africa exemplifies how perceived benefits can motivate behavioural change, especially when supported by institutional frameworks like green building rating systems (Agbajor & Mewono, 2022; Watkins & Sunjka, 2020).

By systematically integrating the TAM framework with empirical insights from the South African and Free State contexts, it becomes possible to elucidate how project teams interpret and evaluate GBT options. This approach clarifies the mechanisms by which barriers undermine, and drivers enhance, behavioural intention and actual usage, thereby informing the conditions necessary for scaling up sustainable construction practices in the province. The analytical lens provided by TAM not only facilitates a nuanced understanding of technology adoption but also highlights the importance of targeted interventions—such as capacity building, awareness campaigns, and policy refinement—to

optimise the perceived value and usability of GBTs among stakeholders in South Africa's evolving built environment (Simpeh et al., 2023; Chigwenya & Zhakata, 2020; Emuze et al., 2015; Simpeh & Smallwood, 2020).

2.3. Technology Acceptance Model

2.3.1. Overview of TAM

The Technology Acceptance Model (TAM) is essential to understanding the basis of the predictors of human behaviour toward the potential acceptance or rejection of technology (Schorr, 2023: 59). In a study by Rajee *et al*. (2019), TAM was expanded to include additional factors such as social influence, environmental attitude, perceived cost, and trust in responsible organisations, to examine their effect on the adoption of GBTs by construction professionals (Rajee *et al*., 2019: 658). TAM was developed by Davis based on explaining the behaviours of technology users and anticipating their behaviours based on the predecessor of TAM, which was the Theory of Reasoned Action (TRA) (Davis & Granic, 2024: 30). TAM is used to distinguish a relationship between characteristics of systems and human factors to explore the intent approaching adoption and usage (Zhang *et al*., 2023: 40). According to Ashiq *et al*. (2019), TAM was conceptualised in three stages of user adoption. The first stage is referred to as the System Stimulus, also known as features and characteristics of information systems that can correspond to several objectives. The second stage is regarded as the Organism, which showcases the number of factors present to motivate the end-user to build an attitude and likelihood of acceptance of the technology. Lastly, the third stage, named, Response, refers to the actual usage of the system which can be predicted from the user's intention (Ashiq *et al*., 2019: 3). Park and Park (2020) stated that perceived usefulness and ease of use are regarded as the main factors that influence attitude within TAM, that also affects other relations such as belief, intention, behaviour, and actual usage. The external factors indirectly influence attitude and other aspects through the perceived usefulness and ease of use. Moreover, other related factors might include, but are not limited to, attitudes and behavioural intentions, perceived compatibility, social influence, and collaboration with other stakeholders (Park & Park, 2020: 3). In addition, because of its basic structure and strong explanatory power, TAM has been perceived as being the best theory about the incorporation of technologies within a spectrum.

Moreover, TAM is widely used within the built environment to evaluate whether newly imported technologies will be accepted or not (Davis & Granic, 2024: 50).

The effectiveness of TAM can be determined after users have been taught effectively about the technology and understand the technology sufficiently, then they can use the technology in the infrastructure (Scherer *et al*., 2019: 20). The factors influencing TAM revolve around an individual's traits that are connected to their culture and society (Ge *et al*., 2020: 7; Chigwenya & Zhakata, 2020: 10). Fussell and Truong (2022) argued in their study that the applicability of TAM has led to its use across various technological spectrums. The primary factors in the model are as follows: perceived ease of use and perceived usefulness, which both influence the attitude and behavioural intention of end users towards the technology (Zhao *et al*., 2024: 13). The exploration of the primary factors will then determine whether the actual usage of the technology is positive or negative (Fussell & Truong, 2022: 253). The growing body of research has been focused on various perspectives based on the development of TAM. The use of technology within the built environment is spreading and, therefore, thorough research about the acceptance and actual usage of GBTs by project teams has been examined (Song *et al*., 2022: 1706; Simpeh *et al*., 2023: 290). Based on a study by Davis, Park, and Park (2020), it was found that there is a relationship between the usefulness and ease of use of technologies, which significantly contributes to the actual usage and acceptance of the technologies. In addition, in an empirical study by Park and Park (2020), it was proved that TAM has useful adaptability and scientific application if it is corrected and expanded appropriately (Park & Park, 2020: 4). Hence, TAM is used when explaining and predicting the process of innovative technology adoption in other technical or disciplinary contexts. Moreover, construction professionals are provided with a theoretical framework based on understanding whether GBTs are accepted or not within the built environment (Wang *et al*., 2019: 5). Fussell & Truong (2022) argued that a combination of perceived usefulness along with ease of use influences the attitude and behavioural intention of project teams towards the actual usage of GBTs (Fussell & Truong, 2022: 260; Darko *et al*., 2017: 42; Patil *et al*., 2022: 1815). The diagram in Figure 2.1 below shows the relationship among the various aspects incorporated within TAM.

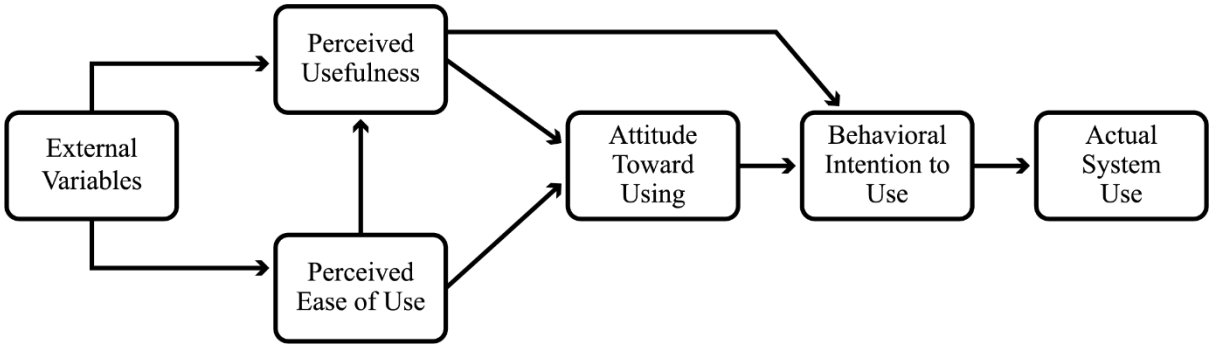


Figure 2.1: Technology Acceptance Model by Davis (1986)

Source: (Park & Park, 2020: 7)

2.4. Perception of Usefulness of GBTs

2.4.1. Overview of Perceived Usefulness as a Concept

In a study by Zhang *et al*. (2019), perceived usefulness has been defined as an employee's perception of the usefulness of adopting green behaviours within the workplace. Perceived usefulness is essential in assisting construction firms to achieve success, especially those involved in multi-storey projects (Zhang *et al*., 2019: 9). According to Wang *et al*. (2019), perceived usefulness refers to an extent that developers seek from the use of GBTs to accelerate the development of GBs, corporate reputation, along with market competitiveness (Wang *et al*., 2019: 9). Perceived usefulness is an important factor for TAM as it reflects how much a specific technology is believed to facilitate the accomplishment of important objectives, and it influences people's attitudes, intentions, and behaviours (Park & Park, 2020: 5; Chigwenya & Zhakata, 2020: 14). In a study by Wilson *et al*. (2021), perceived usefulness is regarded as being people's perception of whether a new technology could change the way they work and improve their performance. Moreover, project teams in the built environment will only opt for GBTs once they see that they add value to the performance of the construction life cycle. Therefore, perceived usefulness could play a vital role in determining the success or failure of GBTs within the construction industry (Wilson *et al*., 2021: 265).

2.4.2. Factors Influencing Perceived Usefulness of GBTs by Project Teams

The perceived usefulness of GBTs includes the following factors: environmental, social, and economic benefits within the construction industry by mitigating global warming and climate change, reduction of carbon dioxide emission, protection of the ecosystem, using renewable natural resources, improvement of health, comfort, and well-being, and alleviating poverty (Darko *et al*., 2017: 35). Principles have been developed for the GBTs to assess buildings for compliance with comfort, energy efficiency, green requirements, and protection of nature. In addition, GBTs enable the reduction of background air and water pollution, and improve human living environments (Sekerin *et al*., 2018: 660). The composition of policies for environmental rewards increases the employees' environmental knowledge, improves employees' awareness regarding environmental protection, and ensures employees' awareness relating to the importance and usefulness of GBTs in the built environment (Zhang *et al*., 2019: 4; Simpeh & Smallwood, 2020: 10). Moreover, construction firms can incorporate the framework of green environmental protection throughout the project life cycle, ensuring that project teams and new recruits are informed. In a study by Park and Park (2020), several factors were identified that influence perceived usefulness, including technology usefulness, policy, market, perceived values, and advertisements. This relationship has been consistently supported by the TAM. If a technology is shown to have a practical benefit, users will have a positive attitude towards adopting it. The perceived usefulness of GBTs can be illustrated through the reduction of operating costs and energy consumption, boosted financial performance, and enhanced productivity and health of the occupants (Marikyan & Papagiannidis, 2024: 5). As a result, they will benefit the users and have an impact on their attitudes (Albarracin & Shavitt, 2018: 315).

2.5. Perception of Ease of Use of GBTs

2.5.1. Overview of Ease of Use as a Concept

Ease of use is illustrated by the degree to which the end-user can effortlessly use a particular system. Wilson *et al*. (2021) defined perceived ease of use as the perception of people weighing the required effort expended to learn a new technology. In addition, the perceived ease of use could affect a project team's perception of GBTs, if the client prefers to use traditional building technology compared with GBTs, which might differ across regions (Wilson *et al*., 2021: 265). In a study by Zhang *et al*. (2019), ease of use is explored as the degree relating to employees' perception on green behaviour within the work environment to be effortless, thus increasing the possibilities and opportunities for green behaviour within the workplace through

management (Zhang *et al*., 2019: 5390). Moreover, Wilson *et al*. (2021) stated that, based in a study by Park & Park (2020), perceived usefulness could also be defined as the public's assessment regarding time and effort required to learn and use a new product. The ability to combine numerous technologies and enable diverse stakeholders to engage continuously in the construction process of GBs are both characteristics of well-developed GBTs, in addition to the study of a single technology (Wilson *et al*., 2021: 265; Park & Park, 2020: 7).

2.5.2. Factors that Influence Ease of Use of GBTs by Project Teams

Construction firms can be influenced by providing the project teams with environmental training to reduce the resistance of project stakeholders to the use of GBTs in the built environment. In addition, training and support programmes for project teams can enhance their understanding and adoption of GBTs (Ferreira *et al*., 2024: 23768). An organisation influences the ease of use of GBTs through promoting environmental protection, education, and training. During current technological breakthroughs, construction firms will have to take into consideration the difficulty of technological integration into a well-known system (Wang *et al*., 2019: 10; Akinshipe & Aigbavboa, 2018: 15). Therefore, project teams should try to implement GBTs which encompass specifications to which the client is already accustomed, to provide the client with a facility that is of easy use to them. The management, the occupants, and the technology constitute the internal factors (Wilson *et al*., 2021: 267). Now, GB consultants who are licensed professionals and fill this position should be able to acquire the fundamental knowledge necessary to increase the effectiveness and adaptability of management systems. From the viewpoint of the occupants, improving their input is crucial since it has a direct bearing on how the successful GBs are implemented (Akinshipe & Aigbavboa, 2018: 30; Aziz & Beg, 2022: 167). The development of a GB depends on every area of technological development. To maximise the benefits of technical possibilities and consider the changing motivations of end users and the environment, this calls for the combined efforts and co-operation of all pertinent technical people and researchers, as well as continually updating the linked technologies (Ashiq *et al*., 2019: 3; Manna & Banerjee, 2019: 1985). The technical performance and reliability of GBTs enable project teams to rely on the functional technology without any downtime for smooth operation. Therefore, the integration of the design of GBTs into the initial stages enables the ease of use of GBTs and ease of interaction of project teams with GBTs (Rahman *et al*., 2018: 20).

Construction firms must educate their employees about GBs, as they are a fast-growing global phenomenon, to provide instruments that drive the construction industry into, and enable, sustainable development. GBTs are found in GBs, which are perceived as sustainable buildings, the aim of which is to deliver buildings that are self-sustaining in terms of the energy consumption of buildings (Chigwenya & Zhakata, 2020: 9). The training material provided by construction firms should include materials that affirm that GBTs enhance the ability of GBs to restore and revitalise the environment together with the positive influence on people and their health as occupants of the buildings (Aziz & Beg, 2022: 163). The aim of GBTs is to eliminate the negative aspects that are aligned with the construction industry and amplify the positive aspects, which ensure that a building consumes lower energy, or even becomes a zero-energy consumption building (Simpeh & Smallwood, 2018: 1827). The optimisation of energy efficiency and reduction of GHG emissions associated with GBTs is part of the AEC's activities. Hence, GBs are an ideal measure that can enable the construction industry to enhance conservation with minimal to no ecological pollution (Mneimneh *et al*., 2022: 450). The use of advanced technologies and the promotion of green and sustainable building are essential for developing countries to achieve a built environment that is efficient and safe (Agbajor & Mewono, 2022: 11).

GBs mitigate the adverse environmental effects of a construction project, as they comprise techniques used to design, develop, build, and control a project in an environmentally friendly manner (Chigwenya & Zhakata, 2020: 8). The development of GBTs has improved the demand for sustainability. Therefore, as a way of adapting to the ever-growing demand, construction professionals must reconfigure their design, operation, and execution methods to fit into the new technology requirements. (Akinshipe & Aigbavboa, 2018: 340). According to Ge *et al*. (2020), various studies were conducted to assess the influence of certain GBTs on environmental loads, which provided results based on which it was concluded that GBTs contribute to the effective reduction of the operating energy consumption of buildings (Ge *et al*., 2020: 2). The development of GBs contributes to the transformation of the built environment.

2.6. Attitude towards Use

2.6.1. Overview of Attitude as a Concept

Attitude encompasses a wide range of concepts such as an object, a person, and an abstract idea, hence making it relevant through various disciplines such as marketing, advertising, political behaviour, and health (Albarracin & Shavitt, 2018: 302; Park & Park, 2020: 5). Harborth and Kreuz (2020) defined attitude as an expression of passion and hate, attraction and repulsion, and likes and dislikes (Harborth & Kreuz, 2020: 127). Furthermore, various individuals have attitudes when they love or hate things or people and when they approve or disapprove of them (Guido, 2018: 2088). Zhang *et al*. (2020) stated that attitude can impact how information is perceived and how well it is retained. In addition, the attitudes and interests of the project teams could significantly impact other stakeholders' perceptions of GBTs (Zhang *et al*., 2019: 7). An attitude is a positive or negative, evaluative reaction to events, programmes, etc., expressed in a person's beliefs, feelings, emotions, or intended behaviours. Positive attitudes towards a subject also show a strong correlation to a project team's scientific success (Zhang *et al*., 2020: 185; Agbajor & Mewono, 2022: 9). It is essential to measure the attitude of project team members towards GBTs while also considering their attitude towards the learning environment in the construction sector. The impact of the attitudes of project teams towards GBTs are crucial since issue resolution calls for tolerance of uncertainty, perseverance, and a willingness to take risks (Guido, 2018: 2890). A given aim is evaluated with favour or disfavour when someone has an attitude towards it. It is a consistent, evaluative reaction to an object. According to the TAM, it is claimed that a person's attitude towards a specific technology influences the person's intention to employ the technology. In many earlier studies, evidence of this connection has been found (Park & Park, 2020: 10; Udeagha & Ngepah, 2022: 17).

2.6.2. Factors that Influence the Attitude of Project Teams towards GBTs

The development of a specific attitude can start with a general attitude. Certain behaviour-related attitudes would be impacted directly by the general ambient attitude. An eco-centric outlook that reflects a dedication to the conservation of natural resources and environmental protection can result in a more favourable attitude towards certain environmentally friendly

goods, practices, or policies (Rajee et al., 2019: 662; Ejidike et al., 2022: 10). Growing awareness of the harmful interaction between our contemporary, industrialised society and the natural world led to the birth of the GBT movement. With theoretical support from the Value-Belief-Norm Theory, the general environmental attitude favours intention and conduct. A social environmental movement's supporters are explained using Value-Belief-Norm (Park & Park, 2020: 12). According to this theory, broad environmental ideals, attitudes, and norms determine pro-environmental behaviours through a focus on values and moral standards. According to the Social Identity Theory and Means-End Model, people's ideas and values hold a substantial influence on their decision-making and behaviours, and both theories have theoretical underpinnings that support the relationship between environmental attitude, awareness, and intentions (Akinshipe & Aigbavboa, 2018: 342; Fussell & Truong, 2022: 255).

The project teams' lack of awareness and knowledge within developing countries hinders the progression of GBTs and influences the attitude of project teams towards GBTs. In a study by Jaffar *et al*. (2022), it was stated that the lack of understanding by the public is the most significant factor regarding the attitude towards promoting GBTs (Jaffar *et al*., 2022: 1554). In developing countries, the green building councils encounter problems such as poverty, weak public health, unemployment, and deprivation of skills, together with education. In addition, the lack of skills, research, and investment in development limits the public's knowledge about the technologies. It slows down the industry's recovery, influencing the attitude of project teams and preventing the BE from achieving its full potential (Simpeh *et al*., 2023: 287; Jaffar *et al*., 2022: 1554). In comparison with traditional methods and materials, Manna and Banerjee (2019) argued that the materials and installation of GBTs are expensive; hence, most developers do not incorporate GBTs within their projects (Manna & Banerjee, 2019: 1984). Chigwenya and Zhakata (2020) stated that the causes of the negative attitude of project teams associated with the adoption of GBTs include an absence of government policy, a general deprivation of information and understanding of the requirement for GB, and the unfavourable economic environment in developing countries (Chigwenya & Zhakata, 2020: 8).

2.7. Change of Behavioural Intention towards Use

2.7.1. Overview of Behavioural Intention as a Concept

The selection of GBTs is an example of "environmentally responsible behaviour" (ERB), a term used to describe acts taken by a person or organisation to promote the sustainable or reduced use of natural resources. The factors that predict ecologically responsible conduct have been well-studied (Davis & Granic, 2024: 25). According to the VBN theory of environmental concern, five factors – personal values, beliefs, awareness of the consequences, responsibility attribution, and personal norms – are significant pre-conditions for engaging in ecologically responsible conduct (Fussell & Truong, 2022: 255). An expansion of this theory produces a conceptual model that includes four categories of characteristics that impact how people behave environmentally: attitude-related factors, contextual factors, personal capabilities, and habit or routine. The term "behavioural intention" describes how someone feels, either positively or negatively, about a certain phenomenon or action (Park & Park, 2020: 8). Since it persists for a very long period after development, attitude is a useful indicator of a person's behavioural purpose. When stakeholders have a good attitude towards a particular action, the likelihood that an individual will take that action to meet expectations will improve (Manna & Banerjee, 2019: 1984). People's assessment of their abilities regarding the knowledge, resources, and time required to complete a task is referred to as perceived behavioural control. When someone believes that they can manage a situation and the resources required to complete a task successfully, they are said to be in control (Aziz & Beg, 2022: 168).

2.7.2. Factors that Influence Behavioural Intentions of Project Teams Regarding GBTs

Post-occupancy evaluation, human aspects, architectural psychology, and the notions and disciplines relating to a healthy building have increasingly attracted the scrutiny of research. Various stakeholders are becoming more aware of the interaction between people and buildings. In addition to the development of GBs, building energy efficiency and environmental improvements influence the behavioural intention of project teams regarding GBTs (Albarracin & Shavitt, 2018: 310; Atanda & Olukoya, 2019: 370). In commercial buildings with organisational structures, centralised control of the electrical equipment is typically used. Building performance is not significantly affected by occupant behaviour, but, for certain homes or offices, occupant behaviour significantly impacts architectural performance (Ashiq *et al*., 2019: 3; Fussell & Truong, 2022: 258). According to Zhang *et al*. (2019), measuring a building's performance regarding the comfort and well-being of its

occupants rather than only its energy efficiency is crucial. All stakeholders are expected to acquire the fundamental information necessary to enhance the effectiveness and adaptability of management systems. Improving occupant feedback is vital since it directly affects the successful implementation of GBTs. Therefore, understanding GBTs is essential for engineers and occupants (Zhang *et al*., 2019: 11). Successful building performance during operation depends mostly on occupants because they have a better awareness of GBs and can use the equipment correctly to help to achieve the primary ecological target. The behaviour of building occupants must also be examined carefully to support human-centred design and create a healthy indoor environment. In the future, it is anticipated that training and education in the use of GBTs, as well as a greater understanding of regional environmental challenges, will be provided (Park & Park, 2020: 9; Drago & Gatto, 2021: 2110).

2.8. Actual Usage of Technology

2.8.1. Overview of Actual Usage as a Concept

One of the most prominent examples of forecasting people's behaviours based on their beliefs and attitudes is the Theory of Planned Behaviour. It was initially founded on the Theory of Reasoned Action, according to which attitudes and arbitrary standards predict behaviour (Darko *et al*., 2017: 326). Owing to the limited ability to explain behaviours that are influenced by numerous factors using the TPB, perceived behavioural control was later proposed as an extra component. According to the TPB, behaviour is influenced by intention, which is identified by attitude, subjective norms, and perceived behavioural control (Park & Park, 2020: 10).

2.8.2. Factors that Influence the Actual Usage of GBTs by Project Teams

TAM was used to administer technologies that are frequently used to explain and forecast consumers' acceptance of new items or technological advancements. Acceptance of new items or technological advancements is affected by the causal chain between beliefs, attitudes, intentions, and behaviours (Davis & Granic, 2024: 40). According to TAM, a person's attitudes toward a technology are predicted by their perceptions of its utility and usability. Attitudes are then thought to determine potential intentions of usage before having an impact on actual usage (Zhang *et al*., 2019: 5388; Ashiq *et al*., 2019: 4). Since assessing the actual usage behaviour is

a challenge, the usage intention is frequently exercised as a substitute. TAM can be used to explain and forecast occupants' acceptance of GBTs in the early phases of implementation because GBTs are a combination of several new green technologies incorporated into residential structures (Manna & Banerjee, 2019: 1986). Since just 3% of the entire amount of water on the surface of the world is potable, water conservation is equally important to the design of GBs. South African buildings must conserve water, prevent pollution, and recycle treated water to ensure the availability of potable water. This can be classified as either indoor or outdoor water use (Jaffar *et al*., 2022: 1556; Oguntona *et al*., 2019: 7). This task in the building construction process is the responsibility of architects, landscape designers, and engineers involved in water supply and drainage engineering. Water efficiency is the practice of using less water and producing less wastewater. The efficiency of every fixture, including taps, toilets, showerheads, urinals, etc., should be examined regularly for leaks and to ensure that they are in effective working order (Wang *et al*., 2018: 19; Owoha *et al*., 2022: 1638).

2.9. Gaps in the Literature

In relation to TAM, the construction stakeholders are required to complete the following process to accept new technologies: (1) pay attention to the new technologies and perceive their qualities; (2) develop a sentimental liking for these new technologies; and (3) finally establish a behavioural intention for the technologies (Elshafey *et al*., 2020: 165). The growth of GBs is dependent on the social and economic development of the area because they are high-quality buildings. The interest of construction stakeholders in GBs is also influenced by their own social and economic circumstances (Park & Park, 2020: 10). The interest of construction stakeholders in GBs has not been explained adequately in the literature to date, given the social and economic progress of South Africa. Also, the associated research that is now available is based primarily on static studies that do not include consideration of how society and the economy are developing (Liu & Hu, 2019: 555). Several barriers still prevent construction stakeholders from accepting GBs, despite the many benefits that they provide for saving energy, land, water, material, and the environment. At first, it was assumed that technology and the state of the economy were the cause of the low acceptability of green buildings (Agbajor & Mewono, 2022: 19).

Table 2.3: Breakdown of literature reviewed in relation to research objectives

Section in Chapter 2	Objectives				
	1	2	3	4	5
Green Building Technologies					
Overview of GBTs	x	x			x
Implementation barriers of GBTs			x	x	x
Implementation drivers of GBTs	x	x	x	x	x
The use of GBTs in South Africa	x	x			x
Technology Acceptance Model					
Overview of TAM	x	x	x	x	
Factors that influence TAM	x	x	x	x	x
Perception of Usefulness					
Overview of perceived usefulness as a concept	x				
Factors that influencing the perceived usefulness of GBTs by project teams	x				x
Perception of Ease of Use					
Overview of perceived ease of use as a concept		x			
Factors that influence the perceived ease of use of GBTs by project teams		x			x
Attitude towards Use					
Overview of attitude as a concept			x	x	
Factors that influence the attitude of project teams towards GBTs			x	x	x
Change of Behavioural Intention towards Use					
Overview of behavioural intention as a concept			x	x	
Factors that influence the behavioural intention of project teams regarding GBTs				x	x
Actual Usage of Technology					
Overview of actual usage as a concept					x
Factors that influence the actual usage of GBTs by project teams					x

(Owoha, Simpeh, Fapohunda, Ahadzie, & Mensah, 2022, p. 1630)

2.10. Chapter Summary

This chapter provides a comprehensive analysis of the existing literature. The various scholarly sources assisted in synthesising the findings and identifying the gaps in literature. Critical

examination was conducted on the existing theoretical frameworks to evaluate the relevance and effectiveness of addressing the research questions. Overall, this chapter provided illustration of how the proposed research aims to contribute to the broader academic. The next chapter showcases a synopsis of the methodologies to be utilised within the thesis.

Chapter 3: Research Methodology

3.1. Introduction

This chapter served as a guide to the study, as it is focused on the techniques that were adopted within the study about the influence of TAM on the use of GBTs. The research methodology encompassed the specific procedures used in the study that were justified against the other available techniques. The overview of the research methodology is presented based on similar existing studies to support the research methodology that was adopted for this study.

3.2. Application of the Research Onion

Melnikovas (2018) stated that the Research Onion is a methodology and general research strategy that paves the way for conducting research. In addition, it incorporates a system of beliefs and assumptions that guide the cohesiveness of research questions and underpin the choices of research method (Melnikovas, 2018: 33). Determining appropriate approaches and procedures is vital as it enables the research to produce significant results about the subject matter. The various layers of the Research Onion unfold specific aspects of the study, and illustrate the variety of philosophies, approaches, strategies, and choices throughout the research (Alturki, 2021: 1).

The Research Onion's aim is to showcase the components of how researchers should design their research and select techniques that are adopted for data collection and analysis (Ghazinoory & Aghaei, 2024: 230). In addition, the Research Onion is regarded as a logical blueprint that enables the researcher to follow a consistent plan for the study (Saunders *et al*., 2019: 139). Moreover, it operationalises the variables that enable measurement, selection of samples of interest to the study, and collection of data to be used based on testing the hypothesis and examining the results. The research question and sub-questions are linked logically to the data collected and the strategies used to analyse the data collected (Pandey & Pandey, 2021: 30). Subsequently, this logical linkage assisted in the validity and accuracy of the study. The Research Onion is a diagram that guides the design of research to provide a comprehensive plan for answering the research questions (Mardina, 2020: 1202). Figure 3.1 below illustrates the Research Onion.

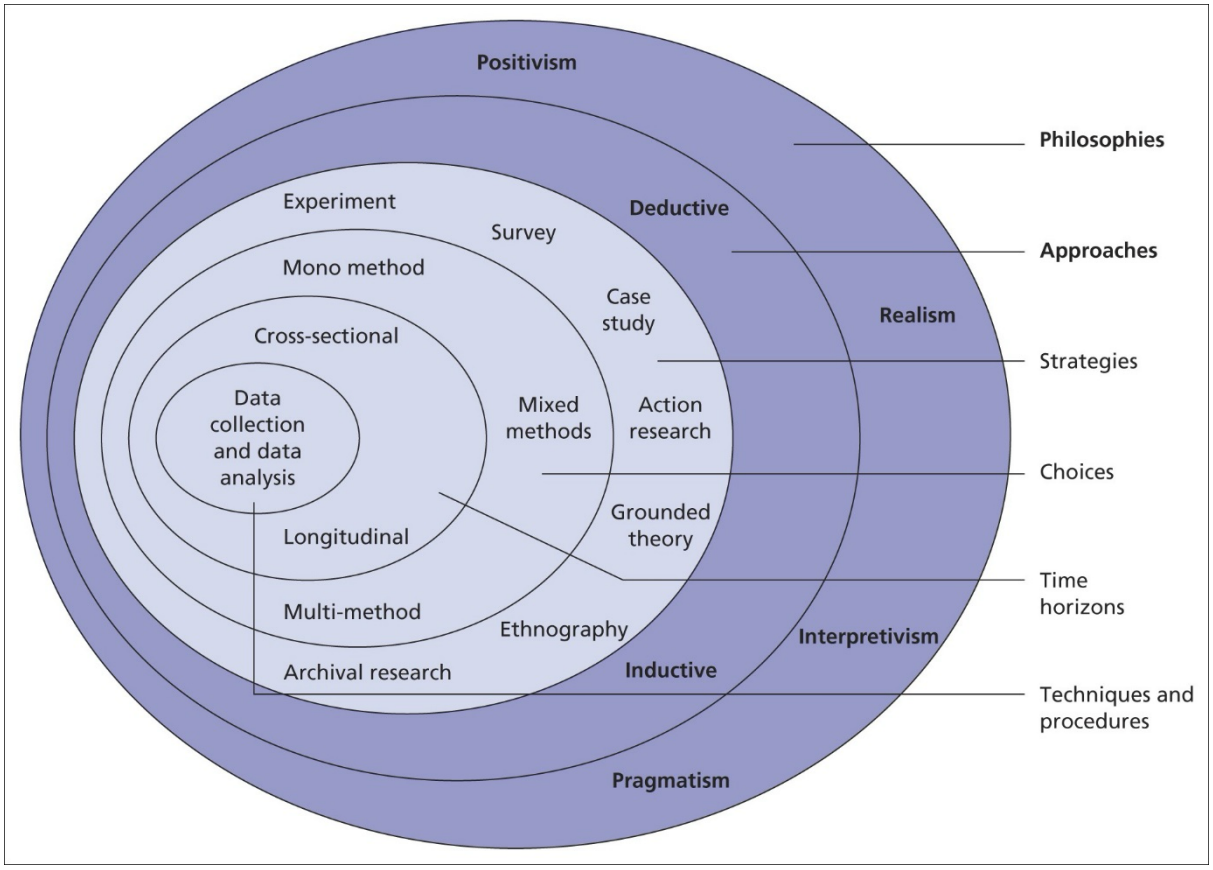


Figure 3.1: Research Onion

Source: (Saunders et al., 2015)

The six layers of the Research Onion were considered to enable the successful completion of the study. Table 3.1 below shows the choices of research methodology within the research design.

Table 3.1: Structural research layers for the study

The structural research layer	Choices
1. Research philosophy	Pragmatism
2. Approach to theory development	Deductive and inductive (abductive)
3. Research strategy	Survey and semi-structured interviews
4. Methodological choice	Mixed methods
5. Research time horizon	Cross-sectional
6. Research techniques and procedures	Survey questionnaires, semi-structured interviews, and focus groups

(Pandey & Pandey, 2021, p. 20)

In this research, the perceived usefulness and ease of use of GBTs by project teams, and the attitudes and behavioural intentions of project teams regarding the usage of GBTs were assessed. The validity and reliability of the findings were ensured through sending the survey to project teams that were professional experts on GBTs and GBs. The semi-structured interviews were conducted on MS Teams with project teams using GBTs and GBs. This information enabled the researcher to draw conclusions based on the findings of the data collected. Moreover, it enabled the researcher to collect and analyse data from project teams who had knowledge of GBTs. This enabled the researcher to provide a sound argument in the report. Figure 3.2 illustrates the research process that was adopted for this study.

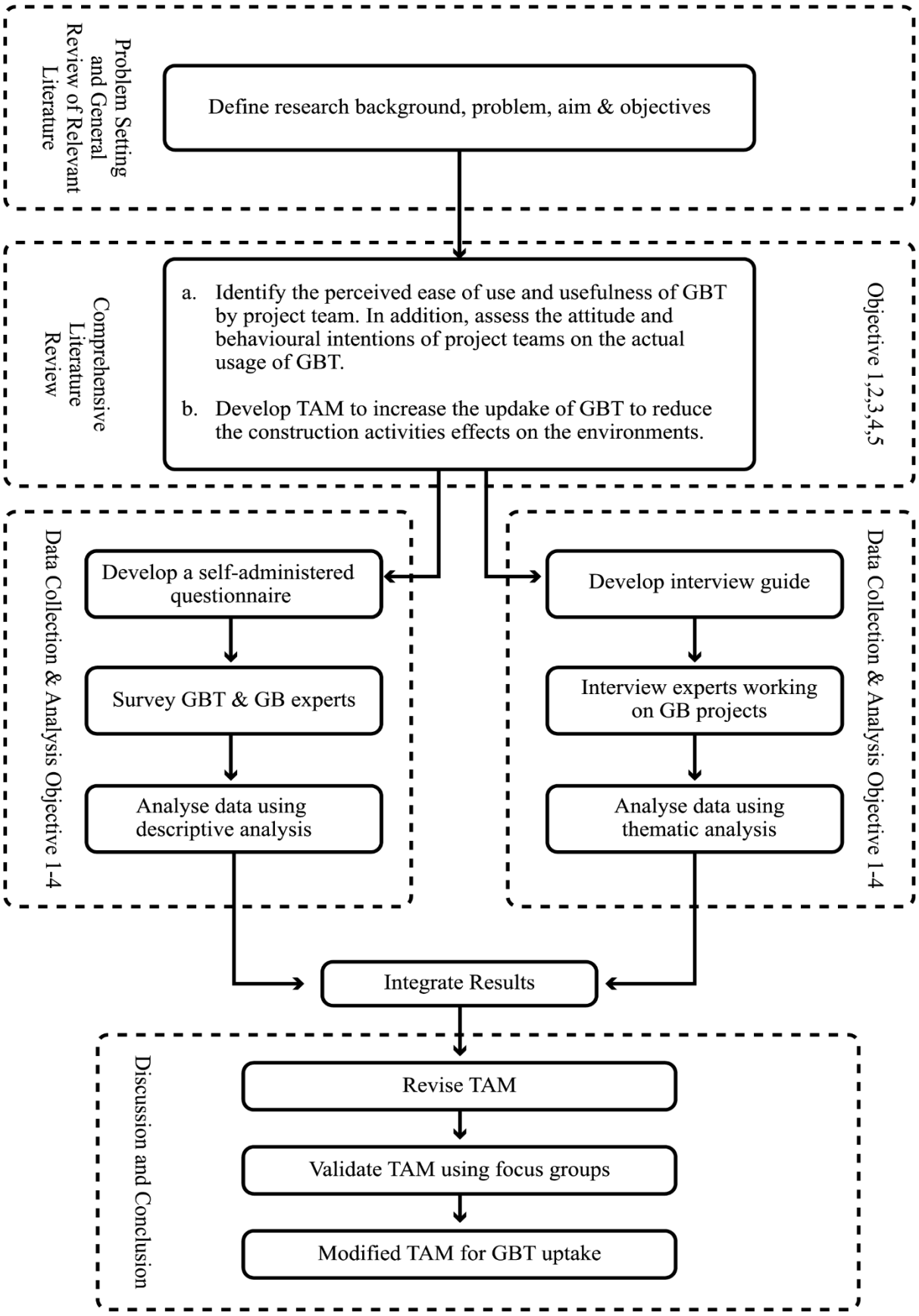


Figure 3.2: Research process

(Alturki, 2021, p. 7)

3.3. Research Philosophy

In a study by Elder-Vass (2022), pragmatism was defined as a philosophical approach that seeks to avoid sceptical and relativist responses and opts for the impossibility of absolute certainty by arguing based on worthwhile knowledge that is present (Elder-Vass, 2022: 263). Pragmatism is also defined as a philosophy that emphasises the importance of practicality and the usefulness of knowledge, then shifts the focus to solely theoretical frameworks. These observations and experimental results are then derived from a scientific theory, which is then tested to modify, develop, or validate the existing knowledge (Rosenthal & Thayer, 2024: 15). The perceived usefulness and ease of use of GBTs by project teams made it possible to analyse the drivers of the study. The attitude and behavioural intention of project teams regarding the use of GBTs enabled an analysis of the barriers and drivers of GBTs in the construction industry (Cohen, 2023: 30). In this study, a pragmatic research philosophy was adopted to facilitate the application of the TAM, thereby supporting efforts to enhance the use of GBT within the construction industry (Alharahshe & Pius, 2020: 41).

In this study, pragmatism was used to ensure that the researcher conducted research that served a practical intent and produced valuable insights into why the construction industry should adopt green technology. TAM serves as a framework within which to analyse the factors that influence the acceptance and uptake of newly developed technologies within various industries (Kelly & Cordeiro, 2020: 3). In terms of GBTs, TAM was used to assess the factors that affect the acceptance and uptake of GBTs by project teams (Morgan, 2020: 66). This study was focused on issues such as the implementation of GBTs in the construction industry, the cost-effectiveness of GBTs, and the perceived benefits of their use. The use of questionnaires and semi-structured interviews enabled the research to provide valuable insights into encouraging the construction industry to adopt green technology. Therefore, pragmatism assisted the researcher in concentrating on practical considerations to offer valuable insights into the adoption of green technology by the construction industry (Frega, 2019: 10).

3.4. Research Approach

The deductive approach is ideal for research to test an existing theory or hypothesis. It enables the researcher to collect either confirmed, refined, or discredited data and provide evidence-based conclusions. In addition, it clarifies the research design because it is aligned with the hypothesis (Pearse, 2019: 148). Furthermore, the deductive approach is used to formulate a clear, focused research question with a defined process to test the hypothesis. The objectivity of the research was maintained using regulated measurement tools and unambiguous data analysis procedures, which reduced the influence of personal opinions and biases (Woiceshyn & Daelenbach, 2018: 189). However, an inductive approach uses the empirical data gathered through interviews, observations, surveys, or experiments to develop general theories or conclusions from the examined data. The aim is to identify the patterns, themes, and relationships that enable the researcher to develop new ideas and insights (Fleischmann & Ivens, 2019: 6846).

The low uptake of GBTs in South Africa is because of the lack of awareness and knowledge of project teams about the use of GBTs in the construction industry. TAM is a well-known model that is used to explain the adoption of technologies in various sectors. The use of TAM enabled the researcher to understand the factors that affect the use of GBTs and develop a model that would increase the adoption of GBTs (Simpeh & Smallwood, 2021). Moreover, using TAM, the researcher developed a model that best assures an increase in the uptake of GBTs by project teams. The researcher adopted both an inductive and a deductive approach. This enabled the researcher to develop a hypothesis or theory in the study based on existing and unknown knowledge or theory (Pearse, 2019: 150).

An inductive approach was used to collect the empirical data about the uptake of GBTs. The data were examined to identify the patterns and relationships among the various variables. Through the analysis of the data, a theoretical framework was developed using TAM to explain the patterns and relationships of the data that were identified (Fleischmann & Ivens, 2019: 6850). The developed theoretical framework was used to create a TAM to generate a strategy that would increase the uptake of GBTs. The researcher used factors such as perception of usefulness and ease of use, attitude, and behavioural intention of project teams regarding GBTs as significant predictors of the increased use of GBTs in South Africa. After the data collection

procedure, the researcher tested the hypotheses by conducting surveys and semi-structured interviews with project teams who had knowledge of the GBTs (Gupta & Park, 2022: 121652).

3.5. Research Strategy

The research strategies used within the study were surveys and semi-structured interviews because they involve collecting data from a population by asking questions and recording responses from the research participants. There are various ways to conduct a survey. It can be conducted online or in person, and data can be collected using both quantitative and qualitative methods (Zhou & Zafarani, 2018: 10). For this study, the survey was conducted online, and semi-structured interviews were conducted using Microsoft Teams. The versatility of a study enables researchers to achieve their research objectives from various angles. A survey can be cost-effective for a researcher compared with other research strategies, such as focus groups or in-depth interviews. The semi-structured interviews assisted in cross-validating the responses from the online survey (Fleischmann & Ivens, 2019: 6847). The survey research strategy is an appropriate choice for a researcher to be able to collect data from a larger group (Aziz & Beg, 2022: 170). Semi-structured interviews were also conducted with a focus group of building owners, architects, contractors, and the various stakeholders who had expert knowledge of GBTs. This assisted in understanding the behavioural intentions and attitudes of project teams, and their perceptions of the use and ease of use of GBTs.

3.6. Research Methods

The researcher used mixed methods for the study. Mixed methods are an approach that encompasses both quantitative and qualitative research methods to gain a clearer understanding and compile a comprehensive report that answers the research problem and questions. Quantitative methodology is a research method that incorporates the collection and analysis of numerical data. This method enabled the researcher to follow patterns and averages, make predictions, test causal relationships, and generalise the results to a broader population (Zhang *et al.*, 2019: 11). A quantitative method is based on the principles of pragmatism and is characterised by a highly structured design and statistical data analysis. The researcher chose the quantitative method because it reduces the influence of personal bias and subjectivity in the collection and analysis of data. It entails the use of regulated data collection tools and statistical

analysis to enable accurate findings from the research. The research process enabled the researcher to replicate findings to verify the results and testable assumptions in future studies (Zhou & Zafarani, 2018: 15).

The purpose of a qualitative research method is to understand, explore, and describe the complexity of human behaviour and social phenomena. Its subjective nature is based on the interpretation of verbal data rather than the analysis of numerical data. It was used to gain a thorough understanding of what must be done to increase the use of GBTs by project teams within the construction industry (Nadarzynski *et al*., 2019: 2). A qualitative methodology is subjective as it emphasises the collection of non-numerical data. It is used to identify the trends and patterns in the data and then to interpret them with understanding. It is a valuable research method that made it possible to develop a TAM based on an understanding of the social phenomena that are displayed by project teams regarding the use of GBTs in the construction industry (Fleischmann & Ivens, 2019: 6850).

The mixed research method made it possible to cross-validate the findings of the study from various sources, which assisted in compiling a robust report. It made it possible to combine the different insights from multiple respondents that added to the range of perspectives within the study. The low uptake of GBTs in South Africa by project teams can be increased through the comprehensive solutions produced using the mixed methodology (Gupta & Park, 2022: 121253).

3.7. Time Horizon

The researcher chose a cross-sectional time horizon as it enabled efficient collection of data from a larger population within a specific period. It was focused on the variability and variety of perceptions, attitudes, or behaviour of a population rather than the changes across time (Pandey & Pandey, 2021: 15). A cross-sectional time horizon is a cost-effective way of collecting data, as the research can be completed quickly. This approach is cost-effective, suitable for descriptive analysis, and reduces the influence of confounding factors. The benefits justify the selection of a cross-sectional time horizon (Corron & Phillips, 2018: 157).

3.8. Data Collection Methods

3.8.1. Secondary Data Collection

The secondary data were collected from raw data and published summaries, including articles, journals, books, and periodicals. The raw data and published summaries are regarded as secondary data because they are information collected earlier by researchers and authors (Pandey & Pandey, 2021: 30). Secondary data were collected for the entire study from the following databases:

- Google Scholar
- Emerald
- Research Gate
- Scientific Direct
- Taylor & Francis

The databases listed above assisted the researcher in achieving the research objectives by extracting the descriptive and narrative information required from the sources found in the databases (Pearse, 2019: 153).

3.8.2. Primary Data

The primary data for this study were collected through an online survey using Question Pro. The reason for choosing an online study was that it provided the research with a larger sample that influenced the accuracy of the study (Agbajor & Mewono, 2022: 18). In addition, the key point was that it assured that various stakeholders with expert knowledge within the construction industry were reached to provide their expertise in using TAM to increase the usage of GBTs. Regulated questions were used to ensure consistency in response and to enable comparison across various populations to improve the reliability of the research (Aziz & Beg, 2022: 170).

3.9. Data Collection Procedures

3.9.1. Define the Population

A research population refers to the group of individuals that a researcher is interested in studying. This population encompasses a group of people who share similar traits relevant to the research question. The sample is selected to ensure that it is representative of the population and that the research findings can be generalised throughout the entire population (Zhou & Zafarani, 2018: 18). The sample was selected following a criterion that encompassed construction stakeholders who had expert knowledge about buildings and the influence of GBTs within the built environment. This enabled the researcher to derive a population that would ensure that the sample for the research was a representative subset of the population (Ashiq *et al*., 2019: 5).

3.9.2. Sampling Method

Sampling is essential in obtaining data from which inferences regarding the broader population can be developed. In survey design and implementation and the analysis of survey data for research and policy purposes, the sampling approach is essential for several reasons that encompass theoretical and practical implications (Pearse, 2019: 154). Non-random probability sampling was used for the study, as it refers to a sampling method whereby participants of a specific population have a known chance to be part of the sample. This sampling method helped the researcher to reduce the possibility of sample or population bias (Chan *et al*., 2018: 1075).

Rather than relying on random selection, which could introduce participants without adequate knowledge of GBTs or the construction industry, the researcher identified and targeted key stakeholders and professionals within the built environment. This approach enabled the inclusion of individuals who were best positioned to provide informed perspectives on the use and adoption of GBTs, thereby enhancing the quality and relevance of the data collected (Al-Shetwi, 2022, p. 170).

The selection process began by defining explicit inclusion criteria, focusing on construction professionals, such as architects, engineers, project managers, and other stakeholders with direct involvement and expert knowledge in green building initiatives. These criteria ensured that all participants had practical experience and a comprehensive understanding of the subject matter, which

was critical for addressing the research questions accurately (Agbajor & Mewomo, 2024, p. 330). The researcher then used professional networks, industry directories, and recommendations from established bodies such as the Council of Green Buildings to identify potential respondents who met these criteria.

Additionally, diversity was prioritised within the expert group to capture a broad range of experiences and insights. This included selecting participants from various roles, organisational sizes, and types of projects within the construction sector, thus enabling a more representative cross-section of expert opinion (Patil, Boraste, & Minde, 2022, p. 1818). The purposive sampling method also allowed for the inclusion of respondents from different project types, further enhancing the generalisability of the findings within the constraints of the non-random approach (Kong & He, 2021, p. 7).

By employing non-random probability sampling, the study minimised the risk of including unqualified respondents and reduced the likelihood of sample or population bias. This methodological choice was critical for ensuring that the data collected were robust, dependable, and directly applicable to the research focus on the adoption and perceived usefulness of GBTs within the construction industry. The targeted selection of participants through non-random sampling ultimately supported the validity of the research findings, as the responses were grounded in relevant industry experience and expertise (Al-Shetwi, 2022, p. 170).

3.9.3. Sample Size

The sample size refers to the number of individuals representing the study population. However, the determination of the sample size is an essential aspect of the research methodology (Akinshipe & Aigbavboa, 2018: 345). The sample size for the study was sufficient to ensure the collection of accurate and reliable data, effectively representing the broader population with minimal error or bias. In determining whether the sample size was adequate, the researcher referenced established sample size calculation formulas and guidelines from past studies. For quantitative research, Yamane's (1967) formula is commonly applied to calculate the minimum sample size required for a given population at a specified confidence level and margin of error. This approach ensures that the sample is large enough to reflect the characteristics of the population, thereby reducing sampling error. Furthermore, literature suggests that, in the context of construction industry research, a sample size of at least 30–50 respondents is often deemed sufficient for generalisability and statistical validity (Krejcie & Morgan, 1970; Bartlett, Kotrlik & Higgins, 2001). In this study, the sample was

drawn from a council of GBs, consisting of construction professionals, and met these established thresholds, thereby supporting the representativeness and reliability of the findings. Zhou & Zafarani (2018: 35) also highlight the importance of aligning sample size with the research aim and population structure to ensure credible and generalisable results. By adhering to these guidelines and referencing past research, the study ensured that the sample size was methodologically sound and sufficient for addressing the research question.

3.9.4. Instrument Administration

A questionnaire was utilised to obtain quantitative data from the sample for the study. A questionnaire is a set of structured questions that can be administered in writing, online, or during personal interviews. The researcher developed a well-structured questionnaire, aligned with the research aim and objectives. The questionnaire was clear, concise, and easy to understand (Chan *et al*., 2018: 1076). The researcher pre-tested the questionnaire with small sample sub-sets to help to identify the ambiguities in the questions or instructions and correct them before administering them to the main sample. The questionnaire was administered to the sample size by using pre-tested questionnaire procedures, such as online survey tools, to ensure reliability and validity (Woiceshyn & Daelenbach, 2018: 190). The responses to the questionnaire were recorded using Question Pro. The researcher validated the integrity of the collected data through the relevant statistical procedure and analysed the available information. After examining the gathered data, the researcher reported the research findings in a valid and reliable research report (Wang *et al*., 2018: 20). Semi-structured interviews were used to obtain qualitative data for the study. The semi-structured interviews were conducted across five case studies, which were used to obtain results from projects that have incorporated GBTs. Various methods were used to perform the interviews, including face-to-face interviews, Microsoft Teams, and Zoom. The interviews were recorded using a cell phone. The recordings were transcribed, and the results were analysed.

Table 3.2: Research methods

Research Objective	**Data Collection Methods**				**Data Collection Methods**		
1. Explore the project team's perceived	**L. Revie**	**Q. Surv**	**Semi - struc**	**Focu s Grou**	**Infer ential Statis**	**Desc riptiv e**	**Rem arks**

usefulness of GBT.							
2. Explore the ease of use of GBT by project teams.	**X**	**X**	**X**	**X**	**X**	**X**	Use and compare the findings from the survey questionnaire and semi-structured interviews
Research Objective	**Data Collection Methods**				**Data Collection Methods**		
3. Determine the attitude of project teams towards GBT.	**X**	**X**	**X**	**X**	**X**	**X**	Use and compare the findings from the survey questionnaire and semi-structured interviews
4. Assess the change in behavioural intentions of project teams regarding the use of GBT.	**X**	**X**	**X**	**X**	**X**	**X**	Use and compare the findings from the survey questionnaire and semi-structured interviews
5. Propose how the factors of TAM could be used to increase the uptake of GBT in South Africa.	**X**	**X**	**X**	**X**	**X**	**X**	Use and compare the findings from the survey questionnaire and semi-structured interviews

(Patil, Boraste, & Minde, 2022, p. 1818)

3.10. Reliability and Validity

The use of a larger sample size and regulated data collection instruments ensured that data were reliable and valid. The use of pragmatism helped to develop new theories or hypotheses. Pragmatism was used to identify the relationship between variables and formulate predictions that can be tested through empirical research (Pandey & Pandey, 2021: 30). The accuracy of the prediction and testable assumptions will strengthen the validity of the research. The deductive approach of the study enabled a replicable process that used a similar hypothesis and research design. This makes results reliable and relevant for future use by researchers (Alharahshe & Pius, 2020: 42). The reliability and validity of the survey will be embodied in

the opportunity for detailed responses, allowing the research participants to take their time when answering. This results in more accurate responses from participants, which is vital for the reliability of data collection. Since the researcher collected data from a large group of construction stakeholders at a single point in time, the influence of confounding factors, such as social, cultural, and historical factors, was reduced (Gemma, 2018: 47). After the results were collected and examined, the researcher applied the recommendations on the construction sites nearby that did not have GBT.

3.10.1. Reliability

The TAM provides a robust theoretical framework through which the factors influencing the use of GBT in South Africa may be systematically addressed. To increase the adoption of GBT, it is essential to leverage the core TAM constructs, which are as follows: perceived usefulness, perceived ease of use, attitude towards use, behavioural intention, and actual usage. Perceived usefulness can be enhanced by clearly demonstrating the tangible benefits of GBT in cost savings, environmental performance, and operational efficiencies through pilot projects and empirical case studies. Simultaneously, improving perceived ease of use involves providing targeted training, simplifying technology interfaces, and offering ongoing technical support, thereby reducing uncertainty and resistance among construction stakeholders.

Furthermore, enhancing positive attitudes of project teams towards the adoption of GBTs can be achieved through highlighting successful local and international case studies and by involving influential industry stakeholders in leadership roles. This approach, combined with transparent communication about the long-term value proposition of GBT, can shift prevailing attitudes and motivate behavioural intention to adopt. Integrating findings from both survey questionnaires and semi-structured interviews allows for a comprehensive understanding of the drivers and barriers to GBT uptake, ensuring that strategies are tailored to stakeholders' real-world experiences and perceptions. Collectively, these measures can create a conducive environment for widespread GBT acceptance and implementation in the South African construction sector.

3.10.2. Validity

The validity of the present research is firmly grounded in the systematic triangulation of data sources, achieved by integrating survey questionnaires and semi-structured interviews. This

methodological pluralism allows for a nuanced and multidimensional exploration of GBT adoption within the TAM framework, strengthening both internal and external validity. By cross-validating findings derived from distinct data collection methods, the research effectively mitigates potential biases and enhances the credibility and trustworthiness of its conclusions.

In addition, the application of well-established theoretical constructs from the TAM ensures analytical robustness, contributing to the internal consistency of the research outcomes regarding the determinants of GBT uptake in the South African context. Careful attention to the local socio-cultural landscape and diverse stakeholder perspectives further bolsters the external validity and the real-world significance of the study's recommendations. Ultimately, this comprehensive approach substantiates the reliability and applicability of the research findings for both academic exploration and practical industry application.

3.11. Ethical Considerations

Ethical considerations assisted in ensuring that the research was conducted in an ethical, responsible, and professional manner. The researcher ensured all participants in the study gave informed consent before participating in the study. This ensured that the participants were adequately informed of the purpose, procedures, and risks of the research, together with the right to withdraw from the study at any given time (Aziz & Beg, 2022: 174). The participants' identities were kept confidential, and the data collected were used solely for research purposes. Confidentiality ensured that the participant's data were not shared or used for any other purpose without their consent. During the research, the dignity, privacy, and autonomy of participants were respected, and exploiting or manipulating the participants was avoided. The researcher complied with the relevant research guidelines and regulations, such as those set by the ethics committees, to ensure the researcher's ethical conduct (Darko *et al*., 2017: 40).

3.12. Chapter Summary

The detailed framework of the methodological decisions made for the study was explained in this chapter. This included elaboration on the research philosophy, approach, strategy, time horizon, data collection, and analysis. The selection of participants to ensure representativeness and reliability was discussed. Moreover, the chapter included an elaboration on the data collection methods used within the study. The data analysis process that would derive

meaningful conclusions was discussed. The research findings and discussions are presented in the next chapter.

Chapter 4: Qualitative Results and Analysis

4.1. Introduction

In this chapter, the findings of the study regarding the use of the TAM to enhance the adoption of GBTs in South Africa are presented and discussed. The aim of the study was to understand and increase the acceptance and implementation of these technologies by evaluating project teams' perceived usefulness, ease of use, attitudes, and behavioural intentions regarding GBTs. The data were collected during semi-structured interviews from five case studies and focus groups comprising project teams who had experience with GBTs. The section synthesizes key findings, identifies central and supporting themes, and provides a cross-case examination to evaluate the extent to which the qualitative evidence supports or challenges the research hypothesis. In this chapter, the findings that provide insights into how TAM can be applied effectively to promote GBTs in South Africa are presented systematically. Moreover, this section provides an in-depth analysis testing the study's hypothesis in relation to the adoption of GBT in South Africa's construction industry, as interpreted through the TAM. The analysis aims to inform construction researchers, academics, and industry professionals seeking to understand the drivers and barriers influencing GBT adoption.

4.2. Interpretation of Findings from Semi-Structured Interviews

Qualitative Case Study 1: Commercial Development Project

The first case study was undertaken in Bloemfontein, Free State, South Africa. The case study incorporated the construction of a shopping complex, comprising bulk excavations, sub-structure, super-structure, and civil works. The sample of this case study comprised project team members, including artisans, project managers, quantity surveyors, and health and safety officers. A total of 11 interviews were conducted.

4.2.1. Perceived Usefulness of Green Building Technologies by Project Teams

Four out of eleven interviewees indicated that GBTs contribute to increased efficiency in construction projects. Two quantity surveyors, an inventory manager, and a procurement

officer alluded that: “This efficiency manifests in various ways, such as reduced waste, streamlined processes, and optimised resource use, leading to cost savings and faster project completion times”. Six out of eleven acknowledged the role of GBTs in enhancing quality control. “These technologies enable better monitoring and management of construction processes, ensuring adherence to standards and specifications. As a result, the overall quality of construction projects is improved, leading to higher durability and performance of buildings,” said the project manager, three construction managers, a quantity surveyor, and a procurement officer. All interviewees unanimously agreed on the importance of GBTs in enhancing performance and resilience to climate change by saying, “These technologies incorporate sustainable practices and materials that reduce environmental impact and increase the ability of buildings to withstand extreme weather conditions. This universal acknowledgement underscores the critical role of green building technologies in promoting sustainable construction practices.” Five out of eleven interviewees identified the significant environmental impact of GBTs by alluding that: “These technologies help reduce the ecological footprint of construction projects using sustainable materials, energy-efficient systems, and waste reduction practices. This results in a lower overall environmental impact throughout the building's life cycle.” Five out of eleven interviewees highlighted the cost-saving and efficiency benefits of GBTs. The quantity surveyor, construction manager, two inventory managers, and procurement officer affirmed this: “These technologies lead to significant reductions in energy and water consumption, lower maintenance costs, and overall operational efficiency.” The initial investment in green technologies often results in long-term financial savings, making them economically viable and attractive for construction projects.

Table 4.1: Factors affected by green building technologies in the construction industry

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Increased efficiency					x			x		x	x
2. Enhanced quality control	x	x		x		x	x				x
3. Resilience to climate change	x	x	x	x	x	x	x	x	x	x	x
4. Performance enhancement	x	x	x	x	x	x	x	x	x	x	x

Six out of eleven interviewees highlighted the positive impact of GBTs on health and well-being. “These technologies often incorporate features that improve indoor air quality, natural lighting, and overall living conditions, which in turn enhance the physical and mental health of building occupants,” said the two inventory managers, construction manager, project

manager, and two quantity surveyors. This aspect is crucial for the creation of healthier and more comfortable living and working environments.

Table 4.2: Whole life cycle costing factors associated with green building technologies in the construction industry

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Environmental impact		x			x	x		x			x
2. Cost-saving and efficiency	x					x	x		x	x	
3. Impact on health and well-being	x		x	x		x	x	x			

4.2.2. Perceived Ease of Use of Green Building Technologies by Project Teams

Three out of eleven interviewees discussed the adoption rate of GBTs in their firms. These interviewees indicated that: “The rate at which these technologies are adopted varies based on factors such as firm size, project requirements, and client demands. A higher adoption rate is often seen in firms with a strong commitment to sustainability and innovation.” Two out of eleven interviewees emphasised the importance of success stories and case studies in promoting the adoption of GBTs. The project and construction managers affirmed by stating, “Sharing these stories helps build confidence and encourages broader acceptance within the firm.” These narratives served as proof of concept, demonstrating the tangible benefits and successful implementation of green technologies in past projects. Most interviewees, ten out of eleven, highlighted the critical role of technical support and training in introducing GBT. The project manager alluded: “Adequate training ensures that staff are well-versed in the application and benefits of these technologies. Continuous technical support helps address challenges and fosters a smoother integration process, enhancing overall effectiveness.” Nine out of eleven interviewees discussed the learning curve associated with GBTs. The time and effort required to become proficient with these technologies can vary. Firms that provide comprehensive training and resources can help their employees to overcome the learning curve more effectively, ensuring that the technologies are used to their full potential. Seven out of eleven respondents advocated their firm’s willingness to invest in GBTs to promote sustainability. Moreover, five out of eleven respondents mentioned using awareness campaigns to enhance the knowledge of project teams regarding the importance of implementing green building technologies.

Table 4.3: Factors enabling the adoption of GBTs

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Adoption rate					x	x			x	x	
2. Success stories and case studies			x	x							
3. Technical support and training	x	x	x		x	x	x	x	x	x	x
4. Learning curve	x	x	x	x	x		x		x	x	x
5. Willingness to invest	x		x	x	x				x		x
6. Awareness campaigns				x	x			x			

Eight out of eleven interviewees indicated that the user-friendly design of GBTs is crucial for their adoption. The artisan affirmed by saying, “Technologies that are easy to understand and implement are more likely to be embraced by the workforce.” User-friendly designs minimise resistance to change and facilitate quicker integration into existing workflows. Moreover, eight out of eleven respondents mentioned that the regulatory environment assists in increasing the use of GBTs, and three out of eleven respondents referred to industry collaborations as an effect of GBT usage.

Table 4.4: Ways to influence the use of GBTs

Factors	1	2	3	4	5	6	7	8	9	10	11
1. User-friendly design		x	x	x	x	x		x	x		x
2. Regulatory environment	x	x				x	x	x		x	
3. Industry collaborations									x		

4.2.3. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies

Seven out of eleven respondents stated that GBTs have affected their company positively, whereas four out of eleven referred to the effect of GBTs as being unfavourable.

Table 4.5: Effect of GBTs on companies

Response	1	2	3	4	5	6	7	8	9	10	11
1. Positive	x	x	x	x	x			x			x

2. Negative						x	x		x	x	

Four out of eleven respondents had a poor attitude towards GBTs, whereas nine had a positive attitude towards GBTs. Five out of eleven respondents stated that GBTs helped to foster job creation within the construction industry, and three out of eleven respondents said that GBTs led to economic benefits. The project manager said, "The firm attracts environmentally conscious clients by partnering with technology providers and experts and implementing GBTs in their projects to improve the project outcomes and sustainability goals."

Table 4.6: Benefits of GBTs to companies

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Negative attitude towards technology						x	x		x	x	
2. Positive attitude towards technology	x	x	x	x	x			x			x
3. Job creation		x		x		x					
4. Economic benefits			x	x	x						

4.2.4. Actual Usage of Green Building Technologies by Project Teams

Ten out of eleven respondents had worked with emerging GBTs, and nine out of eleven respondents had worked with GBTs that were compatible with existing systems.

Table 4.7: Types of GBTs in the construction industry

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Emerging technologies		x	x	x	x	x	x	x	x	x	x
2. Compatible with existing systems	x	x	x		x	x	x	x		x	x

Eight out of eleven respondents stated that GBTs impacted cost-effectiveness and performance enhancement in the construction industry. The three construction managers, project manager, two procurement officers, quantity surveyor, and inventory manager affirmed that: "GBTs are vital for sustainable development of the construction industry because they include materials and methods that make buildings more eco-friendly". Six out of eleven respondents said that GBTs were the environmental benefits of the construction industry. Nine out of eleven highlighted the importance of sustainable practices facilitated by green building technologies. The artisan, in agreement, stated that, "These practices include the use of eco-friendly

materials, energy-efficient systems, and waste reduction strategies. Adopting such practices helps minimise the environmental footprint of construction projects and promotes long-term sustainability."

Table 4.8: Factors of overall performance of GBTs on construction projects

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Impact on cost-effectiveness	x	x	x	x			x	x	x		x
2. Environmental benefits		x	x		x				x	x	x
3. Performance enhancement	x	x		x	x	x		x		x	x
4. Sustainable practices	x	x	x	x		x		x	x	x	x

Ten out of eleven respondents stated that the regulatory environment sets the standards that influence the implementation of GBTs. Seven out of eleven respondents said that the market demand, and two out of eleven respondents stated that financial incentives, influenced the standards set to incorporate GBTs in the construction industry.

"These technologies promote sustainable building practices and provide a competitive advantage. Company policies should enforce best practices in sustainability by including sustainable development criteria in project specifications", said the inventory manager.

Table 4.9: Factors that influence GBT use in the construction industry

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Regulatory environment	x	x	x	x	x	x	x		x	x	x
2. Financial incentives				x				x			
3. Market demand		x	x	x	x			x		x	x

Nine out of eleven respondents stated that the design team was responsible for setting the specifications for the technologies that would be incorporated into construction projects, whereas six out of eleven respondents stated that construction teams were responsible for setting the specifications.

Table 4.10: Project team members who influence specifications

Factors	1	2	3	4	5	6	7	8	9	10	11
1. Design team	x	x	x		x		x		x	x	
2. Construction team				x		x		x			x

Qualitative Case Study 2: Road Construction Project

Case study 2 was a based on a road construction project within Bloemfontein, Free State, South Africa, the aim of which was to link townships and make them accessible. This project involved bulk excavations, cutting and filling, levelling, and civil works. Qualitative data were collected during interviews with a research sample of members of the project team. A total of eight interviews was conducted.

4.2.5. Perceived Usefulness of Green Building Technologies by Project Teams

The project manager, two civil engineers, one cost estimator, and one buyer stated that GBTs increased efficiency in the construction industry. The project manager stated, “The essence of GBTs is to house environmentally responsible and resource-efficient infrastructure”. GBTs enhanced quality control within the construction industry, as stated by the two buyers, one cost estimator, one civil engineer, and one contract administrator. The contract administrators affirmed by stating, “GBTs have encouraged the use of sustainable materials and construction practices”. The project manager, one buyer, one civil engineer, and one cost estimator stated that GBTs enhanced resilience to climate change in the construction industry. The civil engineer said, “GBTs are vital to achieving sustainability goals within the construction industry, as they create an environment of innovation in building design and construction”. All respondents stated that GBTs enhanced the overall performance of the construction industry:

The cost estimator stated: “GBTs are fundamental in improving the overall environmental performance of infrastructure and have provided an increase in demand for sustainable and eco-friendly infrastructures”,

Table 4.11: Factors that promote the use of GBT in the construction industry

Factors	1	2	3	4	5	6	7	8
1. Increased efficiency		x	x		x	x	x	
2. Enhanced quality control		x		x	x	x		
3. Resilience to climate change	x			x			x	x
4. Performance enhancement	x	x	x	x	x	x	x	x

One project manager, one buyer, and one cost estimator stated that GBTs had an environmental impact on the costing of the whole life cycle. Moreover, one project manager, one buyer, one cost estimator, and two civil engineers stated that GBTs had an influence on cost saving and efficiency for the costing of the whole life cycle in the construction industry. The project manager said, “GBTs support innovation and best practices in construction. This serves the economic and environmental benefits of sustainable building practices.”

Table 4.12: Whole life cycle costing factors

Factors	1	2	3	4	5	6	7	8
1. Environmental impact			x		x			x
2. Cost saving and efficiency		x		x	x	x	x	

4.2.6. Perceived Ease of Use of Green Building Technologies by Project Teams

The two civil engineers, one project manager, and one cost estimator stated that GBTs were introduced according to the adoption rate in their firm. The project manager stated, "Market trends and competitive advantage considerations lead to GBTs being introduced.” The two civil engineers stated that GBTs were introduced through success stories and case studies. They affirmed this by saying, “Our firm shares best practices and case studies to implement on our upcoming projects; this occurs through on-site training and field visits.” The two civil engineers, one project manager, two contract administrators, and one cost estimator stated that GBTs were introduced through technical support and training. The cost estimator stated that: “GBTs are introduced through industry conferences and seminars; this assists us in connecting with various professionals who have engaged with GBTs”. The two buyers, one project manager, two contract administrators, and one cost estimator stated that GBTs were introduced through the learning curve. The buyer stated, "Technical challenges can be obtained through implementation and monitoring then amended by proper training and support.” The two buyers, two civil engineers, and two contract administrators stated that the willingness to invest in

GBTs enabled smooth transition. The civil engineer affirmed by saying, “The firm invests in continuous learning and development initiatives, giving us access to industry resources and best practice databases.” The project manager, one civil engineer, one cost estimator and one contract administrator stated that awareness campaigns helped with introducing GBTs within the firm.

The contract administrator said, “These technologies support innovation and best practices in construction. Technologies which are reliable, facilitate smoother project execution and management. Through strategic planning and investment in GBTs, the firm provides continuous learning and environmental awareness.”

Table 4.13: Factors that lead to the introduction of GBTs

Factors	1	2	3	4	5	6	7	8
1. Adoption rate			x		x		x	x
2. Success stories and case studies			x					x
3. Technical support and training	x	x		x	x	x	x	
4. Learning curve		x	x	x	x	x		x
5. Willingness to invest			x	x	x	x	x	x
6. Awareness campaigns	x	x			x		x	

The project manager, two civil engineers, one cost estimator, two contract administrators, and one buyer stated that user-friendly designs were used to incorporate GBTs in construction projects. The project manager indicated, "Technical performance influences the adoption of GBTs”. Moreover, the civil engineer, one cost estimator, and one buyer suggested that the regulatory environment was used to implement GBTs in construction projects. The buyer said, “GBTs are incorporated through fostering a culture of sustainability within the organisation.” The civil engineer and two contract administrators indicated that industry collaboration was also used to implement GBTs in construction projects. The civil engineer affirmed by saying, “The firm invests in continuous learning and development initiatives, giving us access to industry resources and best practice databases.”

Table 4.14: Factors that lead to the incorporation of GBTs

Factors	1	2	3	4	5	6	7	8
1. User-friendly design	x	x	x		x	x	x	x
2. Regulatory environment		x	x	x				
3. Industry collaborations		x				x	x	

4.2.7. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies

The project manager, two civil engineers, one cost estimator, one buyer, and one contract administrator were affected positively after GBTs were introduced in their company, whereas one buyer and one contract administrator were affected negatively.

Table 4.15: Effect of GBTs on companies

Response	1	2	3	4	5	6	7	8
1. Positive	x	x	x	x	x	x		
2. Negative							x	x

Two respondents had a highly unfavourable attitude towards GBTs. The buyer stated, “The equipment and training for GBTs are too costly.” However, six respondents had a favourable attitude towards GBTs. The project manager said, “GBTs have improved project quality and client satisfaction, creating new business opportunities and partnerships.” Four respondents stated that GBTs had opened opportunities for job creation. The cost estimator stated, “GBTs necessitated investment in training and upskilling, making us more employable.” Two respondents said that the GBTs in their company produced economic benefits. The contract administrator indicated that: “GBTs have created new business opportunities and partnerships with other industry professionals.”

Table 4.16: Factors introduced by GBTs into companies

Factors	1	2	3	4	5	6	7	8
1. Unfavourable attitude towards technology							x	x
2. Favourable attitude towards technology	x	x	x	x	x	x		
3. Job creation	x	x			x	x		
4. Economic benefits			x	x				

4.2.8. Actual Usage of Green Building Technologies by Project Teams

The project manager, one civil engineer, one buyer, and one contract administrator had worked with emerging GBTs. The civil engineer stated, "GBTs help reduce the carbon footprint of infrastructures; I have worked with SMART building systems and high-efficiency insulation." However, one civil engineer, one cost estimator, one buyer, and one contract administrator had worked with GBTs that were compatible with existing systems. The cost estimator stated, "GBTs promote sustainability in the construction industry; I have worked with greywater recycling and ventilation systems."

Table 4.17: Types of GBTs in the construction industry

Factors	1	2	3	4	5	6	7	8
1. Emerging technologies		x	x		x			x
2. Compatible with existing systems	x			x		x	x	

The civil engineer and cost estimator stated that GBTs impacted cost-effectiveness. The cost estimator said, "The use of GBTs has reduced maintenance and operational costs." The project manager, one buyer and one contract administrator stated that GBTs had environmental benefits in the construction industry. The buyer stated that: "GBTs have positively impacted our firm because we managed to reduce our environmental impact and started to set internal sustainable goals and targets". Moreover, two civil engineers, one cost estimator, two buyers, and two contract administrators said that GBTs enhanced the performance of the construction industry. The contract administrator stated, "GBTs are fundamental in improving the overall environmental performance of infrastructure and have provided an increase in demand for sustainable and eco-friendly infrastructures," The project manager, one cost estimator, two

civil engineers, one buyer, and one contract administrator stated that sustainable practices were introduced by GBTs.

The project manager said, "GBTs improve the durability and resilience of infrastructures, leading them to contribute positively to project outcomes and client satisfaction,"

Table 4.18: Effect of GBTs on overall performance in construction projects

Factors	1	2	3	4	5	6	7	8
1. Impact on cost-effectiveness			x			x		
2. Environmental benefits	x			x				x
3. Performance enhancement	x	x	x		x	x	x	x
4. Sustainable practices	x		x	x	x	x	x	

The project manager, two buyers, and two contract administrators stated that the regulatory environment set the standards that influenced the implementation of GBTs. Furthermore, the contract administrator concurred by saying, "We are responding to the implementation of GBTs through setting internal sustainability goals and targets, using our policies and relating them to regulatory environments and industry standards like LEED and Green Star." The two civil engineers, two buyers, and one contract administrator stated that the market demand set standards to incorporate GBTs in the construction industry. To confirm this, the civil engineer stated that: "GBTs enhance marketability and value of infrastructures. Therefore, implementation of GBTs by project teams provides a competitive advantage". The cost estimator stated that financial incentives set standards to incorporate GBTs in the construction industry. The cost estimator said, "When the company invests in training and development for project teams, it will enable improvement of the sustainability profile and project outcomes. Therefore, financial incentives will be a provision for SMMEs,"

Table 4.19: Factors that set standards

Factors	1	2	3	4	5	6	7	8
1. Regulatory environment	x				x	x	x	x
2. Financial incentives				x				
3. Market demand		x	x		x	x	x	

The project manager, two civil engineers, one cost estimator, one buyer, and one contract administrator stated that the design team were responsible for setting the specifications for the technologies that were going to be incorporated in construction projects. However, one buyer and one contract administrator stated that construction teams were responsible for setting the specifications.

Table 4.20: Project team members who set specifications

Factors	1	2	3	4	5	6	7	8
1. Design team	x	x	x	x		x		x
2. Construction team					x		x	

Qualitative Case Study 3: Township Development

The third case study was situated in a township in Bloemfontein, Free State, South Africa. The case study incorporated a township development construction, comprising bulk excavations, sub-structure, super=structure, and civil works. The sample of this case study comprised project team members, including artisans, a procurement officer, tender administrators and a health and safety officer. A total of nine interviews was conducted.

4.2.9. Perceived Usefulness of Green Building Technologies by Project Teams

The two foremen and two artisans stated that GBTs increased efficiency in the construction industry. The foreman affirmed by saying, “Reliable GBTs facilitate smoother project execution and management.” Furthermore, the health and safety officer, procurement officer, two tender administrators, foreman and artisan stated that GBTs were resilient to climate change. The tender administrator stated that: “GBTs are designed to make buildings more sustainable and environmentally friendly”. The procurement officer stated that GBTs enhanced quality control in the construction industry. Concurrently, the two foremen, two tender administrators, three artisans, and the health and safety officer stated that GBTs enhanced performance in the construction industry.

The tender administrator said, “GBTs improve energy efficiency, leading to lower operating costs. Moreover, the high performance and reliability increase the project teams’ confidence and acceptance of GBTs.”

Table 4.21: Factors that influence GBT use

Factors	1	2	3	4	5	6	7	8	9
1. Increased efficiency			x	x	x			x	
2. Enhanced quality control		x							
3. Resilience to climate change	x	x				x	x	x	x
4. Performance enhancement	x		x	x	x	x	x	x	x

The foreman, procurement officer, health and safety officer, and artisan stated that GBTs had an environmental impact on the costing of the whole life cycle. The health and safety officer affirmed by saying, "GBTs have assisted in reducing the carbon footprint and promoting environmental conservation." Concurrently, the tender administrator and artisan stated that GBTs had an impact on health and well-being. Moreover, the two foremen, procurement officer, two tender administrators, and two artisans stated that GBTs had an influence on cost-saving and efficiency for the costing of the whole life cycle in the construction industry. The tender administrator said, "GBTs are vital for the reduction of energy consumption and improvement of indoor environmental quality. This improves the health and well-being of building occupants."

Table 4.22: Whole life cycle costing factors influenced by GBTs

Factors	1	2	3	4	5	6	7	8	9
1. Environmental impact	x	x	x	x					
2. Impact of health and well-being					x	x			
3. Cost-saving and efficiency	x	x			x	x	x	x	x

4.2.10. Perceived Ease of Use of Green Building Technologies by Project Teams

The two foremen, tender administrator, health and safety officer, and artisan stated that adoption rate assisted with incorporating GBTs in their firm. The foreman elaborated on this by saying, "Technical performance influences the adoption rate of GBTs, contributing to healthier indoor environments, boosting occupants' productivity." The two foremen, procurement officer, two tender administrators, two artisans, and health and safety officer stated that success stories and case studies had assisted with the introduction of GBTs in their firm. Furthermore, the artisan stated, "Through close monitoring and evaluation of construction

sites that have incorporated GBTs, our firm utilises them as continuous learning and development initiatives." The two foremen, procurement officer, two tender administrators, and three artisans stated that technical support and training had introduced GBTs to their firm. Concurrently, the procurement officer, two tender administrators, and artisan stated that learning curves were the preferred means to introduce GBTs in their firm. The two artisans and two tender administrators stated that it was the willingness to invest in GBTs by firms that helped their company to respond with ease. Moreover, the two foremen, procurement officer, two tender administrators, two artisans, and health and safety officer stated that awareness campaigns had helped their company to respond to the implementation of GBTs.

The foreman said, "Webinars and virtual training provide access to industry resources and best practice databases. This fosters collaboration with technology providers and suppliers and necessitates investment in training and upskilling."

Table 4.23: Factors that promoted GBT use in a firm

Factors	1	2	3	4	5	6	7	8	9
1. Adoption rate	x		x		x		x		x
2. Success stories and case studies	x	x	x	x		x	x	x	x
3. Technical support and training	x	x		x	x	x	x	x	x
4. Learning curve		x			x		x	x	
5. Willingness to invest					x	x	x		x
6. Awareness campaigns	x	x	x	x	x	x		x	x

The two foremen, procurement officer, two tender administrators, two artisans, and health and safety officer stated that user-friendly designs were used to incorporate GBTs in construction projects. The foremen affirmed this by saying, "GBTs affected our firm by necessitating training and upskilling of the project teams." The procurement officer, health and safety officer and tender administrator stated that the regulatory environment was used to incorporate the GBTs in the construction projects. The tender administrator stated, "The urge to comply with industry standards and certifications enabled the smooth transition to incorporation of GBTs by project teams." The two foremen, two tender administrators, three artisans, and health and safety officer responded that industry collaborations assisted in the incorporation of GBTs in the construction projects. The procurement officer stated, "Online modules and e-learning

enable collaboration with sustainability consultants and experts, which increases the uptake of GBTs by project teams."

Table 4.24: Various ways to enable ease of use of GBTs by project teams

Factors	1	2	3	4	5	6	7	8	9
1. User-friendly design	x	x	x	x		x	x	x	x
2. Regulatory environment		x			x				x
3. Industry collaborations	x		x	x	x	x	x	x	x

4.2.11. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies

The two foremen, procurement officer, health and safety officer, and tender administrator stated that the introduction of GBTs affected their company positively. However, the three artisans and the other tender administrators stated that GBTs affected their company negatively.

Table 4.25: Effect of GBTs on a company

Response	1	2	3	4	5	6	7	8	9
1. Positive	x	x	x	x					x
2. Negative					x	x	x	x	

The three artisans and the other tender administrators had a negative attitude towards technology. The artisan stated that: "The lack of knowledge of GBTs hinders us to improve our sustainability profile and project outcomes." However, the two foremen, procurement officer, health and safety officer, and tender administrator had a positive attitude towards technology. The tender administrator stated that: "The implementation of GBTs has driven us to adopt more sustainable practices company-wide." The foreman, tender administrator, and health and safety officer stated that GBTs had enabled their company to create jobs. The foreman stated that: "Through investment and development of new technologies, there is growth recognition of the benefits of GBTs and the upskilling of project teams."

Table 4.26: Factors introduced by GBTS into a company

Factors	1	2	3	4	5	6	7	8	9
1. Bad attitude towards technology					x	x	x	x	
2. Good attitude towards technology	x	x	x	x					x
3. Job Creation	x			x					x

4.2.12. Actual Usage of Green Building Technologies by Project Teams

The foreman, procurement officer, tender administrator, and artisan stated that they had worked with emerging technologies. Namely, these technologies are energy-efficient HVAC systems, SMART building systems, and high-efficiency insulation. The two foremen, two tender administrators, and three artisans stated that they had worked with GBTs that were compatible with existing systems. Namely, these technologies were solar panels, greywater systems, natural ventilation systems, and green roofs.

Table 4.27: Types of GBTs

Factors	1	2	3	4	5	6	7	8	9
1. Emerging technologies	x	x	x				x		
2. Compatible with existing systems	x		x	x	x	x		x	x

The two tender administrators, foreman, and artisan stated that GBTs had an impact on cost-effectiveness. The artisan stated that: “GBTs help in reducing waste and improving resource efficiency.” The two foremen, artisan, and health and safety officer stated that GBTs had environmental benefits for the overall performance of construction projects. The health and safety officer stated, “The essence of GBTs is to house environmentally responsible and resource-efficient buildings.” All respondents stated that GBTs had enhanced the performance of construction projects. The foreman stated that: “GBTs improve durability and resilience of buildings, leading to positive project outcomes and client satisfaction.” The two tender administrators, two foremen, a health and safety officer, and a procurement officer stated that GBTs improved the overall sustainable practices of construction projects. The procurement officer stated that: “Through the incorporation of energy-efficient systems and materials, long-term financial and environmental gains are considered.”

Table 4.28: Factors of overall performance improved by GBTs

Factors	1	2	3	4	5	6	7	8	9
1. Impact on cost-effectiveness			x			x	x		x
2. Environmental benefits	x		x		x		x		
3. Performance enhancement	x	x	x	x	x	x	x	x	x
4. Sustainable practices	x	x	x	x	x			x	

The two foremen, two tender administrators, a procurement officer, and an artisan stated that the regulatory environment set the standard to incorporate GBTs in the construction industry. The tender administrator stated that: "Our firm has been responding to the implementation of GBTs through compliance with the industry standards and certifications." The procurement officer stated that financial incentives set the standard in the construction industry. Concurrently, the procurement officer, artisan, and health and safety officer stated that the market demand set the standard in the construction industry. The procurement officer stated that: "Client demands, and sustainability goals provide standards that there is a need to incorporate GBTs within the construction industry. Moreover, subsidies need to be provided to SMMEs for them to be able to finance the implementation of GBTs."

Table 4.29: Factors that set the standards to increase use of GBTs

Factors	1	2	3	4	5	6	7	8	9
1. Regulatory environment	x		x		x	x	x		x
2. Financial incentives		x							
3. Market demand		x		x				x	

The two-tender administrator, foreman, and health and safety officer stated that the design team was included in the setting of specifications that include GBTs in the construction industry. However, the other foreman, procurement officer and three artisans stated that the construction team was included in the setting of specifications that include GBTs in the construction industry.

Table 4.30: Project team members who set specifications

Factors	1	2	3	4	5	6	7	8	9
1. Design team					x	x	x		x
2. Construction team	x	x	x	x				x	

Qualitative Case Study 4: Estate Development

The fourth case study was situated in Bloemfontein, Free State, South Africa. The case study incorporated an estate development construction comprising bulk excavations, sub-structure, super-structure, and civil works. The sample of this case study comprised project team members including artisans, a procurement officer, project managers, a quantity surveyor, an inventory manager, and a health and safety officer. A total of ten interviews was conducted.

4.2.13. Perceived Usefulness of Green Building Technologies by Project Teams

The two foremen, project manager, quantity surveyor, and two artisans stated that GBTs had increased efficiency within the construction industry. To affirm this, the project manager stated that: “The reliability of GBTs enhances the overall efficiency and success of projects”. The foreman, inventory manager, and quantity surveyor stated that GBTs had enhanced quality control within the construction industry. The inventory manager stated that: “GBTs help in waste reduction and improvement of resource efficiency by enforcing selection of sustainable material and technologies”. The foreman, two health and safety officers, a procurement officer, an inventory manager, a project manager, and an artisan stated that GBTs had increased the resilience of the construction industry to climate change. The foreman stated that: “GBTs include practices and technologies that assist in reducing the carbon footprint and promote environmental conservation”. The two foremen, project manager, quantity surveyor, two health and safety officers, and two artisans stated that GBTs had enabled the construction industry to undergo performance enhancement.

The artisan said, “GBTs enhance building performance and occupant comfort. This reduces the maintenance and operational issues.”

Table 4.31: Factors that influence the usefulness of GBTs

Factors	1	2	3	4	5	6	7	8	9	10
1. Increased efficiency	x	x		x	x				x	x
2. Enhanced quality control	x						x			x
3. Resilience to climate change	x		x	x		x		x	x	
4. Performance enhancement		x	x	x	x	x		x	x	x

The foreman, project manager, artisan, procurement officer and quantity surveyor stated that GBTs had improved the construction industry's environmental impact. The quantity surveyor affirmed this by saying, "GBTs are designed to make buildings more sustainable and environmentally friendly. This helps in the promotion of sustainability and reduction of the environmental impact." The foreman, project manager, health and safety officer, and artisan stated that GBTs had improved the construction industry's impact on health and well-being. The health and safety officer confirmed this by saying, "GBTs have a contribution to healthier indoor environments, boosting the productivity of occupants." The quantity surveyor, inventory manager, foreman, and procurement officer stated that GBTs had improved the construction industry's cost-saving and efficiency. The quantity surveyor said, "Through implementation of energy-efficient systems and practices, the construction industry has been enabled to reduce the operational costs and overall efficiency of projects."

Table 4.32: Whole life cycle costing factors

Factors	1	2	3	4	5	6	7	8	9	10
1. Environmental impact		x	x				x	x		x
2. Impact on health and well-being	x		x			x		x		
3. Cost-saving and efficiency		x		x	x				x	

4.2.14. Perceived Ease of Use of Green Building Technologies by Project Teams

The foreman, two artisans, inventory manager, and two health and safety officers stated that the adoption rate had enabled the introduction of GBTs in their firm. The inventory manager stated that: "The ongoing increase in implementation of GBTs has led to the firm being forced to introduce GBTs within our projects." The two foremen, project manager, quantity surveyor, and artisan stated that success stories and case studies had enabled the introduction of GBTs in their firm. The project manager affirmed this by stating, "GBTs have been introduced within

our firm by sharing best practices through successful projects and case studies used to better the implementation within our firm." The project manager, two artisans, two foremen, a quantity surveyor, and a health and safety officer stated that technical support and training had provided an opportunity for ease-of-use of GBTs to the project teams. The quantity surveyor said, "On-site training and field visits have enabled guidelines that alleviate technical challenges that may cause delays." The project manager, two artisans, two foremen, a quantity surveyor, and two health and safety officers stated that the learning curve had influenced the introduction of GBTs in their firm. The foreman stated, "Technical issues can cause delays. Therefore, through the ongoing progression of GBT implementation, these challenges can be picked up and mitigated through additional training." The inventory manager, procurement officer, foreman, artisan, and project manager stated that their company's willingness to invest in GBTs had enabled them to respond to GBTs. The inventory manager confirmed this by stating that: "The implementation of GBTs within our projects has necessitated training programmes for upskilling." The project manager, two artisans, and foreman stated that awareness campaigns had enabled their company to respond to GBTs. The foreman stated that: "The firm has provided company-wide sustainability programmes to alleviate the lack of knowledge of the usefulness of GBTs within the construction industry."

Table 4.33: Factors that lead to the introduction of GBTs in a firm

Factors	1	2	3	4	5	6	7	8	9	10
1. Adoption rate	x		x		x		x		x	x
2. Success stories and case studies	x	x	x			x	x			
3. Technical support and training		x		x	x	x		x	x	x
4. Learning curve	x		x	x	x	x	x	x	x	x
5. Willingness to invest	x	x			x		x		x	
6. Awareness campaigns				x		x	x	x		

All respondents stated that user-friendly design had enabled the implementation of GBTs in the construction industry. The project manager stated that: "GBTs have been incorporated through on-site demonstrations and pilot projects. This provides a more hands-on and practical demonstration for project teams." The procurement officer, inventory manager, and artisan stated that the regulatory environment had enabled the implementation of GBTs in the construction industry. The artisan stated that: "The environmental impact assessment and project specification forces the project teams to implement GBTs within the projects."

Table 4.34: Factors that lead to the incorporation of GBTs in construction projects

Factors	1	2	3	4	5	6	7	8	9	10
1. User-friendly design	x	x	x	x	x	x	x	x	x	x
2. Regulatory environment			x		x		x			

4.2.15. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies

The two foremen, two health and safety officers, a project manager, a quantity surveyor, and two artisans stated that the implementation of GBTs had affected their firm positively. However, the inventory manager and procurement officer stated that the implementation of GBTs had affected their firm negatively.

Table 4.35: Effect of GBTs on a company

Response	1	2	3	4	5	6	7	8	9	10
1. Positive	x	x			x	x	x	x	x	x
2. Negative			x	x						

The inventory manager and procurement officer had a negative attitude towards GBTs. The procurement officer stated that: “The equipment is expensive, and training is costly, hindering us from reaching the sustainability targets.” However, the two foremen, two health and safety officers, a project manager, a quantity surveyor, and two artisans had positive attitudes towards GBTs within their firm. “The implementation of GBTs in our firm has necessitated investment in training and upskilling of project teams.” The two artisans and foreman stated that GBTs had enabled their company to create jobs. The artisan affirmed this by stating, “The implementation of these GBTs is labour-intensive and the company invests well. Therefore, it enables us to provide employment to the community.” The quantity surveyor stated that GBTs had assisted their company with economic benefits. “Due to GBTs providing healthier indoor environments and boosting occupant productivity, it has led to an increase in client demand.”

Table 4.36: Factors introduced by the use of GBTs

Factors	1	2	3	4	5	6	7	8	9	10
1. Negative attitude towards technology			x	x						
2. Positive attitude towards technology	x	x			x	x	x	x	x	x
3. Job creation	x					x	x			
4. Economic benefits	x									

4.2.16. Actual Usage of Green Building Technologies by Project Teams

The foreman, quantity surveyor, procurement officer, and artisan stated that they had worked with GBTs that were still emerging. These technologies were solar shading devices, geothermal heating systems, recycled building materials, and SMART building systems. However, the two foremen, two artisans, quantity surveyor, project manager, and inventory manager stated that they had worked with GBTs that were compatible with existing systems. These technologies were LED lighting, green roofs, double-glazed windows, wind turbines, and solar water heaters.

Table 4.37: Types of GBTs in the construction industry

Factors	1	2	3	4	5	6	7	8	9	10
1. Emerging technologies	x		x		x		x			
2. Compatible with existing systems	x	x		x		x		x	x	x

The foreman, quantity surveyor, and artisan stated that GBTs had improved the impact on the cost-effectiveness of the overall construction projects. “The advancement in green technology and innovation has led to the incorporation of renewable energy solutions in project designs which provides lower operating costs and resource efficiency”. The foreman, project manager, inventory manager, procurement officer, and artisan stated that GBTs had improved the environmental benefits for the overall performance of construction projects. The procurement officer affirmed by stating that: “The implementation of GBTs has led to the promotion of sustainability and a significant reduction of environmental impact by the construction industry”. The foreman, project manager, quantity surveyor, two artisans, and procurement officer stated that sustainable practices had been enhanced by GBTs. The foremen said, “The implementation of GBTs has increased the demand for sustainable and eco-friendly buildings.” The two foremen, the project manager, two artisans, a quantity surveyor, a procurement officer,

and an inventory officer stated that GBTs had enhanced the overall performance of construction projects. The project manager said, “The essence of GBTs within the construction industry provides an improvement of the overall performance of buildings from inception to monitoring.”

Table 4.38: Factors that improve overall performance on construction projects by project teams

Factors	1	2	3	4	5	6	7	8	9	10
1. Impact on cost-effectiveness	x						x		x	
2. Environmental benefits	x		x		x	x		x		
3. Performance enhancement		x	x	x	x	x		x	x	x
4. Sustainable practices		x	x		x		x		x	x

The two foremen, a project manager, an artisan, a quantity surveyor, a procurement officer, and an inventory officer stated that the design team was involved in the process of setting the specifications of construction projects within the construction industry. However, the foreman, two health and safety officers, and an artisan stated that the construction team was involved in the process of setting the specifications of construction projects within the construction industry.

Table 4.39: Project team members who set specifications for GBTs

Response	1	2	3	4	5	6	7	8	9	10
1. Design team	x	x	x			x	x	x	x	
2. Construction team		x		x	x					x

Qualitative Case Study 5: Commercial Development

The fifth case study was situated in Bloemfontein, Free State, South Africa. The case study incorporated a restaurant construction comprising bulk excavations, sub-structure, super-structure, and civil works. The sample of this case study comprised project team members, including artisans, project managers, quantity surveyors and health and safety officers. A total of ten interviews was conducted.

4.2.17. Perceived Usefulness of Green Building Technologies by Project Teams

The project manager, quantity surveyor, foreman, and two artisans stated that GBTs increased efficiency within the construction industry. The project manager affirmed by stating, "GBTs increase efficiency, leading the project to run smooth without delay." The buyer, quantity surveyor, project manager, and two artisans stated that GBTs enhanced quality control. The quantity surveyor stated that: "The quality of material is controlled through including a sustainability criterion within the project specifications". The contract administrator, health and safety officer, foreman and two artisans stated that GBTs enhanced the resilience of the construction industry to climate change. "GBTs create buildings which are environmentally responsible and resource efficient". The project manager, quantity surveyor, foreman, contract administrator, health and safety officer, and artisan stated that GBTs had enabled performance enhancement within the construction industry. The artisan stated, "GBTs have encouraged innovation and adoption of best practices which promote sustainable building practices that improve the overall quality of projects."

Table 4.40: Factors influenced by GBTs

Factors	1	2	3	4	5	6	7	8	9	10
1. Increased efficiency			x	x	x	x		x		
2. Enhanced quality control			x	x			x		x	x
3. Resilience to climate change	x	x		x					x	x
4. Performance enhancement		x	x	x	x	x	x			

The project manager, quantity surveyor, and foreman stated that GBTs had improved the impact of health and well-being within the construction industry. The project manager, foreman, quantity surveyor, health and safety officer, three artisans and buyer stated that GBTs improved cost-saving and efficiency within the construction industry.

The quantity surveyor said, "GBTs have improved the health and well-being of occupants. They are vital for the reduction of energy consumption and improving indoor environmental quality. This lowers the operating costs,"

Table 4.41: Whole life cycle costing factors

Factors	1	2	3	4	5	6	7	8	9	10
1. Impact of health and well-being	x		x	x						
2. Cost-saving and efficiency	x	x	x		x	x		x	x	x

4.2.18. Perceived Ease of Use of Green Building Technologies by Project Teams

The project manager, quantity surveyor, foreman, and two artisans stated that the adoption rate influenced the firm to incorporate GBTs. “Through collaboration with technology providers and suppliers, the firm could see the rate of implementation of GBTs and saw it necessary to start implementing them in their projects,” said the project manager. The buyer, quantity surveyor, project manager, and two artisans stated that the learning curve had influenced the firm to incorporate GBTs. The buyer stated that: “Webinars and virtual training sessions provide learning curves of what mistakes not to repeat within our implementation of GBTs”. The contract administrator and project manager stated that success stories and case studies were used to incorporate GBTs within the firm. “Collaboration within industry experts and consultants enabled access to case studies and success stories that prepared us to alleviate the lack of knowledge of GBTs,” said the contract administrators. The project manager, foreman, quantity surveyor, health and safety officer, four artisans, and buyer stated that technical support and training were used to enable GBT usage within the firm. The artisan stated, “The mentorship and guidance from experienced professionals have enabled us to incorporate GBTs within our projects with ease.” The health and safety officer, buyer, contract administrator, and foreman stated that user-friendly designs were used to ensure ease of use of GBTs. The project manager, foreman, quantity surveyor, health and safety officer, four artisans, and contract administrator stated that the willingness of the firm to invest in GBTs enabled them to respond to the use of GBTs. The project manager, foreman, and quantity surveyor stated that awareness campaigns enabled the firm to respond to the incorporation of GBTs within the firm.

The project manager said, “Through industry conferences and seminars, collaboration with experienced professionals with the implementation of GBTs. This enabled a diverse spectrum of knowledge on the ease of use of GBTs within the industry. It also alleviated the lack of knowledge of project teams on the usefulness of GBTs, influencing the actual usage.”

Table 4.42: Factors that lead to the introduction of GBTs in firms

Factors	1	2	3	4	5	6	7	8	9	10
1. Adoption rate	x			x				x	x	x
2. Success stories and case studies					x		x			
3. Technical support and training		x	x		x	x	x	x	x	x
4. Learning curve						x	x	x	x	x
5. Willingness to invest	x	x		x	x	x	x	x	x	x
6. Awareness campaigns			x			x			x	

The project manager, foreman, quantity surveyor, health and safety officer, three artisans, and buyer stated that user-friendly designs were used to incorporate GBTs in construction projects. The project manager stated that: “The company has provided us with more hands-on site experience, which enabled us to get first-hand experience with the GBTs”. The project manager, foreman, quantity surveyor, health and safety officer, and contract administrator stated that the regulatory environment was used to incorporate GBTs in construction projects. The foreman stated that: “The firm has enabled us to implement GBTs within projects by integrating them into the project life cycle from the inception, following the company policies and best practices in sustainability”. The buyer and two artisans stated that industry collaborations were used to incorporate GBTs in construction projects. The buyer stated that: “Technical issues can cause delays. Therefore, collaboration with industry experts provides guidance as a source of additional training".

Table 4.43: Factors that lead to the incorporation of GBTs in construction projects

Factors	1	2	3	4	5	6	7	8	9	10
1. User-friendly design	x	x	x	x		x		x	x	x
2. Regulatory environment	x	x		x	x		x			
3. Industry collaborations						x		x	x	

4.2.19. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies

The project manager, foreman, quantity surveyor, health and safety officer, three artisans and buyer stated that GBTs affected their firm positively. However, the contract administrator and artisan stated that GBTs affected their firm negatively.

Table 4.44: Effect of GBTs on a company

Response	1	2	3	4	5	6	7	8	9	10
1. Positive	x	x		x	x	x	x	x	x	
2. Negative			x							x

The contract administrator and artisan stated that they had a negative attitude towards technology. The artisan affirmed this by saying, "There is a need for training and upskilling, but there is no capital to reach that." However, the project manager, foreman, quantity surveyor, health and safety officer, three artisans, and buyer stated that they had a positive attitude towards technology. The quantity surveyor confirmed this by saying, "GBTs have encouraged innovation and best practices through continuous improvement with regard to sustainability." The project manager, foreman, and artisan stated that GBTs had increased the job creation aspect within their firm. The project manager, foreman, quantity surveyor, and artisan stated that GBTs enabled their firm to receive economic benefits. The foreman affirmed by stating that: "The investments in GBTs have enabled our subcontractors to create employment opportunities for labourers due to the implementation of GBT being labour-intensive."

Table 4.45: Factors influenced by GBTs

Factors	1	2	3	4	5	6	7	8	9	10
1. Negative attitude towards technology			x							x
2. Positive attitude towards technology	x	x		x	x	x	x	x	x	
3. Job creation		x		x			x			
4. Economic benefits	x	x		x				x		

4.2.20. Actual Usage of Green Building Technologies by Project Teams

The buyer and artisan stated that they had worked with emerging technologies. These technologies were photovoltaic cells and energy-efficient HVAC systems. The project manager, foreman, quantity surveyor, health and safety officer, three artisans and contract administrator stated that they had worked with technologies that were compatible with existing systems. These technologies were solar panels, low-flow plumbing fixtures, solar water heaters, and energy-efficient lighting.

Table 4.46: Types of GBTs

Factors	1	2	3	4	5	6	7	8	9	10
1. Emerging Technologies						x		x		
2. Compatible with existing systems	x	x	x	x	x		x		x	x

The project manager, buyer, quantity surveyor, and two artisans stated that GBTs had improved the overall impact on the cost-effectiveness of construction projects. The artisan stated, "GBTs lead to improvement of overall performance through long-term cost-savings and better environmental performance." The project manager, foreman, contract administrator, and artisan stated that GBTs had improved the environmental benefits of construction projects. The foreman stated, "The reliability of GBTs improves project outcomes and sustainability goals." The foreman, contract administrator, buyer, quantity surveyor, health and safety officer, and two artisans stated that GBTs had improved the overall performance enhancement of construction projects. The quantity surveyor, foreman, and three artisans stated that GBTs improved the overall performance of sustainable practices.

The project manager said, "GBTs incorporate methods and materials that ensure buildings are more eco-friendly. They are vital for the sustainable development of the construction industry as they enhance the sustainability and marketability of buildings,"

Table 4.47: Factors that improve the overall performance of GBTs on construction projects

Factors	1	2	3	4	5	6	7	8	9	10
1. Impact on cost-effectiveness	x			x		x			x	x
2. Environmental benefits	x	x	x					x		
3. Performance enhancement		x	x	x	x	x	x			
4. Sustainable practices					x	x	x	x		x

The project manager, contract administrator, health and safety officer, and four artisans stated that the regulatory environment set the standards that incorporate GBTs within the construction industry. The artisan stated that: "The inclusion of sustainability criteria in project specifications enhanced the implementation of GBTs". The quantity surveyor stated that financial incentives set the standards to incorporate GBTs within the construction industry. The

foreman, contract administrator, quantity surveyor, and artisan stated that the market demand set the standards to incorporate GBTs within the construction industry.

The contract administrator said, “More collaboration and knowledge-sharing with the industry professionals is essential because it can influence the company policies and best practices. This covers the broader spectrum of market trends and provides a competitive advantage to the firm,”

Table 4.48: Factors that set the standards for the incorporation of GBTs

Factors	1	2	3	4	5	6	7	8	9	10
1. Regulatory environment	x		x		x		x	x	x	x
2. Financial incentives						x				
3. Market demand		x		x		x	x			

The project manager, quantity surveyor, foreman, health and safety officer, and four artisans stated that the design team set the specifications of GBTs to be included in construction projects. However, the buyer, contract administrator, health and safety officer, and artisan stated that the construction team set the specifications of GBTs to be included in construction projects.

Table 4.49: Project team members who set specifications

Factors	1	2	3	4	5	6	7	8	9	10
1. Design team	x			x	x	x	x	x	x	x
2. Construction team		x	x		x		x			

4.3. Interpretation of Focus Group Findings

4.3.1. Perceived Usefulness of Green Building Technologies by Project Teams

The project manager, two contract administrators, a quantity surveyor, a procurement officer, and two tender administrators stated that GBTs affected the construction industry through increasing efficiency. The project manager, two contract administrators, two quantity surveyors, a foreman, and a tender administrator stated that GBTs affected the construction industry through enhancing quality control. The quantity surveyor alluded, “The essence of

GBTs is to house environmentally responsible and resource-efficient infrastructures through encouraging the use of sustainable materials and construction practices." The project manager, two contract administrators, two quantity surveyors, two foremen, and a procurement officer stated that GBTs had helped the construction industry to be resilient to climate change. The project manager, two contract administrators, two quantity surveyors, two foremen, two procurement officers, and a tender administrator stated that GBTs had enhanced the performance of the construction industry.

The tender administrator alluded, "GBTs are reliable technologies that contribute to positive project outcomes and client satisfaction through improving the durability and resilience of infrastructures."

Table 4.50: Factors affected by the use of GBTs in the construction industry

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Increased efficiency	x	x	x	x						x	x	x
2. Enhanced quality control	x	x	x	x	x			x				x
3. Resilience to climate change	x	x	x	x	x	x	x		x			
4. Performance enhancement	x	x	x	x	x	x	x	x	x	x		x

The project manager, contract administrator, quantity surveyor, foreman, and tender administrator stated that GBTs affected the whole-life costing of construction industry through alleviating the environmental impact. The two foremen, a procurement officer, and tender administrator stated that the impact of health and well-being was affected positively by GBTs. The contract administrator, two quantity surveyors, two foremen, two procurement officers, and a tender administrator stated that GBTs enabled the project teams to achieve cost-saving and efficiency.

The foreman said, "The essence of GBTs is their vitality in reducing energy consumption and improving indoor environmental quality. This fosters an improvement for the health and well-being of occupants due to their contribution to healthier indoor environments, boosting productivity."

Table 4.51: Whole life cycle costing factors introduced by GBTs

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Environmental impact	x	x		x			x					x
2. Impact of health and well-being						x		x		x		x
3. Cost-saving and efficiency			x	x	x	x	x		x	x	x	

4.3.2. Perceived Ease of Use of Green Building Technologies by Project Teams

The contract administrator, two quantity surveyors, two foremen, and two procurement officers stated that the adoption rate introduced GBTs into their firm because they did not want to be left behind. “Due to the market trends and competitive advantage considerations, the firm saw the need to necessitate investment in training and upskilling in relation to GBTs,” affirmed the procurement officer. The contract administrator, two quantity surveyors, a foreman, and a procurement officer stated that success stories and case studies introduced GBTs into their firm. The foreman confirmed by stating, “Through industry conferences and seminars, collaboration with industry experts and consultants has been fostered, enabling access to case studies and success stories of GBTs.” The project manager, contract administrator, quantity surveyor, two foremen, a procurement officer, and two tender administrators stated that GBTs were introduced into their firm through technical support and training. The project manager stated that: “Mentorship and guidance from industry professionals enabled us to see the necessity of training programmes in relation to staying up to date with current trends”. The two contract administrators, two foremen, two procurement officers, and a tender administrator stated that user-friendly designs enabled them to introduce GBTs into their firm. The two contract administrators, two foremen, and a procurement officer stated that learning curves enabled the introduction of GBTs within their firm.

Table 4.52: Factors that lead to the introduction of GBTs in construction firms

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Adoption rate			x	x	x	x		x	x	x		
2. Success stories and case studies			x	x	x	x				x		
3. Technical support and training	x	x		x		x	x		x		x	x
4. User-friendly design		x	x			x		x	x	x	x	
5. Learning curve		x	x		x		x			x		

The project manager, two contract administrators, a quantity surveyor, three foremen, a procurement officer, and a tender administrator stated that their firm used user-friendly designs to incorporate GBTs in their construction projects. The project manager affirmed that by stating, "In-house training programmes and development workshops have provided project teams with guidelines on how to implement GBTs." The quantity surveyor, procurement officer and tender administrator stated that the regulatory environment was used to incorporate GBTs within their construction projects. The tender administrator confirmed this by saying, "GBTs are easily implemented into construction projects when the specification in the designs enforces the project team to incorporate sustainable material and green technology." The contract administrator, foreman, procurement officer, and tender administrator stated that the industry collaboration in various projects enables the incorporation of GBTs. The foreman stated, "Through employing sustainability experts and consultants, monitoring of consistent performance can enable the reduction of maintenance and operational issues." The project manager, quantity surveyor, three foremen, and a procurement officer stated that the willingness to invest and awareness campaigns in GBTs enabled the incorporation in construction projects. The project manager stated that: "The company was able to respond to the implementation of GBTs in the construction industry by promoting awareness and education of GBTs to project teams."

Table 4.53: Factors that lead to the incorporation of GBTs in construction projects

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. User-friendly design	x	x	x		x	x	x	x		x	x	
2. Regulatory environment				x					x		x	
3. Industry collaborations			x			x				x		x
4. Willingness to invest	x			x	x	x	x			x		
5. Awareness Campaigns			x		x	x		x	x	x		

4.3.3. Attitude and Behavioural Intentions of Project Teams Regarding Green Building Technologies

The contract administrator, quantity surveyor, three foremen, two procurement officers, and two tender administrators stated that the introduction of GBTs affected their firm positively. However, the project manager, contract administrator and quantity surveyor stated that the introduction of GBTs affected their firm negatively.

Table 4.54: Effect of GBTs on a company

Response	1	2	3	4	5	6	7	8	9	10	11	12
1. Positive		x			x	x	x	x	x	x	x	x
2. Negative	x		x	x								

The project manager, contract administrator and quantity surveyor stated that they had a negative attitude towards GBTs. The project manager stated, "Due to a lack of investment in research and development for new technologies, we tend to be left behind." In contrast, the contract administrator, quantity surveyor, three foremen, two procurement officers, and two tender administrators stated that they had a positive attitude towards GBTs. The foreman stated that: "GBTs improved the quality of projects and client satisfaction". The quantity surveyor, three foremen, and a procurement officer stated that GBTs had opened job creation within their firm. The quantity surveyor stated, "The training and upskilling of project teams have enabled them to broaden their expertise and not remain stagnant." The quantity surveyor, two foremen, and two procurement officers stated that GBTs had provided their firm with economic benefits. The procurement officer stated that: "GBTs improve durability and resilience of infrastructures; this provides a competitive advantage within the market trends". The contract administrator, quantity surveyor, two foremen, and a procurement officer stated that the willingness to invest in GBTs had enabled their firm to progress smoothly.

Table 4.55: Factors introduced by GBTs

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Negative attitude towards technology	x		x	x								
2. Positive attitude towards technology		x			x	x	x	x	x	x	x	x
3. Job creation					x	x	x	x	x			
4. Economic benefits					x	x		x	x	x		
5. Willingness to invest		x			x	x	x			x		

The project manager, contract administrator, two procurement officers, and tender administrator stated that the GBTs with which they had worked were emerging technologies. These technologies were SMART building systems, high-efficiency insulation, and recycled building materials. However, the contract administrator, two quantity surveyors, three foremen,

and a tender administrator stated that the GBTs with which they had worked were compatible with existing systems. These technologies included solar shading devices, wind turbines, double-glazed windows, greywater recycling systems, and natural ventilation.

Table 4.56: Types of GBTs

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Emerging technologies	x		x						x	x		x
2. Compatible with existing systems		x		x	x	x	x	x	x		x	

The project manager, contract administrator, quantity surveyor, foreman, and procurement officer stated that GBTs improved the overall impact on cost-effectiveness for construction projects. The procurement officer confirmed by stating, “GBTs are vital due to their reduction in energy consumption and improving indoor environmental quality; this lowers the operating cost of the infrastructure.” The two contract administrators, a quantity surveyor, two foremen, two procurement officers, and the tender administrator stated that GBTs improved the overall environmental benefits of construction projects. The contract administrators stated, "Through compliance with GB standards and certifications, our firm has lowered their impact on carbon footprint and GHG emission.” The project manager, contract administrator, quantity surveyor, two supervisors, procurement officer, and two tender administrators stated that GBTs improved the overall performance of construction projects. The foreman affirmed this by stating, "The technical performance influences the adoption rate of these GBTs.” The project manager, contract administrator, quantity surveyor, two foremen, two procurement officers, and the tender administrator stated that GBTs enabled project teams to implement sustainable practices in the construction industry.

Table 4.57: Factors improved by GBTs

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Impact on cost-effectiveness	x		x		x			x		x		
2. Environmental benefits		x	x		x		x	x	x	x	x	
3. Performance enhancement	x	x		x		x	x		x		x	x
4. Sustainable practices	x		x	x		x	x		x	x	x	

The project manager, contract administrator, two quantity surveyors, two foremen, and the procurement officer stated that the regulatory environment set the standards to incorporate green building technologies within the construction industry. The contract administrator said, "Through the constant monitoring of sustainability certifications and rating systems, our projects have managed to develop infrastructures that offer healthier indoor environments, boosting occupant productivity." The contract administrator and procurement officer stated that financial incentives set the standards for incorporating GBTs within the construction industry. The contract administrator, two foremen, two procurement officers, and the tender administrator stated that market demand set the standards to incorporate GBTs within the construction industry.

The procurement officer said, "The market demand for GBs is increasing, which is positive. The government should provide financial incentives to help finance the implementation of GBTs by the construction industry project teams,"

Table 4.58: Factors that set standards

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Regulatory environment	x		x	x	x	x	x	x		x		
2. Financial incentives		x							x			
3. Market demand			x				x	x	x	x		x

The project manager, two contract administrators, two quantity surveyors, two foremen, a procurement officer, and a tender administrator stated that the design team included the project team members who were responsible for setting the specifications to include GBTs in construction projects. However, the foreman, procurement officer, and tender administrator stated that the construction team was responsible for setting the specifications.

Table 4.59: Project team members who set specifications

Factors	1	2	3	4	5	6	7	8	9	10	11	12
1. Design team	x	x	x	x	x		x	x		x		x
2. Construction team						x			x		x	

4.4. Hypothesis Testing and Thematic Synthesis of Qualitative Findings on GBT Adoption Using TAM

4.4.1. Synthesis of Case Study Findings

The study hypothesizes that: "The adoption of Green Building Technologies (GBT) in the South African construction industry is significantly influenced by project teams' perceived usefulness, perceived ease of use, attitudes, and behavioural intentions, as articulated in the Technology Acceptance Model (TAM)." It further posits that organizational, regulatory, and market factors moderate these relationships. Across the five qualitative case studies that encompass of commercial, road, township, estate, and restaurant development projects, semi-structured interviews and focus group discussions consistently revealed the following:

- *Perceived Usefulness*: Project teams widely commended GBTs for enhancing efficiency, quality control, the resilience to climate change, and overall project performance. Cost savings and environmental benefits were highlighted by project teams, with many participants noting long-term operational efficiencies and improved occupant health and well-being.
- *Perceived Ease of Use*: Although teams differed in how easily they could implement GBTs, user-friendly design, strong technical support, and thorough training were highlighted as essential factors that enabled adoption. Learning curves and the presence of supportive regulatory environments further influenced the adoption rates.
- *Attitudes and Behavioural Intentions*: Most participants expressed positive attitudes toward GBTs, linking their adoption to job creation, economic benefits, and improved marketability. However, a few projected team members mentioned unfavourable attitudes, often related to cost, lack of knowledge, or insufficient training.
- Actual Usage: Prominent levels of engagement with both emerging and compatible GBTs were reported. Adoption was more prevalent in organizations with strong sustainability commitments and access to success stories or case studies demonstrating tangible benefits.

4.4.2. Thematic Analysis

The qualitative data gathered several main themes and sub-themes following GBT adoption:

- Main Themes:
- Efficiency and Performance Enhancement: GBTs were recommended for streamlining processes, reducing waste, and optimizing resource use, leading to faster completion and higher quality outcomes.
- Quality Control: Improved monitoring and management enabled adherence to standards and specifications.

- Resilience and Sustainability: Adoption of GBTs promoted buildings' ability to withstand climate extremes and reduced environmental footprints.
- Attitudinal Dispositions: Positive attitudes fostered greater adoption, while resistance often stemmed from perceived complexity or cost.
- Cost-Effectiveness: Both immediate and lifecycle savings were considered, with economic viability influencing intent to adopt.

Sub-Themes:

- Technical Support and Training: The access to ongoing support and structured training programs was essential for overcoming learning curves and ensuring effective implementation.
- Regulatory Environment: Compliance with standards, certifications, and favourable policies enabled GBT uptake.
- User-Friendly Design: Simplicity and intuitiveness in technology design reduced the resistance and promoted engagement.
- Market Demand: Client requirements and broader sectoral trends affected organizational adoption strategies.
- Financial Incentives: Subsidies, grants, and internal investment in upskilling increased adoption, especially among small and medium enterprises.
- Awareness Campaigns and Success Stories: Sharing positive outcomes and best practices encouraged broader acceptance within firms and across the industry.

4.4.3. Cross-Case Comparison

While all case studies highlighted the core TAM constructs as influential, some differences emerged:

- Organizational Context: Larger, sustainability-driven firms reported smoother GBT integration, attributed to greater resources for training and technical support. However, smaller firms or those with limited exposure to success stories faced steeper learning curves and more resistance.
- Project Type: Commercial and estate developments emphasized client-driven demand and regulatory compliance, whereas township and road projects highlighted public sector policies and community benefits.
- Barriers: Across cases, resistance was linked to costs (upfront investment and training), knowledge gaps, and perceived complexity. These barriers were related more to less exposure to technical support or unclear regulatory mandates.
- Enablers: Consistent across all cases were the positive roles of technical support, user-friendly design, and visible financial or market incentives in driving adoption and favourable attitudes.

4.4.4. Hypothesis Evaluation

The qualitative evidence robustly supports the study's hypothesis. Project teams' perceptions of usefulness and ease of use are core TAM constructs that emerged as decisive factors in shaping attitudes, behavioural intentions, and actual adoption of GBTs. The positive attitudes were reinforced where technical support, regulatory clarity, and financial incentives were present. Conversely, the hypothesis is challenged in contexts where these enablers were absent, and cost or knowledge barriers predominated, leading to negative attitudes and lower adoption rates. The evidence also affirms the moderating influence of organizational, regulatory, and market factors, as hypothesized.

4.5. Chapter Summary

In this chapter, the results of the study about adopting GBTs using TAM were discussed. The perceived usefulness of GBTs in improving efficiency, quality control, and resilience to climate change was widely recognised. In addition, the ease-of-use factors, such as user-friendly design and technical support, played a vital role in promoting the adoption of GBTs. The attitudes of project teams toward GBTs were positive, even though challenges remain, particularly regarding learning curves and financial concerns. Based on the study, to increase the adoption of GBTs, implementing technical support, providing financial incentives, and improving the regulatory framework are recommended. The factors align with TAM and significantly influence the adoption of GBTs. Through addressing these factors, the construction industry in South Africa can leverage GBTs better to create more sustainable, resilient buildings. The cross-case synthesis affirms that successful GBT adoption in the South African construction sector is contingent upon addressing both individual and contextual factors articulated in TAM. Facilitating technical support, simplifying technology interfaces, strengthening regulatory frameworks, and providing financial and knowledge-based incentives are critical. Future research should further explore interventions for reducing learning curves and expanding access to success stories, particularly among smaller firms. For practitioners, prioritizing training, regulatory compliance, and awareness initiatives will be essential for mainstreaming GBTs and advancing industry sustainability goals.

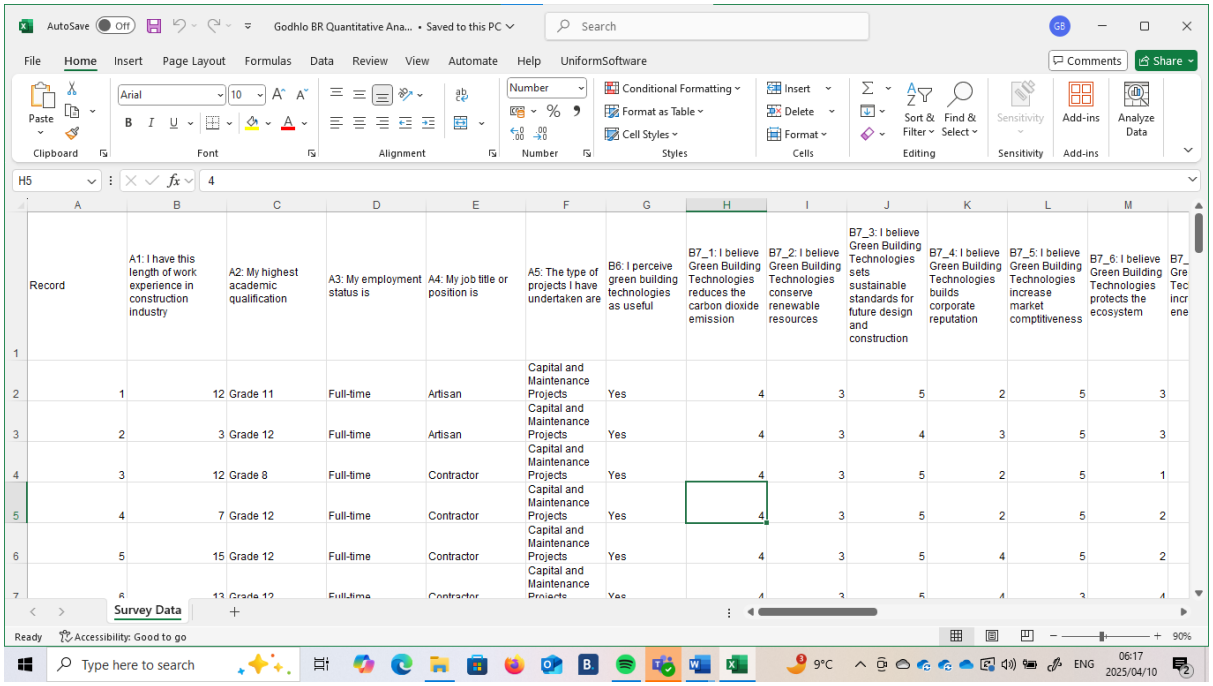
Chapter 5: Quantitative Results and Analysis

5.1. Introduction

In this chapter, the findings of the study about using TAM provide enhancement of the adoption of GBTs within the South African construction industry are presented and discussed. The study aimed at understanding and increasing the acceptance and implementation of these technologies by evaluating the perceived usefulness, ease of use, attitudes, and behavioural intentions of project teams regarding GBTs. The data were collected using survey questionnaires distributed to project teams who had experience with GBTs. In this chapter, findings are presented systematically that provide insights into how TAM can be applied effectively to promote GBTs in South Africa.

5.2. Survey Analysis

The analysis of the data obtained from the survey questionnaire had a two-step process involving Microsoft Excel and the Statistical Package for the Social Science (SPSS) Statistical Software. Initially, the completed surveys were compiled and organised in Microsoft Excel, as illustrated in Figure 5.1. This required inputting the raw data from the questionnaires completed by various project teams, who were knowledgeable about the use of GBTs, into the spreadsheet. The data were cleaned and formatted to ensure consistency and accuracy.



Record	A1: I have this length of work experience in construction industry	A2: My highest academic qualification	A3: My employment status is	A4: My job title or position is	A5: The type of projects I have undertaken are	B6: I perceive green building technologies as useful	B7_1: I believe Green Building Technologies reduces the carbon dioxide emission	B7_2: I believe Green Building Technologies conserve renewable resources	B7_3: I believe Green Building Technologies sets sustainable standards for future design and construction	B7_4: I believe Green Building Technologies builds corporate reputation	B7_5: I believe Green Building Technologies increase market comptitiveness	B7_6: I believe Green Building Technologies protects the ecosystem
1	12	Grade 11	Full-time	Artisan	Capital and Maintenance Projects	Yes	4	3	5	2	5	3
2	3	Grade 12	Full-time	Artisan	Capital and Maintenance Projects	Yes	4	3	4	3	5	3
3	12	Grade 8	Full-time	Contractor	Capital and Maintenance Projects	Yes	4	3	5	2	5	1
4	7	Grade 12	Full-time	Contractor	Capital and Maintenance Projects	Yes	4	3	5	2	5	2
5	15	Grade 12	Full-time	Contractor	Capital and Maintenance Projects	Yes	4	3	5	4	5	2

Figure 5.1: Illustration of data organisation in Excel

Once the data were organised in Excel, they were exported to SPSS for detailed statistical analysis. SPSS was used to perform statistical tests and analyses to extract meaningful insights from the survey responses. This included descriptive statistics to summarise the data and inferential statistics to identify patterns and correlations. The SPSS results provided valuable insights into the responses from project teams. SPSS provided descriptive statistics such as means, medians, and standard deviations that were calculated to provide insight into the general trends and central tendencies of the data. In addition, inferential analyses, such as correlation and regression analyses, were conducted to explore the relationships between different variables related to GBTs. The combination of Excel and SPSS allowed for a thorough examination of the survey data, providing key findings and trends. These insights were essential for understanding the perspectives of project teams on GBTs and are discussed further in the subsequent sections of this dissertation.

5.3. Response Rate

After the questionnaire was finalised, it was distributed to project team members with expertise in GBTs. The survey was conducted over approximately 20 weeks. Out of 100 questionnaires

sent, 87 were returned with valid responses, equating to a response rate of 87%, as shown in Figure 5.2 below.

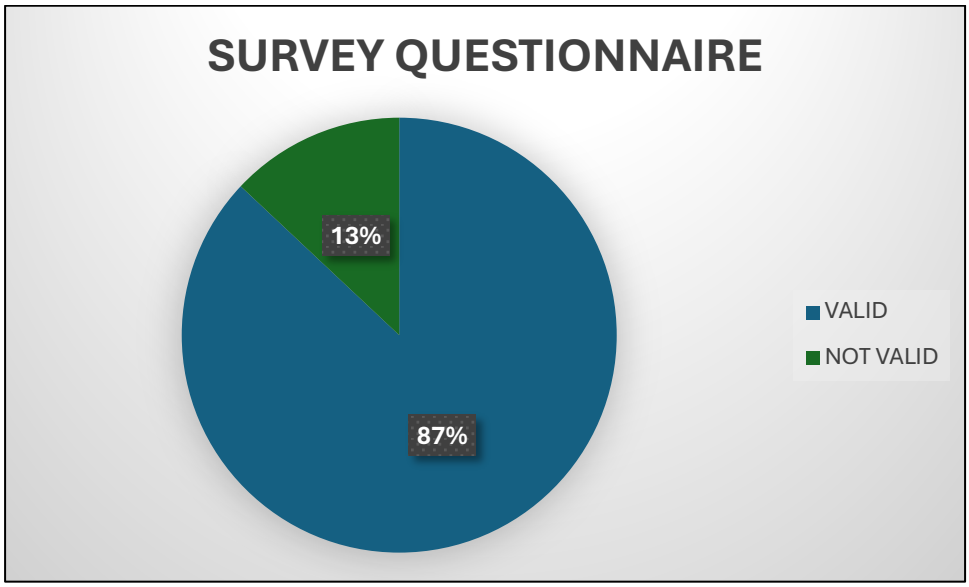


Figure 5.2: Pie chart showing response rate

The high response rate indicated a strong engagement level among the participants and provided a robust dataset for analysis. The validity of the responses further enhanced the reliability of the data derived from this survey.

5.4. Demographic Information

5.4.1. Qualification

Table 5.1 shows the distribution of qualifications among the survey respondents, of whom 18.4% qualified for Grade 12. This indicated a small proportion of respondents without formal high school education, highlighting a foundational level of educational background in the survey sample. Holding a Grade 12 qualification was reported by 28.7% of respondents. This group represented the most significant portion of the sample, suggesting that many respondents possessed at least a high school diploma. Post-matric certificates or diplomas had been completed by 11.5% of the respondents. This category reflected those who were pursuing additional qualifications beyond high school, although it constituted a smaller segment than those with Grade 12 qualifications. Undergraduate degrees were held by 28.7% of respondents.

This proportion was equivalent to those with a Grade 12 qualification, indicating that most respondents had attained higher education degrees. Post-Graduate qualifications were possessed by 12.6% of the respondents. This group represented individuals who had pursued further academic advancement beyond a graduate degree, demonstrating a prominent level of expertise among a notable segment of the sample.

Table 5.1: Qualifications

Qualifications	Number of respondents	Percentage (%)
< Grade 12	16	18.5
Grade 12	25	28.7
Post-Matric Certificate/ Diploma	10	11.5
Degree	25	28.7
Post-Graduate	11	12.6
Total	**87**	**100.0**

The distribution of qualifications presented a diverse educational background among the respondents, holding at least a Grade 12 qualification or higher. This variation in qualification was critical for understanding the expertise and perspectives of the regarding GBTs.

5.4.2. Employment Status

Table 5.2 shows a detailed breakdown of the employment status among the respondents who completed the survey. Most of the respondents, 92%, was employed full-time. This high percentage suggested a stable and committed workforce within the sample, reflecting a significant engagement in professional activities related to green building technologies. In contrast, only 1.1% of the respondents was employed on a contract basis or as students, respectively, indicating that contract positions and individuals still pursuing their education represented a minor segment of the sample. Lastly, 5.8% of the respondents was employed on a part-time basis. This small percentage of part-time workers showed that part-time employment was less common among respondents than full-time positions. The overall distribution of employment status presented a full-time professional demographic, which indicated the respondents' active involvement with GBTs in their respective fields.

Table 5.2: Employment status

Employment status	Number of respondents	Percentage (%)
Full-time	80	92.0
Other - contract-based	1	1.1
Part-time	5	5.8
Student	1	1.1
Total	**87**	**100.0**

5.4.3. Types of Projects

Table 5.3 shows the project types among the survey respondents. A considerable proportion of respondents (39.2%) were primarily involved in new projects. This indicated a strong focus on initiating and developing new projects in which GBTs were implemented. In addition, 37.9% of respondents engaged in both capital (new projects) and maintenance projects, reflecting a dual involvement that encompassed the creation and upkeep of building projects. Moreover, 21.8% of respondents worked on maintenance projects, underscoring a notable segment that was dedicated to the ongoing support and optimisation or retrofitting of existing structures. Only 1.1% of respondents participated in property sales, highlighting that this activity was a minor aspect of their professional engagement. The distribution of project types presented new and maintenance projects with a predominant emphasis on implementing GBTs in their projects within the construction industry.

Table 5.3: Types of projects

Type of project	Number of respondents	Percentage (%)
Capital (New Projects)	34	39.2
Capital and Maintenance Projects	33	37.9
Maintenance Projects	19	21.8
Property Sales	1	1.1
Total	**87**	**100.0**

5.4.4. Job Title

Table 5.4 shows the job titles of the respondents. The most prominent job title, representing 34.5% of the respondents, was contractors. These individuals were actively involved in the construction phase of the project life cycle, playing a critical role in executing and managing building activities, including implementing GBTs. Of the respondents, 20.7% were categorised as "Other". This broad group encompasses a range of project team members, including carpenters, construction managers, supervisors, health and safety officers, inventory managers, junior foremen, liaison officers, quality controllers, sales and development consultants, sales consultants, store managers, and truck operators. This diversity reflected the various roles that contribute to project execution and management of GBTs. Engineers, specifically civil engineers, accounted for 1.1% of the respondents. Inspectors constituted 4.6% of the respondents, concentrating on the maintenance phase of the construction life cycle. They ensured quality and compliance throughout the progression of projects. Project managers oversaw the projects from inception to close-out. They represented 9.2% of the respondents, indicating a significant presence in co-ordinating and guiding project execution. Lastly, 11.5% of respondents were quantity surveyors, who were professionals responsible for cost control and budget management throughout the construction projects. The distribution of job titles showed diverse professional roles engaged in various stages of the project life cycle, illustrating the broad expertise involved in GBTs.

Table 5.4: Job title

Job title	Number of respondents	Percentage (%)
Artisan	**16**	18.4
Contractor	30	34.5
Engineer	1	1.1
Inspector	4	4.6
Other	18	20.7
Project Manager	8	9.2
Quantity Surveyor	10	11.5
Total	**87**	**100.0**

5.5. Interpretation of Survey Questionnaire Findings

5.5.1. Perceived Usefulness of Green Building Technologies

Table 5.5 shows the respondents' perceptions regarding the usefulness of GBTs within the construction industry. Most respondents (96.6%) regarded GBTs as being beneficial, relating to their value and effectiveness in enhancing construction practices. However, 2.3% disagreed, stating that GBTs were not helpful. In addition, 1.1% of respondents needed clarification about the usefulness of GBTs, indicating a minor lack of sufficient information. Overall, the data showed that, among the respondents, a general recognition of the advantages and contributions of GBTs to the construction industry was reflected.

Table 5.5: Project team perceptions of the usefulness of GBTs

Response	Number of respondents	Percentage (%)
Yes	84	96.6
No	1	1.1
Unsure	2	2.3
Total	**87**	**100.0**

5.5.2. Key Indicators of the Usefulness of Green Building Technologies

Table 5.6 shows insights into the key indicators used to assess the usefulness of GBTs, evaluated on a scale from 1 (never) to 5 (always), with mean scores (MS) ranging between 1.00 and 5.00. These results revealed that all indicators were scored above the mid-point of 3.00, indicating that respondents consistently perceived these key indicators to be significant in the construction industry. Significantly, GBTs were recognised for their role in reducing carbon dioxide emissions, conserving renewable resources, and setting sustainable standards for the future. In addition, they were valued for enhancing corporate reputation, increasing market competitiveness, and protecting the ecosystem. Moreover, implementing GBTs contributed to greater energy efficiency and poverty alleviation through job creation. The MSs for these indicators reflected a strong consensus regarding their importance for the project team

members. These key indicators were ranked in the table below, offering further insights into their relative significance.

Table 5.6: Key indicators of the usefulness of GBTs

Factors	Unsure	(Response Percentage - %) Never ---------- Always					MS	Rank
		1	2	3	4	5		
Increases energy efficiency	0.0	1.1	1.1	6.9	18.4	72.4	4.6	1
Sets sustainable standards for future design and construction	2.3	1.1	13.8	12.6	17.2	52.9	4.09	2
Reduces carbon dioxide emissions	0.0	1.2	4.6	21.8	54.0	18.4	3.84	3
Conserves renewable resources	1.2	1.1	8.0	40.2	23.0	26.4	3.66	4
Builds corporate reputation	1.1	4.6	20.7	21.8	24.1	27.6	3.5	5
Alleviates poverty by creating jobs	5.7	5.7	16.1	29.9	17.2	25.3	3.43	6
Increases market competitiveness	4.6	14.9	13.8	26.4	12.6	27.6	3.25	7
Protects the ecosystem	5.8	21.8	17.2	21.8	12.6	19.5	2.9	8

5.5.3. Perceived Ease of Use of Green Building Technologies

Table 5.7 shows the respondents' insights regarding the ease of use of GBTs within the construction industry. A significant majority (93.2%) viewed GBTs as being easily usable. This high percentage suggested that GBTs were accessible and manageable for professionals in the construction industry. A small proportion of 1.1% of respondents disagreed, indicating that GBTs were not easy to use. Moreover, 5.7% of respondents was unsure about the ease of use, reflecting a degree of uncertainty or lack of familiarity with GBTs. Overall, the data presented a positive perception of the ease of use of GBTs, indicating the practical application and integration of GBTs into construction practices.

Table 5.7: Project team perceptions of the ease of use of GBTs

Response	Number of respondents	Percentage (%)
No	1	1.1
Yes	81	93.2
Unsure	5	5.7
Total	**87**	**100.0**

5.5.4. Aspects Promoting Ease of Use of Green Building Technologies

Table 5.8 shows the analysis of factors that promote the ease of use of GBTs by project teams, assessed on a Likert Scale from 1 (Strongly Disagree) to 5 (Strongly Agree). The MS for each factor ranged from 1 to 5, providing insight into the levels of agreement of respondents. MS values above the midpoint indicated a positive influence on the factors that promote the ease of use of GBTs, while lower MS values referred to a lack of agreement on their significance. From the evaluated factors, the promotion of training in GBT implementation was evident as a critical enabler, with a high MS reflecting strong agreement among respondents. Moreover, integrating GBTs within the design phase of construction projects received a substantial MS, highlighting the consensus on the need for early consideration of GBTs to ensure seamless adoption and implementation.

Table 5.8: Analysis of the factors that promote the ease of use of GBTs

Factors	Unsure	(Response Percentage - %) Strongly disagree ---------- Strongly agree					MS	Rank
		1	2	3	4	5		
Training on GBTs	0.0	4.6	4.6	24.1	39.1	27.6	3.8	1
Guide occupants on the use of GBTs	1.1	6.9	18.4	10.3	19.5	43.7	3.76	2
Technical performance and reliability	0.0	3.4	12.6	25.3	27.6	31.0	3.7	3
Integrates GBTs in the design stage	1.1	0.0	9.2	40.2	24.1	25.3	3.66	4
Environmental awareness and protection	0.0	6.9	25.3	14.9	18.4	34.5	3.48	5

In addition, the training of project teams in implementing GBTs within the construction industry obtained a high MS of 3.8 and was ranked first. Environmental awareness emphasised the growing recognition of environmental considerations as a driver for adopting GBTs and was ranked fifth, with 3.48. Moreover, guiding occupants in the use of GBTs indicated that clear guidance and user-friendly instructions were vital to ensure that GBTs were used effectively by project teams. These findings collectively highlighted the multi-faceted nature of the factors contributing to the ease of use of GBTs, focusing on training, early integration, technical reliability, environmental consciousness, and user guidance as key components.

5.5.5. Attitude and behavioural intentions

Table 5.9 shows the insights of the project teams regarding incorporating GBTs in the construction industry. Most respondents, accounting for 95.4%, agreed that GBTs should be integrated into construction practices. The high percentage of agreement suggested that project teams were aligned in their support for adopting GBTs, recognising their potential to enhance environmental performance, improve energy efficiency, and contribute to the overall sustainability of construction projects.

However, a small minority of respondents, 5.60%, indicated uncertainty about incorporating GBTs. The uncertainty showed the importance of addressing potential knowledge gaps or concerns within the industry to ensure the acceptance and successful integration of GBTs. Overall, the data revealed a strong inclination towards embracing GBTs, with most project teams viewing them as being a crucial component of modern construction practices.

Table 5.9: Project team insights into the incorporation of GBTs

Response	Number of respondents	Percentage (%)
Yes	83	95.4
Unsure	4	4.6
Total	**87**	**100.0**

5.5.6. Various GBTs in the Construction Industry

Table 5.10 shows the insights of project teams regarding the impact of various GBTs in the construction industry, measured according to their level of agreement. Among the technologies administered, greywater systems received the highest MS of 4.7, indicating substantial agreement on their positive effect on the construction industry. This suggested that greywater systems were highly valued for their sustainability and conservation benefits. Solar systems had an MS of 4.57, reflecting their significant impact on energy efficiency and adoption of renewable energy. Alternative building technologies, with a mean score of 3.87, and building management systems, with a mean score of 3.66, also received favourable evaluation, indicating moderate agreement on their effectiveness in improving construction practices and overall project performance.

In contrast, geothermal heating and cooling systems had an MS of 2.98, and wind turbines 2.83, receiving more mixed evaluations. This suggested that project teams might perceive these technologies as less impactful, or face challenges in their implementation within the construction industry. Biodegradable materials and electro-chromic devices had MSs slightly below 3.00 (2.79 and 2.77, respectively). This also reflected a lower level of agreement on their effect because of limited familiarity or perceived utility in construction practices.

Table 5.10: Project team insights into the impact of various GBTs on the construction industry

Factors	Unsure	(Response Percentage - %) Strongly disagree ---------- Strongly agree					MS	Rank
		1	2	3	4	5		
Greywater Systems	1,1	0.0	1.0	6.9	12.6	78.2	4.7	1
Solar Systems	0.0	0.0	2.3	8.0	19.5	70.1	4.57	2
Alternative Building Technologies	2.3	1.1	6.9	17.2	50.6	21.8	3.87	3
Building Management Systems	1.1	0.0	13.8	36.8	17.2	31.0	3.66	4
Geothermal Heating and Cooling Systems	2.3	14.9	21.8	21.8	28.7	10.3	2.98	5
Wind Turbines	1.1	5.7	40.2	32.2	6.9	13.8	2.83	6

Factors	Unsure	(Response Percentage - %) Strongly disagree ---------- Strongly agree					MS	Rank
		1	2	3	4	5		
Biodegradable Material	5.7	14.9	23.0	34.5	10.3	11.5	2.79	7
Electro-chromic Device	5.7	21.8	24.1	17.2	16.1	14.9	2.77	8

Overall, the data revealed a spectrum of opinions among project teams. Certain GBTs, such as greywater and solar systems, were widely recognised for their positive impact. In contrast, others, such as geothermal systems and electro-chromic devices, were seen as having more variable or uncertain effects on the industry. Table 5.11 shows the key hindrances to implementing GBTs within the construction industry. The data shows the complexity of implementation ranked first with an MS of 4.38, and the lack of training ranked second with an MS of 3.87. This indicated that insufficient training was a major hindrance to the successful adoption of GBTs, likely because of the specialised knowledge and skills required for their implementation.

Resistance to change was ranked third, with an MS of 3.82. The lack of knowledge about policies was ranked fourth, with a mean score of 3.75, indicating that unfamiliarity with regulatory frameworks and guidelines further hindered the integration of GBTs. The level of uncertainties regarding implementing GBTs was ranked fifth, with an MS of 3.68. The lack of provision of subsidies was ranked sixth with an MS of 3.67. The lack of knowledge about risks was ranked seventh with an MS of 3.64, underscoring that insufficient understanding of potential risks could deter project teams from adopting GBTs. The lack of awareness was ranked eighth with an MS of 3.6. This emphasised the need for greater awareness regarding GBTs. The lack of resources, with an MS of 2.68, and the lack of skills 2.65, were ranked ninth and tenth, respectively. These scores suggested that, while resources and skills are important, they are perceived as being less significant barriers than the other factors identified. Overall, the data provided multi-faceted hindrances to the implementation of GBTs. This suggested a need for improved training, cultural adaptation, and policy knowledge within the construction industry.

Table 5.11: Hindrances to the implementation of GBTs

Factors	Unsur	(Response Percentage - %)	MS	Rank

		Strongly disagree --------- Strongly agree						
		1	2	3	4	5		
Complexity of implementation	1.1	2.3	6.9	8.9	14.3	66.79	4.38	1
Lack of training and support documents	4.5	3.4	5.7	21.8	33.3	31.0	3.87	2
Resistance to change	4.4	1.1	4.6	26.4	42.5	21.8	3.82	3
Lack of knowledge of policies	4.6	9.2	12.6	13.8	17.2	42.5	3.75	4
Level of uncertainties	2.2	3.4	10.3	31.0	21.0	31.0	3.68	5
Lack of provision of subsidies for projects	2.3	3.4	11.5	26.4	28.7	27.6	3.67	6
Lack of knowledge of risks	2.2	6.9	10.3	23.0	28.7	28.7	3.64	7
Lack of awareness	2.2	8.0	14.9	20.7	18.4	35.6	3.6	8
Lack of resources	5.7	18.4	29.9	20.7	13.8	11.5	2.68	9
Lack of skills	5.7	21.8	32.2	12.6	12.6	14.9	2.65	10

5.6. Chapter Summary

In this chapter, the key findings from the study about how TAM could be used to increase the usage of GBTs in the South African construction industry were evaluated. The results showed an increasing interest by project teams because of the level of awareness of the usefulness of GBTs within the construction industry, relating to environmental benefits and energy efficiency. The training programmes and early integration have been recognised as key enablers and were widely accepted as the ease of use of GBTs. However, barriers such as lack of training, resistance to change, and insufficient financial incentives were still present within project teams. These challenges can be addressed through enhanced training, more substantial policy support, and early-stage integration of GBTs. These could provide a significant improvement in the adoption rate of GBTs. These findings portray TAM as being a helpful framework for understanding and promoting the usage of GBTs within the South African construction industry. This offers clear pathways to increase the actual usage of GBTs amongst project teams in the construction industry.

Chapter 6: Discussion

6.1. Introduction

The aim of this chapter is to integrate quantitative and qualitative results to provide a comprehensive understanding of the current state of GBTs and potential strategies for increasing their use in South Africa. The results provided insights that supported the findings of the literature review concerning the use of TAM to improve the use of GBTs. The integration of these results, followed by validation through focus groups, provided a comprehensive understanding of current and potential strategies for increasing the adoption of GBTs in South Africa. The results back up what previous research has said: the TAM is useful for understanding how to get more GBTs used in the country. The findings are presented systematically, and the objectives of the study are discussed. By looking at all the collected data and getting feedback from South African construction professionals, this chapter helps explain what works and what does not, and what can be done to make GBTs more common in South Africa's construction industry. This will enable insights to be applied to promote GBTs in South Africa.

6.2. Integrated Data Analysis

The results shared in Chapters 4 and 5 showed the need to address the mixed attitudes of project teams towards GBTs. Some are keen, while others are hesitant. This can be attained through education, pilot projects, training programmes, and awareness campaigns with project teams to alleviate misconceptions and provide clear evidence of the benefits of GBTs. Showing real examples of the benefits, such as lower electricity bills and better environmental results, can help change minds and encourage more teams to use GBTs. In the following sub-sections, an integrative view of the result is presented.

6.2.1. Perceived Usefulness of Green Building Technologies by Project Teams

The construction project teams were provided with GBT tools to reduce the impact of the construction industry on the climate and environment (Akinshipe & Aigbaboa, 2018: 20). As shown in Table 5.5, the perceived usefulness of GBTs was regarded as being a central component of TAM because of the response of 96.60% of the participants who considered GBTs to beneficial to the construction industry. They highlighted things like using less electricity, setting higher standards for building, and cutting down on pollution. The respondents identified key indicators in Table 5.6, such as increased energy efficiency, setting sustainable standards, and reducing carbon dioxide emissions, to reinforce the positive perception of the usefulness of GBTs. Furthermore, these results provided insights into the impact of GBTs on sustainability, environmental performance, and corporate reputation. Most construction teams in South Africa see GBTs as very promising for reducing environmental damage and helping the country save energy and money. The data provided insights that revealed the significance of GBTs in the construction industry. The case studies and focus groups showed that GBTs increased project efficiency, enhance quality control, and promote resilience to climate change. Teams also said GBTs improve their companies' reputations and help them meet global sustainability goals. In a study by Aziz and Beg (2019: 220), GBTs streamlined processes, encouraged waste reduction and better adherence to construction standards. But not everyone is convinced some project members do not see GBTs as useful because they do not know enough about them. These results suggested that the usefulness of GBTs goes beyond project deliverables and aligns with sustainable development objectives.

6.2.2. Perceived Ease of Use of Green Building Technologies by Project Teams

The data showed a significant need for technical support, training and user-friendly designs. Many South African construction teams said they need more technical support, training, and simpler systems to use GBTs with confidence. The case studies and focus groups revealed that ease of use can be enhanced by introducing awareness campaigns to address the needs and concerns of project teams. This strategy catalyses change. It helps project teams build confidence and ensure a reduction in the resistance to implementing GBTs (Simpeh *et al*., 2023: 288). Moreover, based on the data, the provision of financial incentives is recommended to enable a higher adoption rate. Financial incentives would concurrently provide the required support and encouragement to the project teams to embrace GBTs. Programmes that raise awareness and

provide hands-on training can help people get used to these recent technologies and reduce any fears about trying something new. The ease of use is regarded as an essential factor for adoption and, in this study, 93.20% of the respondents perceived GBTs as being easy to use (Table 5.7). These results showed that the growing familiarity of project teams with the various GBTs had assisted their integration into the construction industry. Moreover, Table 5.8 showed the factors that promote the ease of use of GBTs, such as training and awareness campaigns about GBTs, technical reliability, and the integration of GBTs within the design stage. The easier it is to learn about and use innovative technology, the more likely people are to accept it and put it to use. These factors are essential for ensuring the successful adoption and efficient implementation of GBTs in the South African construction industry (Agbajor & Mewono, 2022: 15). The results showed that ease of use concerns not only the technological design, but also how and when GBTs should be introduced within the construction life cycle.

6.2.3. Attitude and Behavioural Intentions of Project Teams towards GBTs

The results showed a positive attitude towards GBTs among project teams, with 95.40% of respondents shown in Table 5.10 advocating the integration of GBTs within the construction industry. This positive attitude is important, as it often leads to teams using GBTs. This aligned with the insights according to TAM that positive attitudes significantly affect behavioural intentions to implement GBTs. Table 5.11 showed that project teams reflected that change of behavioural intentions, such as cost-effectiveness, regulatory incentives, and environmental impact, played an essential role. The positive attitudes and change of behavioural intentions of project teams towards GBTs were driven by their environmental and economic benefits, such as enhanced energy efficiency, reduced emissions, and cost savings (Udeagha & Ngepah, 2022: 17). Teams were especially interested when they saw that GBTs could save money, help the environment, and meet government rules. Therefore, subsidies and financial support must be improved to foster positive behavioural change and increase the adoption rate of GBTs. The data revealed a positive attitude of project teams towards GBTs. This served as an indicator of the future of sustainability in South Africa. Most respondents from the five case studies and focus groups reported that introducing GBTs within their companies had economic benefits and impacted their jobs positively. This aligned with TAM in which it is stated that positive attitudes increase behavioural intentions that influence the higher adoption rates of GBTs (Park & Park, 2020:

9). However, negative attitudes towards GBTs were present in a minority. These negative attitudes were caused by inadequate training and the complexity of using GBTs. Therefore, technical support, training and user-friendly designs would assist in mitigating the factors of negative attitudes (Drago & Gatto, 2021: 2110).

6.2.4. Actual Usage of Green Building Technologies by Project Teams

The data revealed the actual usage of GBTs by the project team, which indicated the growing acceptance of GBTs within the construction industry. The study showed that often, South African construction teams are actually using GBTs, especially those that fit with their current building methods.The case studies and focus groups showed the widespread implementation of emerging GBTs and those that were compatible with existing systems, indicating that GBTs were being integrated into the construction industry. This means GBTs are slowly becoming part of the industry, but there is still room for much wider adoption. Moreover, this aligned with the final objective of the study, which was to propose how TAM factors increase the uptake of GBTs in South Africa. The research also highlighted that when teams see clear benefits and have the right support, they are more willing to use GBTs. The widespread implementation of GBTs by project teams impacted future adoption positively (Owoha *et al*., 2022: 1638).

6.3. Implications of Interview Results

In this study, financial incentives and market demand were deemed to be factors that influence the adoption of GBTs. In addition, introducing more robust financial incentives, such as tax breaks or subsidies for companies to implement GBTs, could significantly increase adoption rates (Agbajor & Mewono, 2022: 20). Concurrently, promoting long-term financial benefits of GBTs to clients increased the market demand, increasing the adoption rate of GBTs by project teams. A major finding was the need for better regulations and more financial rewards to get teams to use GBTs. Based on the study, it was suggested that a robust regulatory environment could significantly increase the use of GBTs. The results provided insights that project teams responded positively to clear regulations and standards that outline the specifications of construction projects. Increasing knowledge about the regulations and policies can also help teams

feel more comfortable using GBTs, while encouraging a shift in attitudes towards trying new things. According to Park and Park (2020), the regulatory environment plays a vital role in setting the standards for the increase in the use of GBTs. Policymakers must consider implementing regulations that encourage the use of GBTs, including mandatory sustainability standards or incentives for GBT projects. This would enable efforts to address the negative attitude towards GBTs, providing clear evidence of their benefits.

The ease of use of GBTs was influenced by technical support, training and user-friendliness, while the regulatory environment and organisational commitment played vital roles within the South African construction. The findings showed that the project teams perceived GBTs as being helpful in enhancing performance, resilience to climate change, and increasing efficiency in construction projects (Park & Park, 2020: 11). The programmes not only should be focused on the technical aspects of GBTs but also should address change management to alleviate resistance to technology acceptance. Introducing GBTs early in the project planning phase makes the full process smoother. The actual usage of GBTs reflected a balance between emerging technologies and those compatible with existing systems. This showed a strong focus on performance enhancement and sustainability practices.

6.4. Implications of Survey Results

The study showed that there was a need for stronger regulatory frameworks and financial incentives to promote the use of GBTs by project teams. The respondents identified the lack of subsidies as being a significant barrier. Most project teams felt that not enough subsidies or tax breaks were available, making it hard to justify the switch. Therefore, the South African governments and construction industry bodies should consider tax incentives or grant options for GBT projects. This financial viability option would encourage project teams to integrate GBTs within the construction industry (Fussell & Truong, 2022: 252). The key findings provided insights into the importance of training in facilitating the ease of use and acceptance of GBTs. Training is also crucial for the project teams due to the need for structured programmes to learn the skills needed for GBTs, and ongoing support to solve problems that come up during projects. There was a high need for more structured programmes to equip the project teams with the necessary skills to implement GBTs effectively. Continuous technical support was important to ensure that the ongoing challenges were addressed and that uncertainties related to the use

of GBTs were reduced (Patil *et al*., 2022: 1818). The integration of GBTs within the design stage was highly favourable. The early introduction of GBTs in the project life cycle ensured that the implementation and outcomes would be smoother. This encouraged the project teams to consider GBTs from the outset of project planning and avoid complications later in the construction project.

According to Liu and Hu (2019), enhancing training programmes and providing comprehensive support documents would address the lack of expertise and improve the actual use of GBTs by project teams. Incorporating GBTs early in the project design stage could streamline usage and enhance effectiveness. The government and industry groups could help by offering grants or tax relief for GBT projects. To foster a more accepting environment for GBTs, increasing knowledge about policies and regulations would help to mitigate the uncertainties and improve compliance by project teams (Liu & Hu, 2019: 555). The cultural and attitudinal shifts would enable the overcoming of resistance to change and build a culture that supports innovation to facilitate greater acceptance and integration of GBTs.

6.5. Modified Technology Acceptance Model

The modified TAM in this study based on GBTs, was developed by integrating quantitative and qualitative data. This study led to insights that showed the perceived usefulness of GBTs as a significant driver of acceptance by the project teams. Project teams were more likely to adopt GBTs if they perceived them as being helpful in improving performance. The main thing that encourages teams to use GBTs is seeing the real benefits, like better project performance and cost savings. The increased familiarity with GBTs reduced resistance to the use of GBTs (Akinshipe & Aigbaboa, Preparedness of Built Environment Students on Sustainability and Green Building Issues: How are South African High, 2018). Incentives, training, and technical support programmes enhanced this. Project teams gained a positive attitude toward GBTs by addressing the negative attitudes through education and training. This supported the notion that perceived usefulness and ease of use influenced the attitude of project teams. The positive attitudes towards GBTs were influenced by cost-effectiveness and environmental impact. This indicated that strong financial incentives and precise standards were likely to increase the use of GBTs by project teams (Agbajor & Mewono, 2022). The study showed widespread usage of GBTs in the South African construction industry. Project teams used

GBTs that were compatible with existing systems. This aligned with the TAM, in which it was predicted that the perceived usefulness and ease of use, combined with positive attitudes and change in behavioural intentions, would lead to technology adoption (Park & Park, 2020). Positive attitudes come from seeing that GBTs help both the environment and the bottom line. Figure 6.1 shows the modified TAM for GBTs. This model shows that the adoption of GBTs in South Africa is supported by a positive perception of the usefulness of GBTs, ease of use of GBTs, and positive attitudes leading to positive behavioural intentions that increase the actual usage of GBTs by project teams. When these factors are in place, south project teams will more likely use GBTs and recommend them to others construction professionals, thus enabling a wide spread of GBT use.

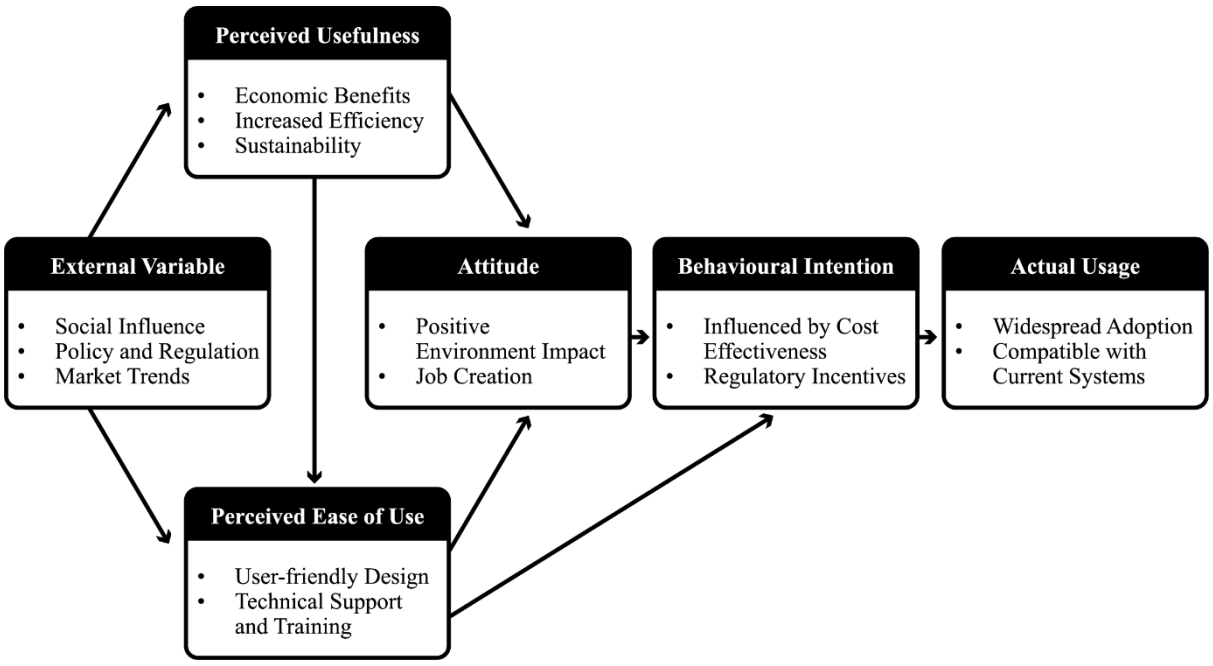


Figure 6.1: Modified TAM for GBTs

6.6. Chapter Summary

This chapter contained an in-depth analysis of the qualitative data from 5 case studies and focus groups. The focus was on the perceived usefulness, ease of use, behavioural intention, attitude and actual usage of GBTs by project teams. The results showed a positive perception of GBTs and their impact on performance enhancement, efficiency, and resilience to climate change.

Key points: improved training, stricter regulations, funding, and sharing achievements. In the chapter, improving communication, strengthening the regulatory framework, investing in training, promoting success stories, and ensuring seamless integration of current practices were suggested. The alignment of these strategies with TAM would be crucial in increasing the usage of GBTs in the South African construction industry. This chapter explained, in simple terms, how GBTs are being used in South Africa and what could help increase their use. If these strategies are followed, and the Technology Acceptance Model is used as a guide, the construction industry in South Africa will be more likely to adopt GBTs and make buildings greener and more efficient.

Chapter 7: Conclusions and Recommendations

7.1. Introduction

In this chapter, the findings of the study are synthesised and recommendations for implementing TAM to enhance the use of GBTs in South Africa are provided. The integration of quantitative and qualitative data enabled the exploration of the factors of TAM and how they can impact the adoption of GBTs. This chapter includes how the objectives of the study were addressed, actionable recommendations, and key insights.

7.2. Conclusions

Based on the study, it was found that TAM factors helped to understand the acceptance and application of GBTs. The project teams were more likely to adopt the GBTs when their perceived usefulness and ease of use were apparent. The perceived usefulness and ease of use influenced the attitudes and behavioural intentions of project teams when adopting GBTs. However, the study revealed significant barriers, such as lack of awareness, training, financial incentives and governmental support, which hindered the widespread adoption of GBTs. Moreover, the study showed the importance of implementing the TAM factors to alleviate barriers, enhance environmental sustainability, and meet sustainable development goals (SDGs) related to buildings and construction.

7.3. Conclusion Related to the Research Objectives

The objectives of the study were addressed by evaluating the factors of TAM and relating them to the factors that influence the adoption of GBTs. The results showed the relevance of considering perceived usefulness and ease of use as potential factors that foster positive attitudes and behavioural intentions among the project teams. Each objective is discussed below in relation to the findings of the study.

7.3.1. Objective 1: Identify the Project Team's Perceived Usefulness of Green Building Technologies

The findings of the study indicated that project teams supported the potential of GBTs to improve environmental sustainability, enhance productivity, and reduce operational costs. However, because of a lack of knowledge, some project team members did not perceive the GBTs as being applicable. To alleviate this matter, stakeholders must invest in awareness programmes that emphasise the importance of GBTs. These programmes include workshops, webinars, and certification programmes. The programmes would acknowledge project teams for the use of GBTs in achieving sustainability goals.

7.3.2. Objective 2: Evaluate the Ease of Use of Green Building Technologies by Project Teams

The findings of the study revealed that project teams perceive GBTs as being beneficial. However, their complexity hinders their widespread adoption. Complex technology and unfamiliarity with GBTs were regarded as being major challenges. The study showed the need for accessible and user-friendly GBTs. Moreover, project teams who received training reported increased confidence in using GBTs, which strengthened the TAM principle of perceived ease of use influencing the adoption rate of GBTs.

7.3.3. Objective 3: Assess the Attitude of Project Teams towards Green Building Technologies

The findings of the study revealed that the positive attitudes of project teams increased with knowledge of the usefulness of GBTs. This showed the positive attitude of the project teams. However, this was hindered by the high upfront cost, inadequate training, and insufficient information about GBTs. Based on the study, it was suggested that improved communication and education about GBTs could increase a positive attitude among project teams.

7.3.4. Objective 4: Assess the Change in Behavioural Intentions of Project Teams Regarding the Use of Green Building Technologies

The findings of the study indicated that government policies, market demand, and organisational culture influenced the intention to adopt GBTs. Moreover, project teams showed that they had favourable behavioural intentions towards GBTs when they received organisational support and had access to the relevant resources. Based on the study, it was stated that addressing individual and organisational factors was vital as this influenced the actual usage of GBTs.

7.3.5. Objective 5: Propose how the Factors of the Technology Acceptance Model could be Implemented to Increase the Uptake of Green Building Technologies in South Africa

The findings of the study revealed that incorporating TAM factors in GBT implementation strategies could increase adoption rates. Focusing on perceived usefulness by project teams, ease of use, positive attitudes, and behavioural intentions would also help in the actual usage of GBTs. The factors of the modified TAM could significantly increase the adoption rates of GBTs. The project teams need to understand the significance of these technologies such as long-term energy savings, improved indoor air quality, and decreased environmental impact. Moreover, the demonstration of the perceived ease of use shows the seamless transition of GBTs within the existing construction practices without experiencing significant changes. The increase in awareness and education regarding GBTs among project teams could enhance their perceived usefulness, enabling teams to be more confident in executing them. Subsequently, user-friendly technologies and supporting resources could increase the perceived ease of use by project teams within the construction industry. This would encourage more project teams to implement GBTs, making the transition less intimidating because a positive feedback loop would provide for broader acceptance. Ultimately, leveraging the core concepts of TAM could drive the wider adoption of GBTs. This would facilitate a shift towards more sustainable construction practices.

7.4. Recommendations for Policy and Practice

To increase the adoption of GBTs, the construction industry should prioritise education and training programmes to increase the familiarity of project teams with GBTs. Moreover, this could be met through collaboration with educational institutions and certification institutions that could support consistent training, improve the skills of construction professionals, and promote GBT knowledge across various industries. A pilot project could also help project teams with practical demonstrations of the use of GBTs.

The initial high cost associated with implementing GBTs was a significant barrier. The private sectors require financial support to offset the initial cost of GBT implementation. Advocating government incentives such as tax rebates and grants could encourage developers and contractors to integrate GBTs into their projects. This approach could reduce the economic burden and encourage widespread adoption.

Policymakers should consider mandating the use GBTs in new construction projects. The introduction of green building codes and rating systems could provide a standardised approach for creating a future direction. The collaboration among construction stakeholders could increase the consistent implementation of GBTs throughout South Africa. Moreover, granting rewards to project teams that implement GBTs could foster positive attitudes towards green practices.

7.5. Future Research Directions

In future research, long-term case studies of adopting GBTs should be explored. The robustness of the modified TAM model requires further inquiry that goes beyond the scope of this cross-sectional study. Moreover, investigating the influence of social and cultural factors on the adoption of GBTs could enable the understanding of contextual barriers and drivers.

Continually conducting research and development about the evolving landscape of GBTs could provide valuable insights into best practices and new GBTs. There is a need to support partnerships between construction industry stakeholders, academia, and government agencies in financing projects related to GBTs. Research institutions could explore region-specific

technologies, while construction industry professionals provide valuable insights into areas of improvement for future GBT designs. The modified TAM could be used as a practical model for understanding and addressing factors that influence the adoption of GBTs. Construction stakeholders can use this model to evaluate the attitudes of their project teams and adopt strategies that increase the ease of use and integration of GBTs in construction projects.

7.6. Contribution of the Study

This study makes a significant contribution by empirically validating the applicability of the modified TAM in the context of GBTs within the South African construction industry. By systematically examining the influence of perceived usefulness, perceived ease of use, attitudes, and behavioural intentions on the adoption of GBTs, the research provides robust evidence supporting the thesis that strategic incorporation of TAM factors can drive the wider implementation of sustainable construction practices. The findings expand the theoretical foundation for understanding technology adoption in construction, offering a nuanced framework that accounts for the unique challenges and opportunities present in the South African construction industry.

Furthermore, the study's recommendations bridge the gap between theory and practice by proposing actionable strategies for policymakers, industry professionals, and educational institutions. These recommendations highlight the practical value of the research in shaping policies, informing training programmes, and guiding future interventions aimed at mainstreaming GBT adoption. The study not only explores academic discourse on technology acceptance in construction but also aligns with the overarching thesis objective: to facilitate a sustainable transformation of the built environment through evidence-based, contextually relevant adoption strategies.

7.7. Chapter Summary

In conclusion, the vital role of TAM in increasing the implementation of GBTs in the South African construction industry was highlighted in the study. The findings showed that, by addressing the challenges related to awareness, ease of use, attitudes, and policy support, the recommendations could provide valuable insights to the construction project teams about promoting sustainable construction practices

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Appendices

Appendix A (Recruitment Letter for interview)

Attention: Interviewees

Dear Sir/Madam,

Re: Invitation to participate in MCONS' research on use of Technology Acceptance Model to increase use of Green Building Technologies

I hope this letter finds you well.

We are writing to humbly request your assistance in an ongoing Master of Construction research project by attending an interview as part of the study's data collection process. The research project, titled "Use of Technology Acceptance Model to increase Green Building Technology use in South Africa," is being conducted by Mr. BR Godhlo under the supervision of Prof. FA Emuze and Mr. KN Mokhojane at the Central University of Technology, Free State.

The purpose of this phase of the study, specifically this interview, is to explore how the Technology Acceptance Model could increase the use of Green Building Technologies by project teams in the South African construction industry. Therefore, we kindly request your support by partaking in the requested interview.

Should you have any inquiries regarding the study, please do not hesitate to contact Mr. BR Godhlo at godhlobr@gmail.com, or alternatively, you may reach him by phone at 0784446812.

Thank you for considering our request. We sincerely appreciate your attention to this matter and eagerly anticipate your feedback.

Yours sincerely,

_____

Mr BR Godhlo (MCONS Candidate)

_____ _____

Prof FA Emuze (Supervisor) Mr KN Mokhojane (Co-supervisor)

Ethics Approval number: 2024-02-01

Interview Questions

Purpose of Survey: To explore how the Technology Acceptance Model could increase the use of Green Building Technologies by project teams in the South African construction industry.

Brief descriptions

Technology Acceptance Model: A model pivotal to understanding the basis of the predictors of human behaviour towards the potential acceptance or rejection of technology (Rajee et al., 2019).

Green Building Technologies: Technologies that are found in facilities perceived as sustainable buildings to enhance buildings' ability to restore and revitalise the environment and positively influences people and their health (Aziz & Beg, 2022).

Section A: General questions:

1. What is your understanding of the TAM?
2. Do you know what are green building technologies?

2.1. If yes, please provide examples of any green building technologies you have come across.

3. How would you describe the essence of green building technologies in the construction industry?
4. May you identify the impact brought by green building technologies in the construction industry?

Section B: Perceived usefulness of GBTs by project teams

1. How do green building technologies improve the overall performance of construction projects?
2. What sets the standard for the incorporation of green building technologies in a construction project?

Section C: Perceived ease of use of GBTs by project teams.

3. How are green building technologies introduced to project teams?
4. What training and support programs are provided to project teams to provide guidelines on how to use green building technologies?
5. How is the technical performance and reliability of green building technologies affecting project teams?

Section D: Attitude and behavioural intentions of project teams regarding GBTs.

6. How has the introduction of green building technologies affected your company?

6.1. Positively or negatively? And how?

7. How is the company responding to green building technologies in the construction industry?

Section E: Actual usage of GBTs by project teams

8. How are green building technologies incorporated in construction projects?
9. Which project team members are included in the specifications of green building technologies in the construction industry?
10. With reference to Whole Lifecycle Costing, in your assessment is it justified to incorporate GBT in new construction projects?

Please indicate any general comment or concern you would like to share below:

_____

_____

_____

_____

---The End---

Appendix B (Cover Letter for survey)

Attention: Questionnaire

Dear Sir/Madam,

Re: Invitation to participate in MCONS' research on the use of Technology Acceptance Model to increase use of Green Building Technologies

I hope this letter finds you well.

We are writing to humbly request your assistance in an ongoing Master of Construction research project by completing the attached questionnaire as part of the study's data collection process. The research project, titled "Use of Technology Acceptance Model to increase Green Building Technology use in South Africa," is being conducted by Mr. BR Godhlo under the supervision of Prof. FA Emuze and Mr. KN Mokhojane at the Central University of Technology, Free State.

The purpose of this phase of the study, specifically this survey, is to explore how the Technology Acceptance Model could increase the use of Green Building Technologies by project teams in the South African construction industry. Therefore, we kindly request your support by following the link to the survey and completing it.

Should you have any inquiries regarding the study, please do not hesitate to contact Mr. BR Godhlo at godhlobr@gmail.com, or alternatively, you may reach him by phone at 0784446812.

Thank you for considering our request. We sincerely appreciate your attention to this matter and eagerly anticipate your feedback.

Yours sincerely,

_____

BR Godhlo (MCONS Candidate)

_____ _____

Prof FA Emuze (Supervisor) Mr KN Mokhojane (Co-supervisor)

Ethics Approval number: 2024-02-01

QUESTIONNAIRE

Purpose of Survey: To explore how the Technology Acceptance Model could increase the use of Green Building Technologies by project teams in the South African construction industry.

This questionnaire consists of section: A

Answer all questions/statements honestly.
Do not write your name or any contact details on the questionnaire.
You have the right to withdraw at any time without prejudice.
Click on the relevant answer.
Likert scales:
Frequency: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always)
Agreement: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), 5 (strongly agree)

Brief descriptions

Technology Acceptance Model: A model pivotal to understanding the basis of the predictors of human behaviour towards the potential acceptance or rejection of technology (Rajee et al., 2019).

Green Building Technologies: Technologies that are found in facilities perceived as sustainable buildings to enhance buildings' ability to restore and revitalise the environment and positively influences people and their health (Aziz & Beg, 2022).

Section A: Demographic Information

1. Please indicate the length of work experience in construction industry

0 – 5 years of service	
6 – 10 years of service	
11 – 15 years of service	

16 – 20 years of service	
20+ years of service	

2. Please indicate your highest academic qualification

Matric/NSC/IEB	
Post matric certificate(s)	
Diploma	
Degree	
Honours/Postgraduate Diploma	
Masters	
Doctorate	

3. Please indicate your employment status

Full-time	
Part-time	
Unemployed	
Student	
Other (please specify)	

4. Please indicate your job title or position

Engineer	
Project Manager	
Contractor	
Quantity Surveyor	
Artisan	

Inspector	
Other (please specify)	

5. Please indicate the type of projects you undertake.

Capital (New projects)	
Maintenance projects	
Other (please specify)	

Section B: Perceived Usefulness of GBTs

6. Based on your experience please indicate if you perceive green building technologies as useful.

Yes	
No	
Unsure	

7. On a scale of 1 (never) to 5 (always), please rate the frequency in which the green building technologies positively affects the construction industry or workplace.

Aspect	**Unsure**	**N/A**	**Never----------Aways**				
			1	2	3	4	5
7.1. Reduces the carbon dioxide emission							
7.2. Conservation of renewable resources							

7.3.	Sets sustainable standards for future design and construction							
7.4.	Builds corporate reputation							
7.5.	Market competitiveness							
7.6.	Protects the ecosystem							
7.7.	Energy efficiency							
7.8.	Alleviates poverty							

Section C: Perceived ease of use of GBTs

8. Based on your experience and exposure, please indicate if green building technologies can be easily used by project teams.

Yes	
No	
Unsure	

9. On a scale of 1 (strongly disagree) to 5 (strongly agree), please indicate the level of agreement on the following aspects done by your construction firm for ease of use of green building technologies on construction industry.

Aspect		**Unsure**	**N/A**	**Strongly Disagree--------Strongly Agree**				
				1	2	3	4	5
9.1.	Promote training on green building technologies							

9.2.	Integrate green building technologies in design stages of projects							
9.3.	Technical performance and reliability							
9.4.	Educate environmental awareness and protection							
9.5.	Guide occupants on the use of the green building technologies							

Section D: Attitude and behavioural intention of project teams towards the use of GBTs

10. Based on your experience, please advise/comment? if green building technologies are the best suited technologies to be incorporated into the construction projects

Yes	
No	
Unsure	

11. Emanating from question 10 above, please rate on a scale of 1 (strongly disagree) to 5 (strongly agree) whether the following technologies or constructability requirements contribute positively to effective green building technologies.

Aspect	Unsure	N/A	Strongly Disagree-----Strongly Agree				
			1	2	3	4	5
11.1. Alternative Building Technologies							
11.2. Building Management System							
11.3. Solar systems							
11.4. Wind Turbines							
11.5. Electrochromic device							
11.6. Geothermal heating and cooling system							
11.7. Greywater systems							
11.8. Biodegradable material							

12. On a scale of 1 (strongly disagree) to 5 (strongly agree), please indicate the level of agreement on the following issues with regards to project teams and the use of green building technologies.

Aspect	Unsure	N/A	Strongly Disagree--------Strongly Agree				
			1	2	3	4	5
12.1. Resistance to change							

12.2. Level of uncertainties							
12.3. Lack of knowledge on risks							
12.4. Lack of awareness							
12.5. Lack of knowledge on policies							
12.6. Lack of resources							
12.7. Lack of skills							
12.8. Lack of training and support programs							

Section E: Actual usage of green building technologies

13. Based on your experience, please indicate if you have worked with projects that incorporate green building technologies.

Yes	
No	
Unsure	

14. On a scale of 1 (never) to 5 (always), please rate the frequency in which the use of green building technologies is prohibited due to the issues below.

Aspect	**Unsure**	**N/A**	**Never----------Aways**				
			1	2	3	4	5
14.1. Level of awareness							

14.2. Inadequacy of skills							
14.3. Provision of subsidies for projects							
14.4. Complexity of implementation							

15. Based on your experience please indicate if you would recommend green building technologies in construction projects?

Yes	
No	
Unsure	

16. Please state any general concerns or comments you would like to share below:

_____

_____

_____

_____

_____

_____

---The End---

Appendix C (Ethical Clearance)

Central University of Technology, Free State

FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

APPLICATION FOR ETHICAL CLEARANCE TO CONDUCT RESEARCH IN THE FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

The Central University of Technology (CUT) Research Ethics and Integrity Policy applies to all undergraduate and post graduate students, and staff members who conduct research on CUT campuses and outside the campus. CUT policy bounds any person who wishes to conduct research with CUT students and/or staff but is not CUT affiliated to abide by the ethics framework. All CUT members who conduct research take responsibility to implement this, Policy.

1. APPLICANT INFORMATION

1.1.	**Title (Prof Dr /Mr /Mrs /Ms)**	Mr	
1.2	**Name(s) and Surname**	Bongani Resego Godhlo	
1.3	**Student / Staff number**	218012847	
1.4	**Department**	Built Environment	
1.5	**Campus**	Bloemfontein	
1.6	**Postal address**	14 Kolbe Avenue Oranjesig Bloemfontein 9301	
1.7	**Contact details**	Office	N/A
		Cell	0784446812

		e-mail	godhlobr@gmail.com
1.8	**Supervisor (s)/Project Leader**	Prof. FA Emuze Mr KN Mokhojane	
1.9	**Qualification registered for/Level of research**	***Please tick relevant option:***	
		Masters qualification	✓
		Doctorate	
		Independent research (Non-qualification purposes)	
1.10	**FRIC Approval Number (LS262a) (where applicable)**		
1.11	**Conflict of interest (Please underline/highlight):** 1) Personal relationship Yes/No 2) Financial benefit Yes/No		
	If yes, please provide details:		

2. DETAILS OF THE STUDY

2.1	**Approved/Proposed title of the study/project /dissertation/thesis**
Use of Technology Acceptance Model to increase Green Building Technology use in South Africa	
2.2	**Research question(s)**

The main question of this study asks, "How would technology acceptance model adoption increase the use of green building technologies by project teams in South Africa?"

The following sub-questions were formulated to respond to the above main research question. The sub-questions include:

• How do project teams perceive the usefulness of green building technologies?

• How do project teams perceive the ease of use of green building technologies?

• What is the attitude of project teams on green building technologies?

• What would change the behavioural intentions of project teams regarding green building technologies use?

• How would the factors of technology acceptance model increase the actual usage of green building technologies in South Africa?

2.3	Aim and objectives of the study

This study aims to explore how technology acceptance model could increase the use of green building technologies by project teams in South African construction industry. The aim of this study will be obtained through the following objectives:

• Identify the project team's perceived usefulness of green building technologies.

• Evaluate the ease of use of green building technologies by project teams.

• Assess the attitude of project teams on green building technologies.

• Assess the change in behavioural intentions of project teams regarding the use of green building technologies.

• Propose how the factors of the technology acceptance model would be implemented to increase the uptake of green building technologies in South Africa.

2.4	Research methodology
2.4.1	Research participants and their age brackets (where applicable, e.g. 10 Students from Civil Engineering Department)

The study will be focused on construction project team including architect, engineers, builders, developers, and other professionals involved in the design, construction, and operation of green buildings from five case projects in Bloemfontein, South Africa.

2.4.2	How will participants be selected/sampled?

Purposive sampling will be used to choose a sample that will be useful to the objectives of this research. The nature of this study necessitates the adoption of a snowball sampling to allow recruitment of various construction project teams that can contribute to the required research data.	
2.4.3	**Research site(s) (e.g. Borong Construction Site)** **Please list**
Qualicon Construction Sites X2 – Bloemfontein: (Brandwag & Bloemfontein Central) Sebedisan Construction Sites X2 – Bloemfontein: (Navilsig & Lilyvale) Lenova Construction & Development Site - Bloemfontein: (Lilyvale)	
2.4.4	**Data collection instruments (e.g. questionnaire(s)/interview schedule(s)/observation schedule(s)/artefacts/other)**
Semi-structured Interviews *Survey Questionnaires*	
2.4.5	**Data collection procedure (Please outline WHEN, WHERE and HOW data will be collected)**
	<u>QUANTITATIVE DATA</u> **When?** March 2024 – June 2024. **Where?** On five construction sites in Bloemfontein. **How?** Conducting Survey Questionnaires. **<u>QUALITATIVE DATA</u>** **When?** March 2023 – June 2024. **Where?** On five construction sites in Bloemfontein.

	How? Conducting Semi-structured Interviews.

3. PROPOSED PLAN OF STUDY/RESEARCH

	Set out your intended plan of work for the research, indicating important target dates necessary to meet your proposed deadlines	
	Research Tasks	**Proposed Deadlines**
	Data Collection	March 2024
	Interpretation of Data	July 2024
	Discussion of Finding	August 2024
	Recommendations & Conclusion	September 2024
	Proofreading the Dissertation	October 2024
	Professional English Editing	October 2024
	Submission for Assessment	November 2024
	Publications for Master of Construction	
	Conference Paper	October 2023
	Journal paper	December 2024

4. ETHICAL ISSUES AND RISK ASSESSMENT

In order to assess whether your proposed research is ethically compliant, ethics risks are categorised into four categories:

(1) Research involving minor risk

The likelihood of projected harm or inconvenience in the research is not greater than that experienced in daily life.

(2) Research involving low risk

Research in which the only anticipatable risk is one of potential awkwardness or discomfort to the participants.

(3) Research involving medium risk

Research in which there is a possible risk of harm or discomfort, but where appropriate steps can be taken to lessen or moderate overall risk.

(4) Research involving high risk

Research in which there is a real and foreseeable risk of harm and discomfort, which may lead to a serious adverse event if not managed in a responsible manner.

4.1	**Will human research participants be used in your study?** *Please mark with an X or √ in the Yes/No/N/A box*	**✓ Yes**	**No**	**N/A**
4.2	**If yes, does the research study involve any of the following:**			
a) Children or youth under the age of 18 (Attach parental consent letter)			✓	
b) Individuals living with disabilities (physical, mental and/or sensory) (Attach consent letter of legal guardian)			✓	
c) Individuals that might find it difficult to make independent and informed decisions for socio, economic, cultural, political and/or medical reasons			✓	
d) Communities that might be considered vulnerable, thus finding it difficult to make independent and informed decisions for socio, economic, cultural, political and/or medical reasons			✓	
e) Individuals who might be vulnerable for age related reasons e.g. the elderly			✓	
f) Individuals whose spoken language differs from the language used for the research				

(Make sure you translate your consent form and participant information sheet in the participants' first language – you should also have an interpreter if you do interviews – describe it below the table)			
g) Women considered to be vulnerable (pregnancy, victimisation, marginalised etc.)		✓	
h) Other (Please explain):			

4.3	Will data collection involve any of the following:	Yes	No	N/A
a)	Access to confidential data without prior permission of participants		✓	
b)	Participants expected to commit an act which might reduce self-respect or cause them to experience shame, embarrassment, or regret		✓	
c)	Expose participants to worrying or upsetting questions or to processes which may have disagreeable or harmful side effects		✓	
d)	The use of stimuli, errands or procedures which may be experienced as stressful, harmful, or hostile		✓	
e)	Any use of materials risky to human beings		✓	

4.4 If you answered "Yes", to any of the previously mentioned, explain (attach as an appendix) and justify. Explain, too, what steps you will take to minimise the potential stress/harm. ***(Please indicate if it is not applicable to your study)***

N/A

4.5 Confidentiality of participants' identity				
4.5.1	**Will the identity and privacy of participants be protected through pseudonyms or other forms of identification and the use of an informed consent form, which specifies (in a language that participants will understand):** *Place an 'X or ü' in the Yes/No box.*	**✓ YES**	**NO**	**N/A**
4.5.2	**Please note that participants should be informed about the following (where applicable)**			
a)	The purpose/s of the research and how it is conducted	✓		
b)	The researcher, project leader and supervisor's identity, their institutional association and their contact details	✓		
c)	Voluntary participation of participants	✓		
d)	Making sure that participants' responses will be treated in a confidential manner	✓		
e)	Be transparent about any possible limits on confidentiality which may apply	✓		

f) Ensuring participants that they are free to withdraw from the research at any time without any negative or undesirable consequences to themselves	✓		
g) How the findings of the study will have any benefits, or may receive as a result of their participation in the research	✓		

4.5.2 Please attach the proposed consent and assent documents prepared to address all the above, if not a full explanation is needed explaining how participants will be respected and protected.

5. DOCUMENTS TO BE ATTACHED TO THE APPLICATION

The following documents must be attached as a prerequisite for approval to undertake research in the Department (where applicable)	
5.1	LS 262a approved by the FRIC (FEBIT)
5.2	Proof of registration/Funding received and funder reference details.
5.3	Data collection instruments as identified under 2.4.4

6. DECLARATION BY THE APPLICANT

I undertake to use the information that I acquire through my research, in a balanced and a responsible manner. I furthermore take note of, and agree to adhere to the following conditions (where applicable):

a) I will schedule my research activities in consultation with the relevant Company or Organisation and research participants (where relevant);

b) I agree that involvement of participants in my research is voluntary, and that participants have a right to decline to participate;

c) I will obtain signed consent forms from participants prior to any engagement with them;

d) I will inform participants about the use of recording devices such as tape-recorders and cameras, and participants will be free to reject them if they wish;

e) I will honour the right of participants to privacy, anonymity, confidentiality and respect for human dignity at all times. Participants will not be identifiable in any way from the results of my research, unless written consent is obtained otherwise;

f) All interviews (recordings) will be transcribed verbatim and analysed as per conventional data analysis techniques (example(s) of interview transcript to be included in final dissertation)

g) I will adhere to the principles of rigorous data collection, analysis and interpretation consistent with the design of the study;

h) I will keep a data trail for possible auditing purposes as well as the safe keeping of raw data for a period of three years after publication of the results;

i) I will send the draft research findings to research participants before finalisation, in order to validate the accuracy of the information in the report;

j) I will not use the resources of the university when I am conducting my research (such as stationery, photocopies, faxes, and telephones) and

k) I will include a disclaimer in any report, publication or presentation arising from my research, that the findings and recommendations of the study do not represent the views of the Central University of Technology.

l) Aside from laboratory as well as consumables or materials supplied by the university needed to complete practical projects which might be central to my study (dependent on study field), I will not use the resources of the University when I am conducting my research (such as stationery, photocopies, faxes, and telephones).

m) All practical artefacts produced in support of my study using the university's laboratories, consumables, and materials will remain the property of the University.

n) If I supplied my own materials and consumables, I will permit access to all practical projects or artefacts to the University for a period of three (3) years for exhibition purposes.

o) All data collected for the research (including, but not limited to, completed questionnaires; statistical analysis performed on the data; interview audio-files/transcripts; artefacts/audio-visual materials; documents) will be kept safe at a designated space at the university for a period of at least three years. Computer files will be backed-up and password-protected.

I declare that all statements made in this application are true and accurate. I accept the conditions associated with the granting of approval to conduct research and undertake to abide by them.

STUDENT SIGNATURE / PROJECT LEADER SIGNATURE / SIGNATURE OF RESEARCHER	
DATE	27 Feb. 24

7. DECLARATION BY SUPERVISOR(S) (where applicable)

I/We declare that I/we shall oversee the student's adherence to all statements as set out above.	
SIGNATURE (Main supervisor)	
SIGNATURE (Co-supervisor)	
DATE	

FOR OFFICIAL USE

APPROVAL OF FEBIT ETHICAL COMMITTEE (FRIC)

Please tick relevant decision and provide conditions/reasons where applicable	
Decision	***Please tick***

			relevant option
1.	Application approved		
2.	Ethical clearance number	FRIC:	
3.	Application approved subject to certain conditions. ***Specify conditions below***		
4.	Application not approved***. Provide reasons for non-approval below***		
SIGNATURE: **Chairperson: Ethics committee**			
DATE			

Cc Dean: FEBIT