

Developing a lean six sigma–based sustainable facility management framework for a South African university of technology

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ABSTRACT

Established in 2004 through the merger of three institutions, Tshwane University of Technology (TUT) has grown into South Africa's largest residential higher education institution, accommodating over 65,000 students across five provinces and providing more than 40,000 residence beds. Despite its scale, TUT continues to experience persistent facility management (FM) challenges, including overcrowded and ageing student housing, deferred maintenance, and declining state funding. These challenges mirror global higher education FM concerns characterised by customer dissatisfaction, resource constraints, and limited adoption of integrated, data-driven management systems.

The primary objective of this study was to develop and validate a Lean Six Sigma (LSS)-based framework for Sustainable Facility Management Systems (SFMS) within a university of technology context. Secondary objectives included identifying and empirically examining Critical Facility Defaults (CFD), Facility Contributing Factors to Management failure (FCFM), Root Causes of Facility Management challenges (RCFM), Sustainable Facility Management strategies (SFM), and the role of Lean Six Sigma (LSS) practices in enhancing sustainability outcomes.

A convergent mixed-methods research design was adopted. The target population comprised facility management stakeholders at TUT, including academics, engineers, project managers, residence managers, and Lean Six Sigma practitioners. A total of 353 questionnaires were distributed and 333 returned giving a total response of 95.1%. Out of a total of 333 questionnaires returned 326 were found valid for the analysis, yielding a valid response rate of 97.9% whereas the rest of the questionnaires were not used due to missing information. The participants for the interview were 21.

Quantitative data were analysed using exploratory factor analysis, reliability and validity testing, Pearson product-moment correlation analysis, multiple regression analysis, and Structural Equation Modelling (SEM). The results confirmed six reliable and distinct constructs (Sustainable Facility Management Scheme based on five predictor variables: Lean Six Sigma, Factors Contributing to Poor Facility

Management, Classes of Facility Defaults, Strategies Used in Facility Management and Root Causes to Poor Facility Management), with strong factor loadings (0.531–0.860), high internal consistency (Cronbach's $\alpha = 0.807$ – 0.896), and acceptable convergent and discriminant validity. Pearson correlation analysis revealed that sustainable facility management systems were negatively associated with facility defaults, contributing factors, and root causes, while showing positive associations with sustainable strategies and Lean Six Sigma practices.

Both SEM and multiple regression analysis validated these relationships, explaining approximately one-third of the variance in sustainability outcomes (SEM $R^2 = 0.35$; regression $R^2 = 0.316$). The regression model confirmed all predictors as statistically significant and produced a robust predictive equation: $SFMS = 3.935 + 0.200(SFM) + 0.096(LSS) - 0.113(CFD) - 0.204(FCFM) - 0.214(RCFM)$.

Framework validation by the respondent group demonstrated high reliability and practical relevance, particularly in addressing financial efficiency, social sustainability, and digital readiness within FM systems. This study contributes to facility management scholarship by presenting one of the first empirically validated, context-specific Lean Six Sigma frameworks for sustainable facility management in South African universities of technology, offering both methodological advancement and a practical roadmap for FM leadership.

Keywords: Facilities Management; Sustainability, Lean Six Sigma Technique; DMAIC; Structural Equation Modelling, Multiple linear regression analysis

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Above all, I give thanks to Almighty God for granting me the strength, resilience and wisdom to complete this academic journey. His grace sustained me in moments of challenge and triumph alike.

DEDICATION

This thesis is lovingly dedicated to my entire family, whose unwavering support and encouragement sustained me throughout this academic journey. Your belief in my potential gave me the strength to persevere through every challenge and to pursue excellence with determination and purpose.

A special and heartfelt dedication goes to my late mother, Nare Jacqueline Mogashoa, whose legacy of resilience, integrity and compassion continues to guide my path. Though she is no longer physically present, her values and enduring love have remained a constant source of inspiration. Her memory has been the silent strength behind every milestone I have achieved. This work stands as a testament to the foundation she laid in my life and the sacrifices she made for my growth.

To my family, particularly my kids, thank you for your prayers, patience and belief in me. This achievement belongs to all of you.

DECLARATION

“I hereby declare that the dissertation/thesis submitted for a Doctoral degree in Business Administration at North West University is my own original work and has not previously been submitted to any other institution of higher education. I further declare that all sources cited or quoted are indicated and acknowledged by means of a comprehensive list of references”

Name: M.A MOGASHOA

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Date: 22 September 2025

Table of Contents

TABLE OF PUBLICATIONS	ii
ABSTRACT	iii
ACKNOWLEDGEMENTS.....	v
DEDICATION	vi
DECLARATION	vii
LIST OF FIGURES	xvi
LIST OF TABLES	xviii
LIST OF ACRONYMS	xx
CHAPTER ONE.....	1
INTRODUCTION AND BACKGROUND	1
1.1 CHAPTER OVERVIEW	1
1.2 INTRODUCTION AND BACKGROUND	1
1.2.1 Institutional Context and FM Challenges	1
1.2.2 FM Practices and Model Limitations	2
1.2.3 Need for Performance-Driven Sustainable FM	2
1.2.4 Lean Six Sigma in FM: Limited Application.....	3
1.2.5 Empirical Evidence of FM Deficiencies.....	3
1.2.6 Research Gap and Rationale for the Study	4
1.3 PROBLEM STATEMENT	4
1.4 SIGNIFICANCE OF THE STUDY	6
1.5 AIM AND OBJECTIVES OF THE STUDY	7
1.5.1 Primary objective	7
1.5.2 Secondary Objectives.....	7
1.6 RESEARCH QUESTIONS.....	8
1.7 OUTLINE OF THE THESIS.....	8
1.8 CHAPTER SUMMARY	11

CHAPTER TWO.....	12
LITERATURE REVIEW	12
2.1 CHAPTER OVERVIEW	12
2.2 CONCEPTS OF LEAN SIX SIGMA	12
2.3 INTEGRATING LEAN SIX SIGMA INTO FACILITY MANAGEMENT	14
2.4 LEAN THINKING AND SIX SIGMA WITH GREEN PRACTICES	18
2.5 LEAN SIX SIGMA APPLICATION	19
2.6 FACILITY MANAGEMENT IN HIGHER EDUCATION.....	21
2.7 SUSTAINABLE FACILITY MANAGEMENT (SFM).....	22
2.8 FACILITY MANAGEMENT CHALLENGES	23
2.9 FACTORS CONTRIBUTING TO EFFECTIVE FACILITY MANAGEMENT	24
2.9.1 Stakeholders' involvement.....	25
2.9.2 System Integration in Facility Management	27
2.9.3 Funding of Institutional Facilities.....	28
2.9.4 Sustainability and Environmental Stewardship in FM	29
2.9.5 Risk Management and Regulatory Compliance.....	32
2.10 EXISTING SUSTAINABLE FACILITY MANAGEMENT FRAMEWORKS.....	33
2.11 EFFICIENT UTILISATION OF RESOURCES IN FM.....	35
2.12 ISO 14001 IN FACILITY MANAGEMENT.....	36
2.13 INTEGRATING LSS & SUSTAINABILITY IN FM FRAMEWORKS FOR HEIs ..	37
2.14 MANAGEMENT MODEL THROUGH LSS FOR UoT	39
2.15 LEAN TOOLS FOR FACILITIES MANAGEMENT AT UoT.....	40
2.15.1 5S for Facilities Management (FM) at UoT	41
2.15.2 Value Stream Mapping for FM at UoT	41
2.15.3 Total Productive Maintenance in FM at UoT.....	42
2.15.4 Pareto Tools for FM at UoT	43
2.15.5 Ishikawa Fishbone for FM at UoT	43

2.16 THEORETICAL FRAMEWORK AND INTEGRATION	46
2.17 GREEN CAMPUS STANDARDS FOR FM AT UoT.....	49
2.18 A STRATEGIC FRAMEWORK FOR GREEN FM USING LSS AT UOT.....	52
2.19 INSTITUTIONAL FACTORS AND SUSTAINABILITY DIMENSION	55
2.19.1 Economic Sustainability and Resource Optimisation.....	56
2.19.2 Social Sustainability and Stakeholder Engagement.....	56
2.19.3 Institutional Governance and Policy Integration.....	57
2.19.4 Integration of Lean and Six Sigma for Sustainable Practices	57
2.19.5 Role of Digital Transformation in Continuous Improvement.....	57
2.19.6 Total Quality Management and Corporate Sustainability	58
2.19.7. Sustainability in Higher Education Quality Processes.....	58
2.19.8 Challenges and Prospects of Continuous Improvement.....	58
2.20 STRATEGIES USED IN FM AND SUSTAINABILITY	60
2.21 FACTORS IN POOR FM IN HIGHER EDUCATION.....	64
2.22 ROOT CAUSES OF POOR FM IN HIGHER EDUCATION	65
2.23 IFMA STRATEGIES	67
2.24 FACILITY MANAGEMENT AND FINANCIAL PERFORMANCE	70
2.25 THEORETICAL FRAMEWORK.....	71
2.26 DIGITALISATION IN FACILITY MANAGEMENT	72
2.27 SYSTEM INTEGRATION IN FACILITY MANAGEMENT.....	75
2.28 CHANGE MAINTENANCE PROCESS.....	78
2.29 FACILITY MANAGEMENT DURING THE PANDEMIC	80
2.30 REVIEW OF CONCEPTUAL MODELS	83
2.31 FACILITY MANAGEMENT THEORY SUPPORTING THE STUDY.....	87
2.31.1 Systems Theory in Integrated FM for Higher Education	87
2.31.2 Continuous improvement theory on FM in higher education.....	89
2.31.3 Sustainable Development Theory on FM in UoT	90

2.31.4 Technology Acceptance Model in UoT Facility Management	92
2.31.5 LSS-Based SFMF Conceptual Framework for UoT	93
2.31.6 FM Change Framework (Kotter's 8 Steps)	95
2.31.7 Construct Underpinning Development of the Sustainability FM Scheme	99
2.32 CHAPTER SUMMARY	101
CHAPTER THREE	103
RESEARCH METHODOLOGY	103
3.1 CHAPTER OVERVIEW	103
3.2 RESEARCH METHODOLOGY	103
3.3 RESEARCH DESIGN	104
3.4 RESEARCH APPROACH.....	104
3.5 RESEARCH PARADIGM.....	105
3.5.1 Pragmatic Research Philosophy.....	105
3.5.2 Positivist Research Philosophy.....	106
3.5.3 Interpretivist Research Philosophy	106
3.5.4 Realist Research Philosophy	107
3.6 RESEARCH POPULATION AND SAMPLING.....	108
3.6.1 Research Population	108
3.6.2 Sampling Method/Technique	108
3.6.3 Probability Sampling	109
3.6.4 Non-probability Sampling.....	109
3.6.5 Sample Selection.....	110
3.6.5.1 Qualitative sampling selection	110
3.6.5.2 Sampling justification	112
3.6.5.3 Sampling Techniques	114
3.7 DATA COLLECTION METHODS	114
3.7.1 Quantitative Data Collection	114

3.7.2 Qualitative Data Collection	115
3.8 QUANTITATIVE DATA ANALYSIS.....	116
3.9 Qualitative Analysis	117
3.10 RELIABILITY AND VALIDITY	117
3.10.1 Reliability	117
3.10.2 Validity	118
3.11 TRUSTWORTHINESS OF THE STUDY	119
3.12 ETHICAL CONSIDERATIONS	121
3.13 CHAPTER SUMMARY	123
CHAPTER FOUR	124
QUANTITATIVE DATA ANALYSIS AND FINDINGS.....	124
4.1 CHAPTER OVERVIEW	124
4.2 THE RESPONSE RATE	124
4.3 DEMOGRAPHIC INFORMATION.....	124
4.4 DESCRIPTIVE ANALYSIS	126
4.5 EXPLORATORY AND RELIABILITY ANALYSIS	134
4.6 CORRELATION ANALYSIS	138
4.7 STRUCTURAL EQUATION MODELLING	140
4.7.1 Assessment of the Measurement Model.....	140
4.7.2 Assessment of the Structural Model	143
4.8 MULTIPLE LINEAR REGRESSION ANALYSIS.....	145
4.8.1 Significance of the Model.....	145
4.8.2 Multiple Linear Regression Assumptions.....	146
4.8.2.1 Assumption of Multicollinearity	146
4.8.2.2 Assumption of Normality	146
4.8.2.3 Assumption of Homoscedasticity	147
4.8.2.4 Assumption of Outliers.....	148

4.8.3 Evaluating the Model	150
4.8.4 Evaluation of the Independent Variables	150
4.9 CHAPTER SUMMARY	152
CHAPTER FIVE	154
QUALITATIVE DATA ANALYSIS AND PRESENTATION OF RESULTS.....	154
5.1 CHAPTER OVERVIEW	154
5.2 DEMOGRAPHIC DETAILS.....	154
5.3 QUALITATIVE DATA ANALYSIS USING ATLAS.TI.....	156
5.3.1 Code Groundedness and Distribution Across the 21 Interviews	158
5.4 Presentation of the Results.....	160
5.4.1 Identification of Various Classes of Facility Defaults.....	163
5.4.2 Facility Default Classifications	165
5.4.3 Analysis of the Various Classes of Facility Defaults	168
5.4.4 Theoretical interpretation of qualitative findings.....	182
5.5 CHAPTER SUMMARY	184
CHAPTER SIX.....	185
RESULTS DISCUSSION AND FRAMEWORK DEVELOPMENT.....	185
6.1 CHAPTER OVERVIEW	185
6.2 CLASSES OF FACILITIES DEFAULTS IN THE UOT	188
6.3 FACTORS IN POOR FM AT A UOT	189
6.4 ROOT CAUSES OF POOR FM AT A UOT	190
6.5 STRATEGIES FOR EFFECTIVE FM AT A UOT	191
6.6 Synthesis of Literature and Empirical Findings.....	192
6.7 SUSTAINABLE FM FRAMEWORK VIA LSS FOR A UOT	194
6.7.1 <i>Define phase</i>	196
6.7.2 <i>Measure phase</i>	196
6.7.3 <i>Analyse Phase</i>	199

6.7.4 <i>Improve Phase</i>	204
6.7.5 <i>Control Phase</i>	207
6.8 STATISTICAL VALIDATION OF SUSTAINABLE FM USING LSS	214
6.9 CHAPTER SUMMARY	217
CHAPTER SEVEN	219
CONCLUSION AND RECOMMENDATIONS	219
7.1 CHAPTER OVERVIEW	219
7.2 CONCLUSION.....	219
7.3 RECOMMENDATIONS	222
7.3.1 Interpretation of Findings	223
7.5 FUTURE RESEARCH STUDIES.....	226
7.6 CONTRIBUTION TO THE BODY OF KNOWLEDGE	227
7.7 LIMITATIONS OF THE RESEARCH	227
8. REFERENCES	229
APPENDIX I	258
GATEKEEPER PERMISSION LETTER	258
APPENDIX II	259
LETTER OF CONSENT FOR RESEARCH PARTICIPATION.....	259
ANNEXURE III.....	262
STUDY QUESTIONNAIRE.....	262
APPENDIX IV	266
INTERVIEW QUESTIONS.....	266
APPENDIX V	272
ETHICS APPROVAL LETTER OF STUDY	272
APPENDIX VI	274
TUT Research Ethics Committee Approval	274
APPENDIX VII	276

FRAMEWORK VALIDATION QUESTIONNAIRE276
APPENDIX VIII281
FRAMEWORK VALIDATION STATISTICAL ANALYSIS REPORT281

LIST OF FIGURES

Figure 1.1: Chapter outline	9
Figure 2.1: Stakeholder involvement	26
Figure 2.2: System integration	28
Figure 2.3: Triple Bottom Line	31
Figure 2.4: Stages of facility management transformation	61
Figure 2.5: Legislative framework	62
Figure 2.6: Suppliers' categorisation for facility managers.....	70
Figure 2.7: Theoretical framework elements.....	72
Figure 2.8: Stages of digital change	73
Figure 2.9: Digital data transformation diagram.....	73
Figure 2.10: Devices and digital transformation.....	74
Figure 2.11: Device transforming businesses.....	75
Figure 2.12: System integration.....	75
Figure 2.13: Enterprise infrastructure management	77
Figure 2.14: Facility management in universities	78
Figure 2.15: Facility management characteristics.....	79
Figure 2.16: FM approach	82
Figure 2.17: FM Values	83
Figure 2.18: FM model.....	85
Figure 2.19: Conceptual framework components	86
Figure 2.20: System Theory for integrated FM in higher education	89
Figure 2.21: PDCA model for UoT FM.....	90
Figure 2.22: Sustainability theory applied to FM in UoT	92
Figure 2.23: Conceptual framework.....	95
Figure 2.24: Conceptual model.....	100
Figure 3.1: Research process.....	105
Figure 3.2. Sampling strategies	113
Figure 4.1: Scree Plot.....	137
Figure 4.2: Sustainable Facility Management Framework.....	144
Figure 4.3: Scree Plot:.....	147
Figure 4.4: Scatter Plot	148
Figure 5.1: The thematic qualitative data analysis method.....	156
Figure 6.1: Pareto of factors contributing to poor FM in UoT	198

Figure 6.2: Parato Analysis of root causes to poor FM in UoT200
Figure 6.3: Fishbone Analysis of Poor FM.....203
Figure 6.4: LSS-Based Sustainable FM Framework for UoT210
Figure 6.5: The Structural Model216

LIST OF TABLES

Table 2.1: Lean, Six Sigma and Sustainability.....	16
Table 2.2: Synthesis matrix on lean tools for FM at UoT	45
Table 2.3 LSS-based Theoretical Sustainable FM Frameworks at UoT.	48
Table 2.4: Synthesis Green Campus FM Standards at UoT.....	50
Table 2.5: Strategic Facility Planning (SFP) Process Model.....	67
Table 2.6: IFMA Plans	69
Table 3.1: Summary of research paradigms.....	107
Table 3.2: Probability Sampling Techniques.....	109
Table 3.3: Non-Probability Sampling techniques	110
Table 3.4: UoT learning Sites	111
Table 4.1: Campus	125
Table 4.2: Age	125
Table 4.3: Level of Education	126
Table 4.4: Facility Default Classes at UoT.....	127
Table 4.5: Factors in Poor FM at UoT	128
Table 4.6: Root Causes of Poor FM in UoT.....	130
Table 4.7: Strategies for FM and Sustainability in UoT.....	131
Table 4.8: Lean, Six Sigma, VSM & Sustainability in UoT	132
Table 4.9: Sustainable FM Scheme for a South African University	133
Table 4.10: Exploratory and Reliability Analysis Results	135
Table 4.11: Correlation Analysis Results	139
Table 4.12: Discriminant Validity Results using the Fornell-Larcker Criterion.....	142
Table 4.13: Assessment of the Structural Model Results	143
Table 4.14: ANOVA Results of The Model	145
Table 4.15: Critical values for evaluating Mahalanobis distance values	149
Table 4.16: Residual Statistics	149
Table 4.17: Model Summary.....	150
Table 4.18: Regression Coefficients of the Model	150
Table 5.1: Demographic Characteristics.....	155
Table 5.2: Atlas.ti Excel Export.....	159
Table 6.1: Explanation of DMAIC phases	195
Table 6.2: Factors contributing to poor FM.....	197

Table 6.3: Root Causes of Poor FM in UoT.....	200
Table 6.4: Pareto Analysis of Poor FM Root Causes in UoT	201
Table 6.5: Pareto-based interventions.....	205
Table 6.6: Strategic intervention on factors contributing to poor FM.....	206
Table 6.7: Structural Equation Modelling Results	215
Table 7.1: Conclusion of study objectives.....	221

LIST OF ACRONYMS

4IR:	Fourth Industrial Revolution
5M:	Man, Machine, Method, Material, Measurement
5S:	Sort, Set in Order, Shine, Standardise and Sustain
AI:	Artificial Intelligence
AOEP:	Allocation, Optimisation, Enablement and Preservation
ANOVA:	Analysis of the Variance
AR:	Augmented Reality
AV:	Audio Video
BAS:	Building Automation Systems
BIM:	Building Information Modelling
BREEAM:	Building Research Establishment Environmental Assessment Method
CAFM:	Computer-Aided Facility Management
CCTV:	Closed-Circuit Television
CFMPF:	Campus Facility Management Performance Framework
CI:	Continuous Improvement
CMMS:	Computerised Maintenance Management System
COVID-19:	Coronavirus Disease
CSF:	Critical Success Factors
CST:	Critical System Thinking
DMAIC:	Define, Measure, Analyse, Improve, Control
AEHS:	Association for Environment, Health and Safety
EIM:	Enterprise Infrastructure Management
EMS:	Energy Management System
EMS:	Environmental Management Systems
FMIS:	Facility Management Information Systems
FMS:	Facility Management System
FM:	Facility Management
FMEA:	Failure Mode and Effects Analysis
GIS:	Geographic Information Systems
GLSS:	Green Lean Six Sigma
HEI:	Higher Education Institution
HOD:	Head of Department

HVAC:	Heating, Ventilation and Air Conditioning
ICT:	Information and Communication Technology
IFMA:	International Facility Management Association
IFM:	Integrated Facility Management
ISO:	International Organisation for Standards
IT:	Information Technology
KPI:	Key Performance Indicator
LCA:	Life Cycle Assessment
LEED:	Leadership in Energy and Environmental Design
LSS:	Lean Six Sigma
LED:	Light-Emitting Diode
MIS:	Management Information System
MFR:	Maintenance Fault Report
OHS:	Occupational Health and Safety
PDSA:	Plan, Do, Study and Act
PEOU:	Perceived Ease of Use
PO:	Purchase Order
POPI Act:	Protection of Personal Information Act
POE:	Post Occupancy Evaluation
PU:	Perceived Useful
RBV:	Resource-Based View
SDT:	Sustainable Development Theory
SFP:	Strategic Facilities Planning
SME:	Small and Medium Enterprises
SOP:	Standard Operating Procedure
SWOT:	Strengths, Weaknesses, Opportunities and Threats
UoT:	University of Technology
TAM:	Technology Acceptance Model
TBL:	Triple Bottom Line
TPM:	Total Productive Maintenance
TQM:	Total Quality Management
TUT:	Tshwane University of Technology
TTF:	Task-Technology Fit
UTAUT:	Unified Theory of Acceptance and Use of Technology

UNSDG: United Nations Sustainable Development Goals
VSM: Value Stream Mapping
WIP: Work in Progress

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 CHAPTER OVERVIEW

This chapter offers an overview of the study, outlines the problem that necessitated the research and presents the objectives and research questions guiding the investigation. In addition, it emphasises the importance and relevance of the study to the reader

1.2 INTRODUCTION AND BACKGROUND

1.2.1 Institutional Context and FM Challenges

Tshwane University of Technology (TUT) was established in 2004 following the merger of three independent institutions and is currently the largest contact higher education institution in South Africa. Operating across five provinces, Gauteng, Mpumalanga, Limpopo, Western Cape, and KwaZulu-Natal, TUT serves approximately 65,000 students and manages one of the largest student accommodation portfolios in the country, comprising accredited, leased, and university-owned facilities with more than 40,000 residence beds.

Despite this scale, TUT faces persistent facility management (FM) challenges that are characteristic of many higher education institutions (HEIs), particularly in developing contexts. Student accommodation infrastructure is under extreme pressure due to overcrowding, ageing and dilapidating buildings, incomplete construction projects, deferred maintenance and declining government funding (Chiodelli et al., 2021; Krishna et al., 2021). In South Africa, reduced state funding and increased financial strain on universities have further constrained institutions' ability to adequately maintain and refurbish facilities (Cele & Adewumi, 2024). As a result, poor FM practices have contributed to inadequate learning and living environments, cost inefficiencies and declining student satisfaction.

1.2.2 FM Practices and Model Limitations

Facility management is a multidisciplinary field that integrates people, place, process and technology to ensure the functionality, safety, comfort and efficiency of the built environment (Vukmirović & Gavrilović, 2020; Szelaḡowski & Berniak-Woźny, 2024). Within HEIs, effective FM is critical to supporting institutional missions, enabling teaching and learning, and ensuring the sustainability of physical assets. However, customer dissatisfaction with FM services remains common in universities, reflecting weaknesses in planning, execution and monitoring of FM processes (Zamora-Ramos, 2023).

Although several FM models and approaches have been proposed, many remain fragmented, reactive and insufficiently aligned with sustainability objectives and performance measurement requirements (Bucoń & Czarnigowska, 2021; Lin et al., 2022). Existing models often fail to integrate financial planning, maintenance prioritisation, operational efficiency and continuous improvement into a single coherent system. At TUT, poor FM has resulted in facilities that inadequately support organisational objectives, contribute to escalating costs, and lack readiness for future demand, particularly within student accommodation and support infrastructure.

1.2.3 Need for Performance-Driven Sustainable FM

A robust FM approach should not only optimise building operating costs but also enhance asset utilisation, service quality and long-term sustainability (Opoku & Lee, 2022). Effective FM requires strong managerial leadership, skilled personnel and systematic processes capable of balancing competing demands related to cost, quality, safety and sustainability (Goodermote, 2020). In practice, FM performance in HEIs should be assessed through ongoing monitoring of maintenance activities, energy consumption, asset condition assessments and alignment with institutional strategy (Lane, Cehlin & Thollander, 2024).

However, evidence from South African universities suggests that many facility challenges are not solely attributable to infrastructure age or environmental conditions, but rather to weak maintenance planning, inadequate staffing, limited training and

ineffective management practices (Ferreira & de Souza, 2021). These shortcomings have contributed to significant maintenance backlogs. For example, at TUT, a Finance Committee of Council report indicated that R37 050 067 was allocated from the government's Infrastructure Efficiency Fund in 2018 to address deferred maintenance backlogs, highlighting the scale of accumulated FM inefficiencies (TUT, 2018).

1.2.4 Lean Six Sigma in FM: Limited Application

Lean Six Sigma (LSS) is a performance-improvement methodology that integrates Lean principles of waste elimination with Six Sigma's focus on reducing process variation and defects. It has been widely applied in manufacturing and service environments to improve efficiency, reduce costs and enhance quality, often yielding measurable improvements in productivity and Return on Investment (ROI). The core improvement cycle of Lean Six Sigma is the Define–Measure–Analyse–Improve–Control (DMAIC) framework, which provides a structured and data-driven approach to problem solving.

Despite its proven benefits, Lean Six Sigma remains underutilised within facility management, particularly in higher education contexts. Studies indicate that FM processes often lack systematic measurement, root-cause analysis and continuous improvement mechanisms that are central to LSS methodologies (Dragone et al., 2021; Sahu et al., 2022). Sahu et al. (2022) argue that integrating Lean and Six Sigma enables organisations to identify inefficiencies, map FM processes, eliminate waste and sustain improvements across the FM value chain. However, at TUT, there is limited evidence of structured Lean Six Sigma adoption within FM operations, particularly in managing student accommodation, maintenance planning and financial efficiency.

1.2.5 Empirical Evidence of FM Deficiencies

Empirical studies have consistently reported deteriorating conditions of student accommodation and support facilities in South African universities, including poor fixtures, fittings and communal spaces (Dragone et al., 2021; Krishna et al., 2021). et al. (2023) further highlight that ineffective FM processes contribute to prolonged

response times, poor service coordination, and escalating operational costs in institutional settings. These deficiencies negatively affect students' academic experiences, leading to frustration, delays, and declining satisfaction with university services (Mat Noor et al., 2024).

Facilities such as laboratories, clinics, computer systems and recreational spaces frequently experience operational failures due to inadequate maintenance and monitoring systems. In the context of digital transformation, universities are increasingly expected to adopt advanced systems and applications to support real-time FM monitoring and decision-making; however, many existing FM frameworks are not sufficiently upgraded to meet these operational demands (Alrubaidi, 2024).

1.2.6 Research Gap and Rationale for the Study

While the literature acknowledges the importance of sustainable facility management and the potential of Lean Six Sigma in improving organisational performance, there is a notable absence of empirically validated, integrated FM frameworks tailored to universities of technology in South Africa. Existing FM models remain fragmented and rarely incorporate Lean Six Sigma principles within a sustainability-oriented, performance-driven structure. Furthermore, there is limited empirical evidence demonstrating how specific facility defaults, contributing factors and root causes interact with improvement strategies to influence sustainable FM outcomes.

This study addresses this gap by developing and validating a Lean Six Sigma-based sustainable facility management framework for a university of technology, using Tshwane University of Technology as a case study. By integrating quantitative modelling and qualitative insights, the study seeks to provide a context-specific, systematic, and evidence-based framework capable of addressing persistent FM inefficiencies, enhancing sustainability and improving institutional performance.

1.3 PROBLEM STATEMENT

Tshwane University of Technology (TUT), established in 2004 through the merger of three institutions, is South Africa's largest contact university, serving more than 65,000

students across five provinces (Blanár, 2023). Despite its extensive physical infrastructure and strategic role in national skills development, the institution has experienced persistent and systemic facilities management (FM) challenges. These challenges include overcrowded and deteriorating student accommodation, deferred maintenance, inefficient FM practices, and limited integration of data-driven management systems.

The consequences of these FM challenges extend beyond operational inconvenience and have had direct and measurable implications for institutional performance, student welfare, financial sustainability and strategic alignment. Poorly maintained and overcrowded facilities have adversely affected student living and learning conditions, contributing to dissatisfaction, reduced well-being and disruptions to academic progression. From an institutional perspective, ineffective FM practices have resulted in escalating maintenance backlogs, unplanned expenditure, inefficient allocation of limited financial resources, and reduced return on infrastructure investment. These inefficiencies have constrained TUT's ability to align its facilities portfolio with its long-term strategic objectives, including sustainability, digital transformation and service excellence.

Furthermore, deferred maintenance and reactive FM approaches have increased lifecycle costs of facilities, undermining cost efficiency and placing additional pressure on already declining government funding. The absence of an integrated, performance-driven FM framework has limited management's ability to proactively identify facility defaults, address contributing factors, and eliminate root causes of poor FM performance. As a result, FM at TUT has remained largely fragmented, reactive and insufficiently aligned with institutional strategy.

Although international studies have demonstrated the value of smart campus technologies, sustainable FM practices and Lean Six Sigma-based process improvement in higher education institutions (Matarneh et al., 2020; Alyoussef, 2023; Samsurijan & Rohayati, 2024), there has been limited empirical application of these approaches within South African universities, particularly universities of technology. At TUT specifically, Lean Six Sigma principles had not been systematically applied to FM

to address inefficiencies, improve sustainability outcomes or support evidence-based decision-making.

The absence of a context-specific, empirically validated and integrated sustainable FM framework at TUT therefore constituted a critical institutional gap. Without such a framework, FM challenges continued to negatively affect student welfare, institutional performance and financial efficiency, while weakening the university's capacity to achieve its strategic and sustainability objectives. This study was undertaken to address this gap by developing and validating a Lean Six Sigma-based sustainable facility management framework tailored to the operational realities of Tshwane University of Technology.

1.4 SIGNIFICANCE OF THE STUDY

This study contributes to facilities management (FM) scholarship and practice by developing and empirically grounding a Lean Six Sigma-based sustainable FM framework tailored to the context of the Tshwane University of Technology (TUT). In response to persistent infrastructure deterioration, inefficient maintenance practices and rising operational costs within TUT's extensive campus and student accommodation portfolio, the study provides a structured, evidence-based approach to improving FM performance in a resource-constrained public higher-education environment.

At a conceptual level, the study advances existing knowledge by integrating Lean, Six Sigma and sustainability principles into a unified framework for higher-education FM in the Global South. While Lean Six Sigma has been widely applied in manufacturing and selected service sectors, its systematic application within university FM remains underdeveloped. This research extends theory by demonstrating how the DMAIC methodology can be adapted to address the complexity, interdependencies and service-oriented nature of FM in universities.

Methodologically, the study contributes by illustrating how empirical FM data, stakeholder perceptions and analytical techniques can be translated into a practical improvement framework. The research strengthens analytical rigour by explicitly

linking data collection, analysis and framework development, offering a replicable approach for other universities seeking to design context-specific FM solutions.

From a practical and managerial perspective, the study delivers a usable decision-support framework that enables FM managers and institutional leaders to enhance maintenance responsiveness, optimise resource utilisation and align FM operations with institutional strategy, student well-being and sustainability objectives. For TUT, the framework provides a clear roadmap for modernising FM systems, reducing reactive maintenance and improving service reliability.

At a broader level, the study contributes to higher-education policy and governance discourse by providing evidence to support sustainable infrastructure investment, accountability and performance improvement in public universities. Overall, the study fills a critical gap in the FM literature by offering a context-specific, empirically informed framework that strengthens the long-term effectiveness and resilience of facilities management in higher education.

1.5 AIM AND OBJECTIVES OF THE STUDY

1.5.1 Primary objective

The aim of the study was to develop a sustainable facility management framework using the Six Sigma DMAIC approach for the University of Technology in South Africa.

1.5.2 Secondary Objectives

To achieve the aim of the study, the following secondary objectives were pursued at Tshwane University of Technology (TUT):

- The study assessed the various classes of facility defaults present at Tshwane University of Technology.
- The study evaluated the factors contributing to poor management of facilities at Tshwane University of Technology.

- The study determined the root causes of poor facility management practices at Tshwane University of Technology.
- The study identified and assessed suitable strategies and practices for the effective maintenance of facilities at Tshwane University of Technology.
- The study developed and validated a sustainable facility management framework based on Lean Six Sigma techniques for Tshwane University of Technology.

1.6 RESEARCH QUESTIONS

The following research questions will be addressed in this study:

- What classes of facility defaults were identified at the Tshwane University of Technology?
- Which key factors contributed to poor facilities management within the Tshwane University of Technology?
- What underlying root causes accounted for recurring issues in facility management at the Tshwane University of Technology?
- Which strategies and best practices were identified to improve the effectiveness and efficiency of facility maintenance at the Tshwane University of Technology?
- How were Lean Six Sigma methodologies applied to develop a sustainable facility management framework for the Tshwane University of Technology?

1.7 OUTLINE OF THE THESIS

The following chapters will be elaborated in the current study.

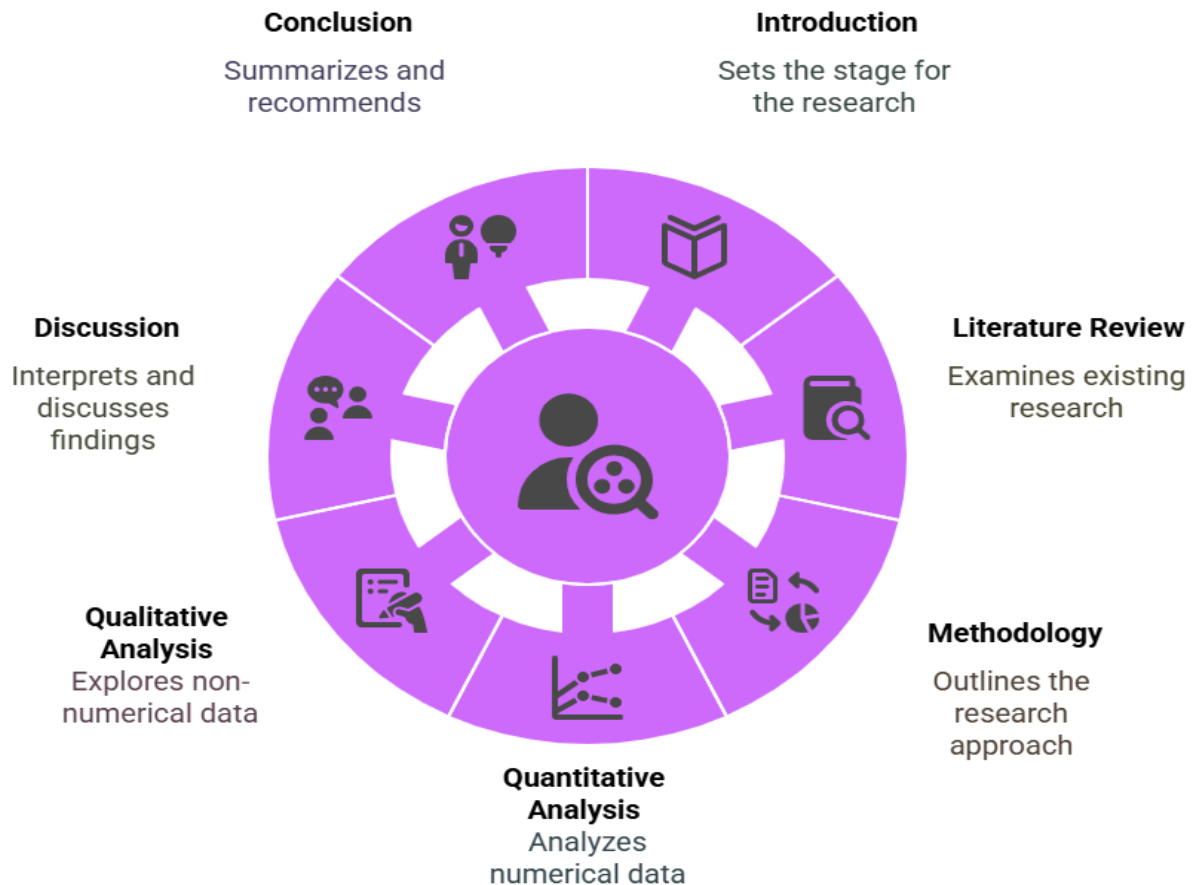


Figure 1.1: Chapter outline

The research is structured into the following chapters, each serving a specific purpose in advancing the study’s objectives.

Chapter One: Introduction of the study

This chapter presents the introduction and background to the study. The research problem statement and research objectives have been stated as well as the rationale of the study. This chapter thus outlines the scope and focusses of the study.

Chapter Two: Literature review and theoretical framework

This chapter explores relevant existing literature relating to the policy frameworks and Lean Six Sigma. This chapter helps to locate this study as a contribution to other studies on the subject. This chapter also presents the theoretical framework that drives the study. This chapter helps in understanding the frameworks that explore sustainability management. It also helps the study to construct a suitable framework that can be used for the study area.

Chapter Three: Methodology

This chapter outlines the methodology adopted to explore the facility management challenges and the development of a sustainable framework at Tshwane University of Technology. It details the research approach and design, explaining how the study was structured to address the research problem effectively. The chapter describes the sampling strategy, including the selection criteria and sample size and provides an overview of the research instruments used for data collection. It explains the procedures followed during the data collection process and elaborates on the techniques employed for data analysis. The methodology focuses on ensuring validity, reliability and alignment with the overall research objectives. The statistical analysis was conducted to validate sustainable facility management using Lean Six Sigma at a university of technology.

Chapter Four: Quantitative results

This chapter presents the quantitative data that the study gathered. The presentation of the data analysis forms a foundation for the discussion, analysis and interpretation of data.

Chapter Five: Qualitative results

This chapter presents the qualitative data that the study gathered based on the interviews with the University staff members and student leaders.

Chapter Six: Results discussion, synthesis and framework development

This chapter presents a comprehensive discussion and interpretation of the data gathered and analysed in the previous chapter. This chapter focuses on the synthesis of Literature, quantitative and qualitative analysis. The purpose of this chapter is to interpret the findings in relation to the study's objectives and research questions while linking them to the existing body of literature and the theoretical framework underpinning the research. By analysing the empirical evidence, this chapter aims to provide insight into the underlying issues affecting facility management in the South African University of Technology and to explain how the Lean Six Sigma approach can be effectively utilised to develop a sustainable facility management framework. Later, the framework validation was discussed.

Chapter Seven: Conclusions and recommendations

The final chapter brings the study to a close by presenting a comprehensive summary of the key findings, drawing conclusions based on the data analysis and offering practical recommendations. It reflects on the research objectives, evaluates whether they were achieved and discusses the implications of the results for facility management at Tshwane University of Technology. The chapter also proposes actionable strategies grounded in Lean Six Sigma principles to address identified challenges and improve sustainability in facilities management. Furthermore, it outlines potential areas for future research, contributing to the ongoing discourse in higher education infrastructure and operational excellence.

1.8 CHAPTER SUMMARY

This chapter introduced the study by providing a comprehensive background to the challenges of facilities management (FM) within higher education institutions, focusing on the Tshwane University of Technology (TUT). It highlighted persistent issues such as overcrowded and deteriorating student residences, deferred maintenance and disjointed operational practices, all compromising service quality and institutional efficiency. The problem statement underscored the urgency of addressing these FM shortcomings, especially in declining public funding and increasing student demands. The chapter articulated the central aim of the study to develop a sustainable FM framework using Lean Six Sigma techniques and outlined key research objectives and questions that guided the inquiry. The chapter emphasised the significance and potential impact of the study, arguing that integrating Lean Six Sigma methodologies offers a viable solution for improving operational performance, sustainability and service delivery in university settings. Lastly, it outlined the expected contribution of the research to academic literature and practical implementation in sustainable facilities management.

CHAPTER TWO

LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

This chapter reviews literature that provides a foundation for understanding facility management (FM) in South African universities of technology, with a focus on sustainability challenges and operational inefficiencies. It critically examines scholarship on FM, sustainable facility management (SFM), and the use of Lean Six Sigma (LSS) in higher education, while developing the theoretical and conceptual basis of the study. Key themes include the evolving role of FM in universities of technology, sustainability requirements in infrastructure operations, and the increasing relevance of continuous improvement approaches such as LSS. The chapter further explores LSS as a data-driven process improvement methodology capable of reducing waste, minimising variation, and improving operational efficiency in complex higher education environments. Drawing on empirical studies from higher education, facility operations, and sustainability contexts, the review highlights successful applications of LSS and identifies a notable gap in its use to develop FM frameworks suited to South African universities of technology.

Addressing this gap, the study proposes a context-specific and sustainable FM framework that integrates LSS tools, including DMAIC, value stream mapping, and root cause analysis, to support operational excellence and institutional transformation. The chapter is structured into four sections: FM in higher education institutions; the theory and application of Lean Six Sigma; the integration of Lean Six Sigma with sustainable facility management; and the theoretical frameworks underpinning the study. It concludes with a synthesis of the key insights from the literature.

2.2 CONCEPTS OF LEAN SIX SIGMA

Lean Six Sigma (LSS) is an integrated continuous improvement methodology that combines Lean thinking and Six Sigma principles to enhance operational efficiency, quality and organisational performance. Lean focuses on eliminating non-value-adding activities to maximise customer value, whereas Six Sigma emphasises reducing

process variation and defects through structured, data-driven analysis (Yadav et al., 2023). The integration of these complementary philosophies enables organisations to streamline processes while improving accuracy, reliability and consistency.

Lean thinking originates from the Toyota Production System (TPS) and is grounded in the systematic elimination of muda (waste), mura (variation) and muri (overburden) to optimise workflow efficiency (Rymaszewska, 2022). Core Lean tools, including 5S, Value Stream Mapping (VSM) and Just-in-Time (JIT), facilitate process visualisation and enable the identification and removal of inefficiencies across value chains (Scala et al., 2021). In contrast, Six Sigma employs the DMAIC (Define, Measure, Analyse, Improve, Control) framework and advanced statistical techniques such as control charts, regression analysis and Design of Experiments (DoE) to ensure process capability and sustained performance improvement (Alghuried et al., 2024).

The link between Lean and Six Sigma is widely recognised as a strategic advantage, particularly in service-oriented and complex operational environments where quality, timeliness and resource optimisation are critical (Francescato et al., 2023). Six Sigma's structured problem-solving approach complements Lean's waste-reduction philosophy, making LSS adaptable across both manufacturing and non-manufacturing contexts (Yadav et al., 2023). Empirical evidence further indicates that organisations implementing LSS achieve measurable improvements in customer satisfaction, cost efficiency and employee engagement, reflecting both internal and external performance gains (Sordan et al., 2022).

A defining feature of LSS is its emphasis on proactive, data-driven decision-making. Rather than relying on reactive quality control, LSS promotes systematic root-cause analysis through tools such as Failure Mode and Effects Analysis (FMEA) and Statistical Process Control (SPC), enabling early identification of risks and process weaknesses (Alghuried et al., 2024). However, successful implementation depends heavily on leadership commitment, staff capability development and an enabling organisational culture (Francescato et al., 2023). Common challenges include resistance to change, inadequate training and weak strategic alignment (Scala et al., 2021).

Recent literature increasingly emphasises the strategic alignment of LSS with organisational objectives, digital transformation and sustainability agendas. The emergence of Green Lean Six Sigma (GLSS) highlights the growing integration of environmental responsibility into operational excellence frameworks (Yadav et al., 2023). This evolution reflects the transition of LSS from a manufacturing-centred methodology to a multidimensional, cross-sectoral framework with continued relevance in complex, resource-constrained and sustainability-focused environments. The literature establishes Lean Six Sigma as an effective methodology for improving efficiency, quality and sustainability across multiple sectors. However, most empirical evidence is drawn from manufacturing and healthcare, with limited focus on facilities management in higher education. Existing studies also prioritise operational outcomes, often overlooking institutional context, governance and resource constraints. Empirical evidence on Lean Six Sigma application in facilities management at South African Universities of Technology remains scarce, highlighting the need for context-specific research to support its integration into sustainable facility management frameworks.

2.3 INTEGRATING LEAN SIX SIGMA INTO FACILITY MANAGEMENT

The integration of Lean Six Sigma into Facility Management (FM) has gained increasing attention as higher education institutions seek to improve operational efficiency, sustainability and service quality. FM environments, particularly within universities, are characterised by complex infrastructure systems, diverse stakeholder demands and constrained resources, making them well-suited to structured improvement methodologies such as LSS. By combining Lean's waste-reduction focus with Six Sigma's analytical rigour, LSS provides FM departments with tools to diagnose inefficiencies, optimise resource utilisation and enhance service delivery.

Despite its potential benefits, the integration of LSS into FM presents several challenges. Organisational resistance to change, limited financial and human resources, and insufficient methodological expertise among FM personnel often hinder effective implementation. In the South African University of Technology context, these challenges are compounded by institutional structures, regulatory constraints and contextual socio-cultural dynamics. Addressing these barriers requires a

comprehensive change management approach underpinned by leadership commitment, stakeholder engagement and sustained capacity development.

The increasing digitalisation of FM operations introduces both opportunities and complexities for LSS integration. Bardu et al. (2024) highlight challenges associated with data integration, system interoperability and the absence of standardised FM platforms, which impede the implementation of holistic FM strategies. Issues such as system obsolescence, cybersecurity risks and fragmented data environments necessitate strategic technology selection and lifecycle planning to support long-term FM sustainability.

At the same time, sustainability has become a central concern in FM, particularly within universities seeking to align with global environmental benchmarks. Radebe and Ozumba (2021) identify limited awareness, weak senior management commitment and budgetary constraints as key barriers to sustainable FM practices. These limitations hinder alignment between FM operations and institutional sustainability goals and underscore the need for policy-driven support mechanisms and greater organisational accountability.

Technological innovations offer viable pathways for strengthening LSS-driven FM practices. The adoption of Internet of Things (IoT) technologies has enabled real-time monitoring, predictive maintenance and energy optimisation within FM systems. Li et al. (2021) demonstrate that IoT-based energy management systems enhance decision-making by providing continuous, data-driven insights, enabling FM units to shift from reactive to proactive maintenance strategies. Such digital enablers enhance LSS effectiveness by improving measurement accuracy and process control.

Empirical studies increasingly illustrate the tangible benefits of LSS integration in university FM contexts. Ratvasky and Furterer (2024) report significant improvements in service efficiency and resource utilisation following LSS implementation in university facility services. Similarly, Fernandes et al. (2024) show that integrating Lean principles with Industry 4.0 technologies, including Computerised Maintenance Management Systems (CMMS), enhances maintenance planning and inventory control while reducing operational waste.

Emerging research highlights the growing convergence of Lean Six Sigma (LSS), digitalisation, and sustainability. Integrating artificial intelligence and advanced analytics has been shown to strengthen LSS effectiveness and support organisational adaptability in rapidly evolving technological environments (Wankhede & Agrawal, 2025). Beyond efficiency improvements, LSS also contributes to enhanced occupational health and safety outcomes. Studies indicate that combining DMAIC and Value Stream Mapping with ergonomic principles improves productivity while protecting employee well-being, which is particularly important in physically demanding facilities management roles (Vicente et al., 2024). The successful application of LSS in facilities management is closely linked to leadership commitment and employee engagement. Sustained performance improvements are more likely when data-driven decision-making is reinforced by participative leadership and continuous staff involvement (Bagherian et al., 2025). Gomaa’s (2025) systematic review further reinforces the adaptability of LSS across sectors, cautioning that without continuous performance measurement and control mechanisms, early improvements may not be sustained. Within this context, the DMAIC framework plays a pivotal role in embedding continuous improvement in FM operations. By providing a structured approach to problem definition, analysis, and control, DMAIC closely aligns with established quality and sustainability models, including Total Quality Management (TQM), ISO standards, and the Plan-Do-Study-Act (PDSA) cycle. This alignment positions LSS as a robust, integrative framework that can support sustainable FM transformation within higher education institutions. The Lean methodology, for instance, follows the Plan-Do-Study-Act (PDSA) cycle, while Six Sigma applies the DMAIC structure outline in

Table 2.1: Lean, Six Sigma and Sustainability (Kumar et al., 2023)

LEAN Approach	Environmental Performance	SIX Approach	SIGMA
Plan	Set Priorities and map impacts	Define	
Do	Determine data needs and select relevant indicators	Measure	
Study	Observe facility operations Products evaluation	Analyse	
Act	Results understanding Performance enhancement	Improve	
		Control	

Lean Six Sigma (LSS) is an integrated improvement methodology that combines the waste-reduction principles of Lean with the defect-reduction strategies of Six Sigma. It uses the DMAIC (Define, Measure, Analyse, Improve, Control) cycle to reduce variability and enhance process efficiency (Olutade, Adeyinka & Durodola, 2023). The articulation between Lean and Six Sigma enables organisations to not only improve quality and performance but also to deliver greater value to customers through streamlined processes and reduced operational costs. Systematic reviews of Lean Six Sigma implementation reveal its cross-sectoral relevance and adaptability across manufacturing, healthcare, services and sustainability-focused contexts (Tampubolon & Purba, 2021; Ghasemibojd & Franchetti, 2025).

Tampubolon and Purba (2021) analysed over 50 case studies and found that LSS improves customer satisfaction, enhances productivity and reduces lead times in manufacturing, healthcare and services. The review also highlights that successful LSS implementation often requires customisation to organisational culture, industry requirements and workforce capability factors that influence the depth and pace of LSS adoption. Recent studies have positioned LSS as a dynamic organisational capability, especially during times of disruption. Ndrecaj *et al.* (2023) argue that LSS supports sustainable performance in uncertain environments by fostering real-time responsiveness, process resilience and continuous improvement. Their findings emphasise that LSS not only reduces cost but also equips organisations to adapt to crises such as pandemics and supply chain volatility, making it a strategic asset beyond operational efficiency.

LSS is increasingly recognised for its contributions to environmental and social sustainability. According to Huang *et al.* (2023), LSS facilitates sustainable manufacturing by reducing waste, emissions and energy consumption. Moreover, its structured problem-solving approach enhances employee engagement and promotes a culture of accountability and innovation. These findings reinforce the growing relevance of LSS in advancing the triple bottom line, people, planet and profit. Small and medium-sized enterprises (SMEs) are also leveraging LSS for operational gains. A recent systematic review by Sumant *et al.* (2024) shows that LSS significantly enhances process performance, cost savings and product quality in SMEs, despite their resource constraints. The study cautions that limited technical expertise and

change resistance remain barriers to sustained implementation. Future research should focus on building scalable LSS models tailored to SME contexts. The literature demonstrates that Lean Six Sigma can significantly enhance facility management performance through improved efficiency, digital integration and sustainability outcomes. However, much of the empirical evidence is drawn from manufacturing, healthcare and selected service settings, with limited application to facilities management in higher education. Existing studies also tend to focus on isolated tools or technologies rather than integrated, institution-wide FM systems. In the context of South African Universities of Technology, empirical evidence on how Lean Six Sigma can be systematically embedded within sustainable FM practices remains limited. This gap highlights the need for an integrated, context-specific framework that aligns Lean Six Sigma with institutional constraints, sustainability objectives and FM operational realities.

2.4 LEAN THINKING AND SIX SIGMA WITH GREEN PRACTICES

The integration of Lean thinking and Six Sigma with environmental sustainability principles has emerged as Green Lean Six Sigma (GLSS), a comprehensive methodology aimed at simultaneously improving operational performance and ecological outcomes. Lean eliminates non-value-adding activities, while Six Sigma reduces process variability through statistical control; when aligned with green practices, these approaches collectively support quality, efficiency and environmental stewardship within the DMAIC (Define, Measure, Analyse, Improve, Control) structure (Kaswan & Rathi, 2021). GLSS thus extends traditional continuous improvement by embedding sustainability considerations directly into process optimisation.

Empirical studies demonstrate the effectiveness of structured GLSS frameworks across multiple sectors, particularly manufacturing and healthcare. Gomaa (2023) developed a GLSS model that integrates green performance indicators, life-cycle thinking and tools such as Failure Mode and Effects Analysis (FMEA) into Lean Six Sigma initiatives, achieving an improvement in a facility's sustainability index from 72.1% to 93.8%. Similarly, Nagadi (2022) reported successful GLSS implementation in healthcare settings, resulting in reduced medical waste, improved energy efficiency and enhanced patient throughput. These outcomes indicate that GLSS enables

organisations to realise simultaneous operational and environmental gains. Key drivers of adoption include regulatory pressures, institutional sustainability objectives and the pursuit of integrated economic–environmental performance (Yadav et al., 2023).

From an environmental performance perspective, GLSS delivers measurable reductions in energy consumption, greenhouse gas emissions and material waste, particularly when supported by data analytics and employee engagement (Huang et al., 2023). By adapting Lean and Six Sigma tools to environmental objectives, organisations can improve ecological indicators without compromising process reliability or customer satisfaction. Furthermore, GLSS supports circular economy principles by promoting resource efficiency and sustainable production and consumption patterns (Yadav et al., 2023).

Despite these benefits, GLSS implementation remains challenging. Integrating green metrics into traditional DMAIC phases introduces methodological complexity, while limited green-specific training and sectoral differences constrain effective deployment (Yadav et al., 2023). Consequently, scholars call for the development of standardised yet sector-sensitive GLSS frameworks that balance scalability with contextual flexibility, enabling wider adoption across diverse operational environments.

2.5 LEAN SIX SIGMA APPLICATION

Lean Six Sigma (LSS) sits at the intersection of efficiency and quality, combining Lean's waste-reduction principles with Six Sigma's focus on precision and process control. Within Higher Education Institutions (HEIs), LSS has increasingly been adopted to improve administrative, academic, and support services by streamlining processes, enhancing service delivery, and fostering a culture of continuous improvement. Between 2020 and 2025, growing performance pressures prompted many HEIs to explore LSS implementation, leading to increased scholarly attention on the critical success factors (CSFs) that influence its effectiveness. Empirical studies consistently highlight leadership commitment, effective communication, employee involvement, and continuous training as central to successful LSS adoption in universities (Rasheed, 2025). Research conducted in public HEIs further demonstrates that these factors are interdependent: top management commitment strengthens

communication and staff engagement and reinforces the need for a system-wide, collaborative approach to LSS implementation (Gastelum-Acosta et al., 2023). Leadership is particularly influential, with evidence that sustained improvement depends on visible leadership, strategic direction, and ongoing support to embed LSS in institutional culture (Rasheed, 2025). Beyond conceptual models, case studies illustrate the practical value of LSS in higher education settings. Applications of the DMAIC methodology have led to measurable efficiency gains and improved user satisfaction in academic support services, demonstrating LSS's adaptability across diverse university functions (Sunder, 2020). Other studies show that embedding LSS principles into institutional policy and planning enables universities to align operational improvement with broader national development objectives (Tsapi, 2025). Collectively, the literature positions LSS as a structured and effective pathway for HEIs seeking to achieve excellence with constrained resources. Within facilities management (FM), LSS has proven effective in improving maintenance efficiency, optimising space utilisation, reducing energy waste, and improving response times to facility-related issues (Samanta & Gurumurthy, 2023; Gooma, 2023). While universities in countries such as the United Kingdom and India have reported successful LSS integration into FM practices, its application within South African universities of technology remains limited (Tissir et al., 2023). Nevertheless, its potential lies in generating data-driven insights that support operational efficiency, cost control, and environmental reporting.

The integration of LSS with Green Facility Management (GFM) offers a synergistic approach to achieving both sustainability and efficiency objectives. Green FM prioritises environmental stewardship, while LSS introduces structure, standardisation, and accountability to sustainability initiatives (Mabrouk & Ibrahim, 2021). Tools such as Value Stream Mapping can be used to analyse energy and water consumption across campuses, while digital technologies, including Building Information Modelling, Internet of Things applications, and predictive analytics, enable real-time monitoring, predictive maintenance, and automated sustainability reporting (Saleh et al., 2024). For South African universities of technology, a strategic framework for integrating LSS and GFM must address leadership, governance, stakeholder engagement, and contextual constraints, including regulatory compliance, institutional capacity, and funding availability. Although national policy encourages sustainable infrastructure development, there is limited guidance on the operational integration of methodologies

such as LSS (DHET, 2022). A practical framework should therefore be built on four pillars: leadership and governance for sustainability; operational excellence through LSS tools; environmental performance measurement; and digital integration supported by data analytics. The literature strongly supports the integration of Lean Six Sigma into Green Facility Management strategies within South African universities of technology. A context-specific framework that integrates process excellence, environmental accountability, leadership commitment, and digital innovation can enhance the sustainability, effectiveness, and resilience of FM operations while positioning universities as leaders in sustainable institutional transformation.

2.6 FACILITY MANAGEMENT IN HIGHER EDUCATION

In recent years, Universities of Technology (UoTs) have redefined their approach to facility management (FM), moving from traditional maintenance-focused models to more integrated, forward-looking frameworks. This shift reflects growing recognition of FM's role in sustaining infrastructure, enhancing operational performance, and improving campus usability. Pressures arising from ageing facilities and the expectations of digitally literate students have further encouraged the adoption of holistic and technology-driven FM approaches (Mahmoud et al., 2024). A central feature of this transformation is the increasing use of digital technologies such as Building Information Modelling (BIM) and Augmented Reality (AR). Studies show that integrating open BIM with AR enables real-time visualisation of building systems, improves access to maintenance information, and reduces operational delays compared to conventional FM practices (Chung et al., 2021). For UoTs, where scalability and technical innovation are critical, these tools offer practical solutions to complex infrastructure management challenges. Alongside this, research emphasises the importance of embedding FM requirements at the early design stage. Integrating FM data into 3D design models enhances lifecycle planning, traceability, and proactive maintenance, providing long-term strategic benefits for institutions managing extensive and technically complex campuses (Macia Perez et al., 2021). Innovative approaches to managing existing infrastructure have also emerged through the use of reality capture technologies. Point cloud-based FM frameworks enable accurate modelling of legacy buildings, allowing institutions to document assets precisely and address maintenance needs where records are incomplete or outdated (Duong & Lin, 2022).

These developments align with broader trends that position FM as a strategic contributor to sustainability, energy efficiency, healthy indoor environments, and user satisfaction (Mahmoud et al., 2024). Effective implementation, however, depends on sustained investment in maintenance capacity and technological adaptation. Performance-oriented FM frameworks have further strengthened this shift. The Campus Facility Management Performance Framework provides a structured, multidimensional approach to evaluating FM performance across areas such as workforce capability, digital integration, communication, and environmental responsibility (Schultz & Klungseth, 2022). Such frameworks support evidence-based decision-making and help align FM practices with institutional strategy, which is particularly important for UoTs with complex technical and academic infrastructure demands. The literature indicates a clear shift towards digitally enabled, performance-driven FM in higher education. However, much of the existing evidence is drawn from well-resourced institutions in developed contexts, limiting its applicability to South African Universities of Technology. Current studies often emphasise technological capability while giving limited attention to contextual challenges such as funding constraints, governance complexity, and maintenance backlogs. Empirical research that incorporates these realities into FM frameworks for UoTs remains scarce, underscoring the need for context-specific models that align digital innovation with sustainable facility management practices.

2.7 SUSTAINABLE FACILITY MANAGEMENT (SFM)

Sustainable Facility Management (SFM) has gained increasing prominence in South Africa and internationally since 2020, as higher education institutions face growing pressure to operate in environmentally responsible and resource-efficient ways. Sustainability in FM has shifted from a peripheral concern to a strategic priority, prompting universities to reassess how they manage physical assets, energy use, and campus infrastructure. As a result, sustainability is increasingly embedded within the core FM practices rather than treated as an additional or isolated initiative. Contemporary SFM strategies include energy-efficient lighting, water-conservation technologies, and paperless administrative systems. However, the goal of SFM extends beyond visible environmental actions to supporting net-zero energy

objectives, waste reduction, and improved building performance (Opoku & Lee, 2022). When supported by data-driven technologies, SFM enables universities to monitor and manage key sustainability indicators, such as energy and water consumption, thereby facilitating continuous improvement across the facility lifecycle. Despite these advances, SFM implementation remains uneven, particularly in developing contexts. Common barriers include limited sustainability awareness, weak senior management commitment, financial constraints, skills shortages, and time pressures, all of which hinder effective adoption (Radebe & Ozumba, 2021). Addressing these challenges requires more than conceptual models; it demands empirical evidence, supportive institutional policies, and targeted capacity-building initiatives. Technological innovation has emerged as a key enabler of sustainable campus operations. Intelligent monitoring systems and occupancy-based data allow FM units to optimise maintenance planning and energy management through informed, proactive decision-making. While the literature confirms the importance of SFM in improving environmental and operational performance, much of the existing research remains conceptual or technology-focused, with limited empirical insight into how sustainability is embedded in everyday FM processes. In South African Universities of Technology, structural constraints such as limited funding, capacity shortages, and competing priorities further complicate implementation. These gaps highlight the need for an integrated, performance-driven approach that embeds sustainability into routine facility management practices.

2.8 FACILITY MANAGEMENT CHALLENGES

Facility management (FM) is increasingly recognised as a strategic function central to the efficiency, sustainability, and safety of the built environment. FM professionals, however, continue to face persistent challenges in delivering high-quality services under growing operational and resource constraints. Common problems include operational inefficiencies such as delayed work-order processing and inconsistent quality control, which contribute to rising maintenance costs, reduced occupant satisfaction, and declining asset reliability (Santos et al., 2025). Digital technologies, particularly Building Information Modelling (BIM) and Internet of Things (IoT) applications, offer significant opportunities to improve FM performance. Yet their adoption is often constrained by fragmented data systems, interoperability issues, and

skills shortages, which limit the effective use of real-time analytics, space optimisation, and predictive maintenance (Barbu et al., 2024). As a result, many FM units struggle to realise the full value of investments in smart building infrastructure. Sustainability presents an additional challenge, as energy use and waste management account for a large proportion of operating costs. Facilities are required to meet environmental standards while maintaining financial viability, a balance that is increasingly difficult due to inflationary pressures and global supply chain disruptions. Workforce shortages further compound these challenges. Skills gaps driven by retirements, weak talent pipelines, and limited upskilling have reduced operational responsiveness and eroded institutional knowledge, particularly in technically specialised maintenance areas (Areesophonpichet, 2024). Securing executive support for digital systems such as Computer-Aided Facility Management platforms also remains difficult, where returns on investment are unclear.

The growing digitisation of FM has introduced new cyber risks. Integrating building automation systems with external networks increases exposure to cyber threats, which are often insufficiently addressed in traditional FM practices (Li et al., 2022). At the same time, compliance with environmental, health, and safety standards remains uneven, especially where staff awareness and enforcement mechanisms are weak. Addressing these challenges requires integrated risk governance and stronger cyber-physical resilience. The literature identifies a complex set of interrelated challenges affecting FM, including operational inefficiencies, sustainability pressures, workforce constraints, and digital risks. However, these issues are often examined in isolation, limiting understanding of their combined impact. In Universities of Technology, where ageing infrastructure and resource constraints are common, such challenges are likely to be more acute. This gap underscores the need for an integrated analytical approach that addresses the systemic nature of facility management challenges in higher education.

2.9 FACTORS CONTRIBUTING TO EFFECTIVE FACILITY MANAGEMENT

Facility management has progressively evolved from an operational support function into a strategic organisational capability that directly influences institutional performance, service quality and long-term sustainability. This evolution has been

driven by a convergence of interrelated factors, including governance and leadership commitment, stakeholder participation, technological integration, financial planning, regulatory compliance and environmental stewardship. Within higher education institutions, these factors do not operate in isolation; rather, they interact dynamically to shape how facilities are planned, operated, maintained and optimised. Effective facility management, therefore, requires aligning strategic objectives with day-to-day operational practices, supported by innovation, data-driven decision-making, and active stakeholder engagement.

This section synthesises and discusses the key factors contributing to effective facility management, as identified in the literature and the study's empirical findings. The discussion establishes a conceptual foundation for subsequent analysis and demonstrates how these factors collectively inform the development of the proposed facility management framework.

2.9.1 Stakeholders' involvement

In any development or transformation process, especially in facility management, change cannot succeed without the involvement of those most affected. Stakeholders, particularly those engaged in day-to-day operations, must be fully included in shaping new strategies or systems, as they are the ones who will ultimately implement and sustain these changes. As organisations move toward digital transformation, early and active stakeholder participation becomes even more critical. During the early phases, such as defining system requirements, conceptual design, verification and validation, stakeholder input is crucial in ensuring that the systems are functional, relevant and future proof. Although their involvement might taper off in the later stages, like operations and maintenance, their initial contributions are vital for long-term success.

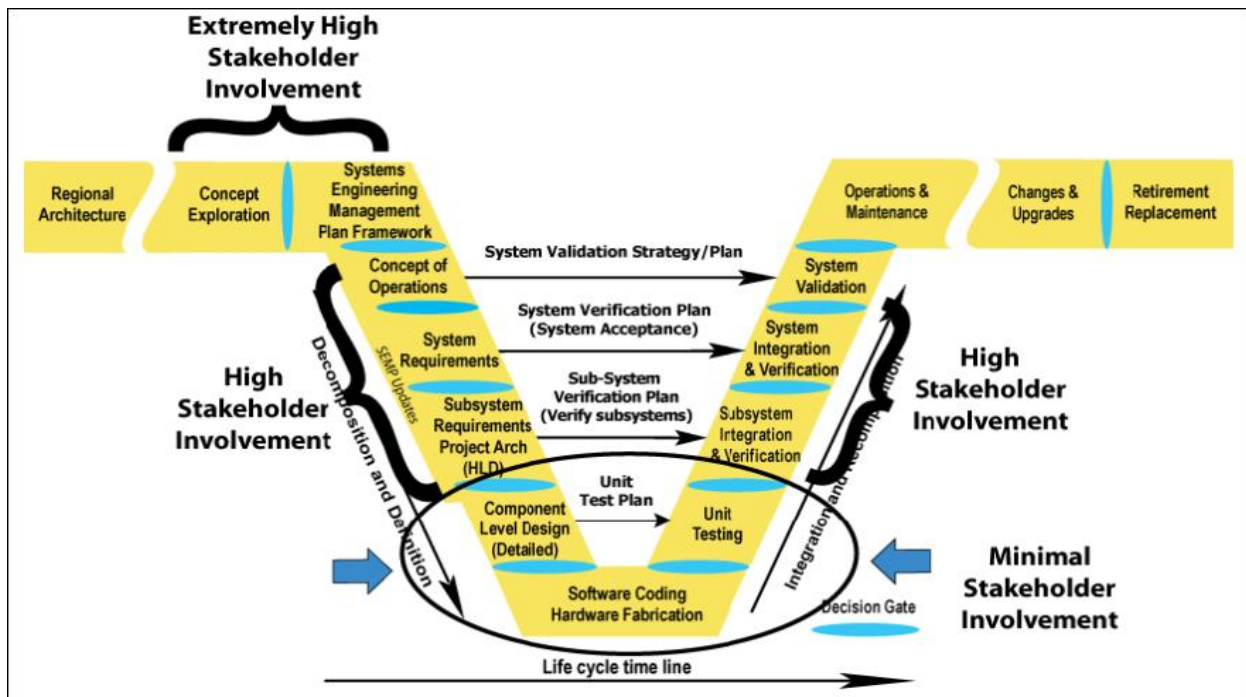


Figure 2.1: Stakeholder involvement (David et al., 2015)

In facility management, collaboration is required at every level, from the design of buildings to the selection of materials. Effective outcomes depend on cohesive teamwork and shared responsibility. According to the Facility Management Association (FMA, 2022), in-house facility managers are expected to bring a diverse skill set to the table. These include formal qualifications in facility management, a commitment to continuous professional development, a strong understanding of enhancement strategies, the ability to network with suppliers and specialists and an awareness of digital innovations. Various communication tools should be deployed to foster deeper engagement and ensure that everyone's voice is heard. Information sessions, focus groups, interactive workshops, surveys, committees and dedicated websites can all serve as channels for inclusive dialogue. These platforms allow for shared understanding and promote participation in the decision-making process, ensuring that transformation is implemented for stakeholders.

Figure 2.1 shows that in the development or change process, stakeholders should be involved since they will be the ones adopting the new approach. Transformation targets the improvement of service delivery and business performance. In this regard, people involved in the whole business process should be aware of potential changes and the implications for their businesses. In the process of digital change, for instance,

stakeholders must be highly involved in the stages of system requirements, conception, verification, validation and integration compared to stages like operations and maintenance.

From buildings to materials, collaboration between stakeholders involved in the process of facility management is required for effective outcomes. Observations showed that in-house facility managers have the following: Formal qualifications in facility management, ability for continuous professional development, enhanced awareness, networking with new and existing suppliers and technical specialists, as well as digital improvement awareness (FMA, 2022). Several communication tools such as information sessions, focus groups, workshops, surveys, committees and websites should be adopted to improve interaction between parties, especially regarding participation in the decision-making process.

2.9.2 System Integration in Facility Management

In today's fast-evolving facility management landscape, the power of integration cannot be overstated. Beyond simply connecting systems, a truly integrated facility management platform acts as the central nervous system of campus operations, streamlining workflows, enhancing responsiveness and enabling data-driven decision-making. As highlighted by Smartsense (2021), an effective facility management system does more than oversee buildings and assets. It must automate the procurement of facilities, manage a wide range of assets, streamline maintenance workflows, reduce repair and operational costs and coordinate the activities of suppliers, contractors and other key stakeholders. In essence, integration becomes the foundation for achieving operational excellence. Figure 2.2 illustrates how critical system integration is for optimising physical resource utilisation. Institutions can monitor, manage and control various functions in real time by interlinking all operational systems within a unified platform. Whether remote system oversight, real-time location tracking, or instant internal communication, the benefits of a single connected infrastructure are far-reaching.

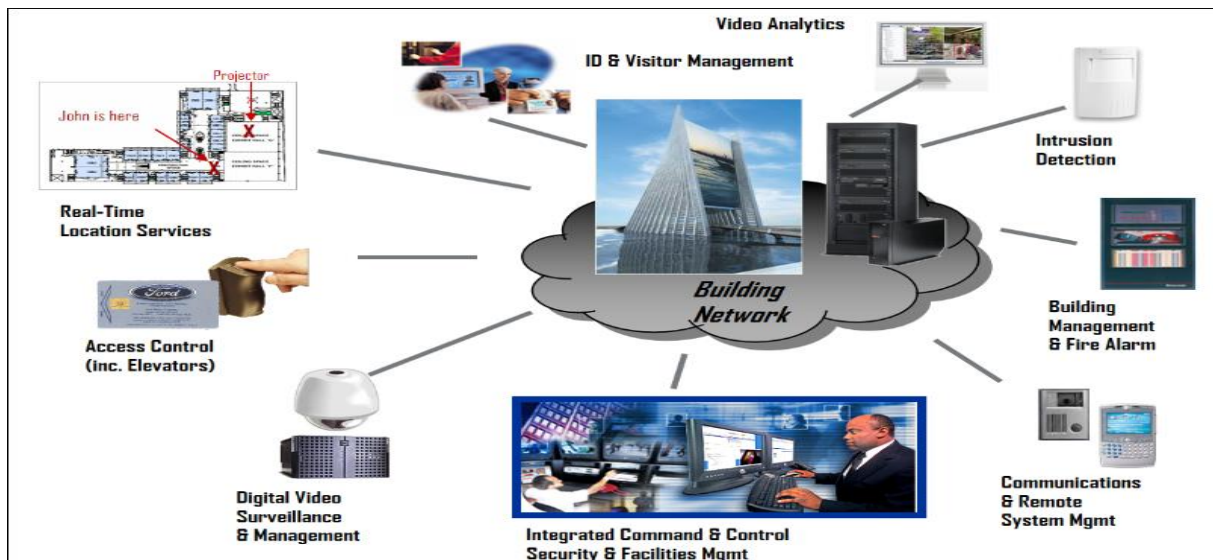


Figure 2.2: System integration (Source: Aikon Solutions.com)

Equally important is the security architecture that comes with integration. These platforms are designed to detect potential intrusions, enforce multiple levels of access control and maintain continuous oversight across the system. This ensures smooth operations and resilience against cyber threats and system vulnerabilities.

2.9.3 Funding of Institutional Facilities

Adequate and sustainable funding of institutional facilities is pivotal for ensuring operational efficiency and service delivery quality within educational, healthcare and public sector organisations. Recent studies underscore that funding shortfalls often result in deferred maintenance, deterioration of assets and compromised service quality (Opoku & Lee, 2022). According to Akomea-Frimpong *et al.* (2022), institutions that strategically allocate financial resources to proactive facility maintenance experience lower lifecycle costs and improved asset value retention. This indicates that robust funding models must consider both capital expenditure for new infrastructure and recurring costs for operations and maintenance. In recent years, there has been a global shift towards diversifying funding sources beyond government appropriations. Opoku and Lee (2022) argue that public-private partnerships (PPPs) have emerged as viable mechanisms for financing large-scale institutional facilities, especially in developing economies where budget constraints are prevalent.

Moreover, performance-based funding models are increasingly being adopted to enhance accountability and align resource allocation with institutional goals (Rezvani *et al.*, 2023). In higher education, for instance, funding frameworks are now linked to measurable outcomes such as sustainability performance, energy efficiency and student satisfaction with campus facilities (Opoku *et al.*, 2023). This approach incentivises facility managers to adopt innovative practices and implement green infrastructure, which can lead to long-term cost savings and environmental benefits. Digital transformation is also reshaping how institutional facilities are funded and managed. Emerging technologies such as Building Information Modelling (BIM) and digital twins facilitate data-driven decision-making that strengthens the business case for securing funding (Alojail & Khan, 2023). Real-time monitoring and predictive maintenance analytics provide robust evidence to justify budget requests and attract alternative funding streams such as green bonds and sustainability-linked loans. As facilities increasingly operate within sustainability frameworks, innovative financing tools that link funding to carbon footprint reduction and energy performance will become even more critical in the years ahead (Zhao *et al.*, 2022).

2.9.4 Sustainability and Environmental Stewardship in FM

Sustainability and environmental stewardship have become integral to modern FM, evolving from cost-saving and compliance-driven practices to strategic organisational imperatives. As FM increasingly intersects with sustainability goals, practitioners are expected to manage built environments in ways that preserve natural resources and reduce ecological footprints. According to Ramos (2024) sustainable FM aligns environmental, social and economic dimensions through integrated strategies such as energy efficiency, waste minimisation and green procurement. Environmental stewardship in FM emphasises responsible resource use and proactive ecological management. Facilities managers play a critical role in reducing environmental impact through lifecycle thinking, occupant education and infrastructure optimisation. As highlighted by Sedhom *et al.* (2023), environmental stewardship within FM encompasses not only operational efficiency but also advocacy for behavioural change and stakeholder engagement. Their study shows that environmental initiatives such as green cleaning, renewable energy adoption and water conservation often depend on leadership commitment and cross-functional collaboration.

Technological innovations are reshaping how sustainability and stewardship are implemented in FM. Smart energy systems, real-time monitoring and predictive analytics are being used to optimise resource usage and track environmental performance. Malik (2024) argues that data-driven facility operations allow managers to make timely decisions that improve sustainability outcomes. The deployment of sensor-based technologies enables adaptive control of HVAC systems, reducing emissions while enhancing occupant comfort. These innovations demonstrate how digital transformation is amplifying FM's ability to act as a steward of the environment.

Translating sustainability and stewardship principles into practice remains a challenge, particularly in regions with limited institutional capacity or awareness. Research by Radebe and Ozumba (2021) in African universities found that despite growing awareness of sustainable FM, implementation is hindered by budget constraints, policy gaps and a lack of skilled personnel. Their findings suggest that without regulatory frameworks and incentives, environmental stewardship tends to be marginalised in day-to-day FM operations. Therefore, successful integration of sustainability requires not only technical solutions but also governance mechanisms and institutional will.

To advance environmental stewardship in FM, several scholars recommend embedding sustainability into strategic planning, performance measurement and professional development. As per Opoku and Lee (2022), sustainability training, leadership development and stakeholder accountability mechanisms are essential enablers. Their framework advocates for a systems-thinking approach where FM is repositioned as a strategic partner in sustainable development. This redefinition helps institutions align facility operations with long-term environmental goals, ensuring that FM contributes meaningfully to climate action and resource conservation.

According to Rosário *et al.* (2025), the Triple Bottom Line centres on three interconnected economic, social and environmental pillars. These are often expressed as profit, people and planet in simpler terms. Together, they form a compass for businesses and institutions, encouraging decision-makers to balance financial goals with social responsibility and environmental stewardship.

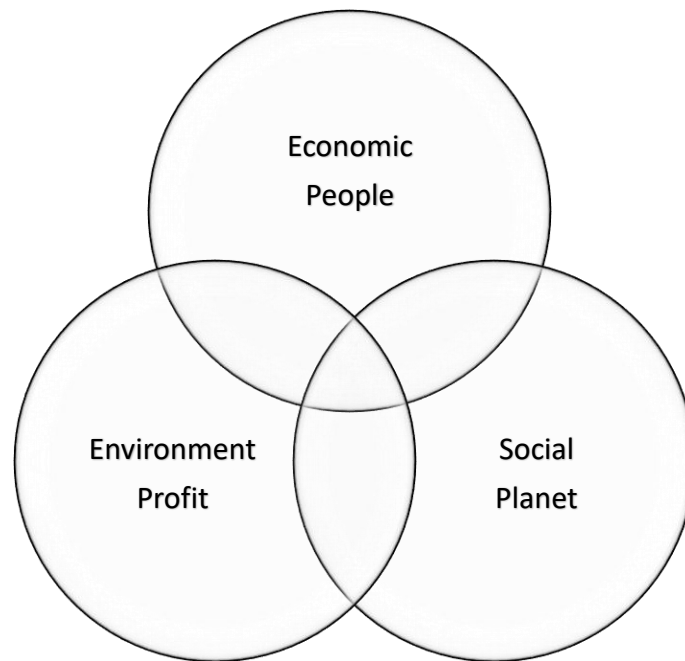


Figure 2.3: Triple Bottom Line (TBL) (Khan, Irshad, Ahmed & Khattak, 2021)

In facility management, particularly within universities, adopting the Triple Bottom Line (TBL) approach means embedding sustainability into all levels of planning and operations. This involves not only delivering cost-effective and energy-efficient buildings but also creating environments that support well-being, social engagement, and long-term institutional resilience. Recent sustainability research continues to affirm TBL as a critical framework for integrating economic, social, and environmental dimensions into organisational performance assessment. A bibliometric review of 207 scholarly publications demonstrates that a balanced application of TBL addressing socio-environmental challenges alongside economic goals enhances innovation, resilience, and long-term organisational performance (Nogueira et al., 2025). Similarly, longitudinal bibliometric analysis reveals a clear shift from theoretical discussion to practical sustainability applications, including circular economy practices, life-cycle assessment, and climate impact mitigation, highlighting TBL's growing role in policy and strategic decision-making (Nazma & Devi, 2023). Together, these studies show that contemporary TBL approaches are increasingly central to sustainability governance. Both studies emphasise the importance of rigorous measurement and consistent reporting across economic, social, and environmental pillars to ensure that TBL strategies deliver tangible outcomes (Nogueira et al., 2025; Nazma & Devi, 2023). In the context of higher education, this positions sustainable facility management not as an optional

initiative, but as a strategic necessity for long-term institutional performance and societal impact.

2.9.5 Risk Management and Regulatory Compliance

Risk management and regulatory compliance have become increasingly important in complex and highly regulated global environments. The ISO 31000:2018 standard provides a widely accepted framework for effective risk management by embedding risk processes into governance, strategy, and decision-making (ISO, 2018). By aligning risk management with organisational objectives, institutions can proactively address strategic and operational risks, strengthen resilience, enhance stakeholder confidence, and support long-term value creation (Adeniran et al., 2024).

Digital technologies are transforming how organisations manage risk and compliance. Emerging research shows that artificial intelligence, blockchain, and predictive analytics can automate compliance processes and improve the real-time identification of regulatory risks, particularly in emerging markets (Alex-Omiogbemi et al., 2024). These technologies enhance transparency, reduce manual errors, and lower compliance costs. Similarly, cloud-based compliance systems that incorporate machine learning have been shown to improve anomaly detection and significantly reduce regulatory audit preparation time (Wang & Yang, 2025). The financial sector illustrates how risk management is embedded within regulatory compliance frameworks. Financial institutions manage multiple interrelated risks, including credit, liquidity, operational, and reputational risks, using integrated tools such as risk registers, control self-assessments, and regulatory horizon scanning (Adeniran et al., 2024). These practices enable organisations to align risk appetite with regulatory expectations and improve accountability in highly regulated environments. Governance, Risk, and Compliance (GRC) frameworks further strengthen integration by promoting cross-functional alignment. The ISO 19600:2014 compliance management standard advocates a risk-based approach that emphasises leadership commitment, systematic risk identification, performance evaluation, and continuous improvement (ISO, 2014). When implemented alongside ISO 31000, GRC frameworks support ethical conduct, regulatory adherence, and organisational sustainability. Despite these advances, implementation challenges persist. In emerging economies, weak regulatory infrastructure and legacy information systems limit real-time risk

monitoring (Alex-Omiogbemi et al., 2024). In sectors such as healthcare and pharmaceuticals, stringent data integrity and traceability requirements necessitate tailored compliance strategies and specialised risk assessments (Ojo et al., 2024). As regulatory demands continue to evolve, continuous monitoring, staff training, and agile governance structures remain essential for effective integration of risk management and compliance.

2.10 EXISTING SUSTAINABLE FACILITY MANAGEMENT FRAMEWORKS

Sustainable Facility Management (SFM) has emerged as a strategic approach to reduce environmental impacts while enhancing operational efficiency throughout the facility life cycle. Contemporary SFM frameworks emphasise the systematic integration of sustainability objectives into facility planning, operations, and performance monitoring, particularly within resource-constrained institutional environments. These frameworks provide structured mechanisms for aligning sustainability priorities, governance arrangements, and operational performance. Recent studies indicate that leading SFM frameworks are increasingly informed by international management standards such as ISO 14001 (environmental management systems) and ISO 41001 (facility management systems). These standards promote lifecycle thinking, continual improvement, and stakeholder accountability, offering a formalised structure within which sustainability objectives can be operationalised (Opoku & Lee, 2022). This standards-based orientation aligns with Lean Six Sigma (LSS) principles, particularly in relation to process control, waste reduction, and data-driven decision-making.

A defining feature of contemporary SFM frameworks is the shift from reactive maintenance to proactive, performance-oriented sustainability management. Opoku and Lee (2022) demonstrate that effective frameworks integrate sustainability metrics directly into energy, water and waste management processes, supported by benchmarking and continuous performance evaluation. Their framework further highlights that sustainability in FM extends beyond technical efficiency to include governance structures, stakeholder participation and socio-environmental accountability, which are particularly relevant within higher education institutions.

In parallel, circular economy principles have increasingly been embedded within SFM frameworks. Rezvani et al. (2022) propose models that incorporate material reuse,

waste minimisation and lifecycle optimisation into facility management processes. These approaches strengthen sustainability outcomes while improving long-term cost efficiency and asset longevity. From an LSS perspective, such frameworks resonate with the elimination of non-value-adding activities and the optimisation of resource flows across the facility lifecycle. Despite the conceptual advancement of SFM frameworks, implementation challenges remain evident, particularly in developing and public-sector contexts. Moayed et al. (2023) identify fragmented policy environments, limited institutional capacity and weak stakeholder engagement as persistent barriers. These findings highlight the need for adaptable and process-oriented frameworks supported by leadership commitment and continuous learning mechanisms, characteristics that align closely with LSS methodologies.

Within higher education, particularly at Universities of Technology, SFM frameworks have evolved toward integrated, data-enabled models that support strategic asset planning and institutional sustainability. Mahmoud et al. (2024) observe that contemporary FM in universities encompasses sustainability governance, performance measurement and long-term infrastructure resilience, extending beyond routine maintenance functions. This evolution reinforces the strategic role of FM in institutional performance. Technological tools such as Building Information Modelling (BIM), digital asset information models and reality-capture technologies are increasingly incorporated within SFM frameworks as enabling mechanisms rather than standalone solutions. Studies by Chung et al. (2021), Macia Perez et al. (2021), and Duong and Lin (2022) illustrate how digital platforms support lifecycle information continuity, predictive maintenance, and informed decision-making when embedded within structured FM frameworks that support sustainability objectives and continuous improvement. Sector-specific frameworks have emerged to address the operational demands of university campuses. Schultz and Klungseth's (2022) Campus Facility Management Performance Framework presents a multidimensional model that integrates sustainability, information systems, workforce capability, and performance measurement. Such frameworks are particularly relevant to Universities of Technology, where infrastructure intensity and technical complexity necessitate structured, measurable and improvement-driven FM systems. Collectively, the reviewed literature demonstrates that effective SFM frameworks are characterised by standards alignment, lifecycle orientation, stakeholder engagement and performance-

based management. These characteristics provide a strong conceptual foundation for the development of an integrated Lean Six Sigma-based sustainable facility management framework, in which sustainability objectives are systematically embedded within continuous improvement processes.

2.11 EFFICIENT UTILISATION OF RESOURCES IN FM

Efficient resource utilisation is central to effective facility management (FM), particularly as organisations face increasing pressure to reduce costs, improve sustainability, and maintain high service standards. FM resources extend beyond physical assets to include energy, water, space, human capital, and technology. Poor utilisation of these resources has been shown to increase operating costs, degrade environmental performance, and reduce service quality (Saleh et al., 2024). Consequently, contemporary FM increasingly relies on integrated, data-driven approaches to optimise resource use across the facility lifecycle. Space management is a major opportunity to improve resource efficiency. Many educational and healthcare facilities continue to experience underutilisation due to outdated allocation models and limited occupancy data (Gholami et al., 2021). The adoption of occupancy sensors and space utilisation software enables facilities managers to identify inefficiencies, consolidate space, and reduce costs. Similar strategies, such as flexible workspaces and hot-desking, have emerged in response to hybrid working arrangements (Alghuried et al., 2024). Energy management is another critical dimension of resource efficiency. Inefficient HVAC systems, lighting, and equipment usage account for a substantial share of operational waste. Building Management Systems and smart energy analytics platforms now allow real-time monitoring, anomaly detection, and automated energy-saving responses (Lavy et al., 2024). Evidence suggests that integrating energy-efficient technologies can reduce utility costs by up to 30% while supporting environmental sustainability (Mane & Sharma, 2023). Human resources also play a vital role in FM performance. Inefficient staffing patterns and reactive maintenance practices contribute to wasted labour and reduced service effectiveness. Lean principles, including work standardisation, cross-training, and shift optimisation, have been successfully applied to improve productivity and workforce utilisation (Samanta & Gurusurthy, 2023). Preventive and predictive maintenance models, supported by condition monitoring, further enhance labour allocation and equipment

reliability. Digital technologies have significantly strengthened resource efficiency in FM. The integration of IoT, AI, BIM, and digital twins enables real-time diagnostics, lifecycle cost analysis, and proactive planning (Saleh et al., 2024). Improved data interoperability across systems supports better coordination between space, energy, and asset management, reducing duplication and improving decision accuracy. Resource-efficient FM is increasingly aligned with broader sustainability objectives, including the United Nations' Sustainable Development Goals, particularly SDG 11 and SDG 12 (Lavy et al., 2024). Green building certification schemes such as LEED and BREEAM further guide FM strategies through measurable performance benchmarks. However, challenges remain, including budget constraints, resistance to change, skills shortages, and limited access to real-time data. Research indicates that integrating Lean Six Sigma into FM operations is effective in addressing these barriers by reducing waste, minimising variation, and improving resource deployment (Tissir et al., 2023). Overall, efficient resource utilisation enables FM to move beyond a cost-focused role toward becoming a strategic contributor to organisational excellence.

2.12 ISO 14001 IN FACILITY MANAGEMENT

ISO 14001, the international standard for Environmental Management Systems, has become increasingly relevant in facility management as organisations seek to reduce environmental impacts and strengthen sustainable operational practices. The standard provides a structured framework for managing environmental aspects, including energy use, waste, water consumption, and regulatory compliance (Zimon et al., 2022). In FM contexts, ISO 14001 supports the formalisation of environmental responsibilities and aligns operational performance with institutional sustainability goals. Facility managers oversee a wide range of environmental risks, including indoor air quality, hazardous materials, and waste disposal. ISO 14001 addresses these through a systematic Plan-Do-Check-Act cycle that promotes continual improvement (Camilleri, 2022). Empirical evidence shows that ISO 14001 adoption leads to improved regulatory compliance, cost reductions, and enhanced resource efficiency by requiring measurable objectives, impact assessments, and ongoing performance evaluation (Simion Luduşanu et al., 2025). The standard also promotes environmental awareness and accountability among FM personnel. By embedding environmental

principles into procurement, maintenance, and waste management processes, FM departments can influence organisation-wide sustainability behaviours (Mabrouk & Ibrahim, 2021). In higher education institutions, the implementation of ISO 14001 has supported sustainable campus initiatives, such as energy retrofitting, green building certification, and the integration of sustainability into teaching and learning (Farrukh et al., 2022). Recent studies highlight the benefits of integrating ISO 14001 with other management systems and digital tools. Combining ISO 14001 with ISO 50001 and ISO 45001 enhances organisational resilience and operational efficiency (Saleh et al., 2024). Technologies such as BIM, IoT, and energy analytics platforms further support environmental monitoring, predictive maintenance, and automated reporting, strengthening EMS implementation in complex facilities. Despite these advantages, ISO 14001 implementation faces challenges, including limited staff training, inadequate data systems, and perceptions of EMS as a compliance burden rather than a strategic tool (Camilleri, 2022). Resource constraints can also limit certification efforts, particularly in smaller facilities. Nevertheless, evidence suggests that with strong leadership commitment and stakeholder engagement, ISO 14001 delivers sustained environmental and economic benefits (Zimon et al., 2022). As such, ISO 14001 represents a critical mechanism for embedding environmental stewardship within FM and enhancing its strategic contribution to organisational sustainability.

2.13 INTEGRATING LSS & SUSTAINABILITY IN FM FRAMEWORKS FOR HEIs

The integration of Lean Six Sigma (LSS) and sustainability principles has emerged as a strategic approach to improving facilities management (FM) performance within Higher Education Institutions (HEIs). Universities are increasingly expected to operate efficiently, minimise environmental impact, and demonstrate leadership in sustainable development. In this context, FM plays a critical role in ensuring that campus infrastructure and services support academic activities while aligning with global sustainability objectives (Lavy et al., 2024). Lean Six Sigma, which combines Lean's focus on waste elimination with Six Sigma's emphasis on defect reduction and process control, has gained traction in non-manufacturing environments, including FM (Tissir et al., 2023). Within HEIs, where FM covers energy management, space utilisation, maintenance, cleaning, and logistics, LSS provides structured tools for continuous

improvement. The DMAIC framework has been widely applied to improve service quality, reduce maintenance backlogs, and enhance user satisfaction (Samanta & Gurumurthy, 2023). Empirical evidence shows that applying LSS in university buildings can significantly improve energy efficiency and reduce response times for service requests (Farrukh et al., 2022). Sustainability in FM extends beyond energy efficiency to include water conservation, waste minimisation, carbon reduction, green procurement, and stakeholder engagement (Mabrouk & Ibrahim, 2021). Environmental management systems such as ISO 14001 enable HEIs to formalise sustainability commitments and integrate them into daily FM operations through structured planning, compliance monitoring, and continuous improvement (Simion Luduşanu et al., 2025). Green building certifications and sustainability dashboards further support transparency and performance measurement. The integration of LSS and sustainability offers a synergistic pathway for achieving both operational efficiency and environmental stewardship. While LSS improves process efficiency and cost control, sustainability introduces a long-term ecological and social perspective (Yadav et al., 2023). Green Lean Six Sigma models demonstrate how environmental indicators can be embedded within LSS metrics, enabling FM departments to reduce energy waste, improve resource efficiency, and strengthen stakeholder engagement (Lavy et al., 2024). Digital technologies such as BIM, IoT, and energy management systems support this integration by providing real-time data for both performance analytics and environmental monitoring (Saleh et al., 2024). Despite these benefits, implementation challenges remain. Organisational silos, limited skills, data quality issues, and resistance to change frequently undermine integration efforts. Leadership commitment, cross-functional collaboration, and alignment with institutional strategy are consistently identified as critical enablers (Alghuried et al., 2024). The literature highlights a gap in empirically validated, context-specific frameworks that integrate LSS and sustainability for Universities of Technology, particularly in developing contexts.

2.14 MANAGEMENT MODEL THROUGH LSS FOR UoT

Universities of Technology (UoTs) face increasing pressure to manage complex infrastructure sustainably while maintaining efficiency, service quality, and cost control. FM in UoTs is often characterised by fragmented practices, limited data integration, and weak alignment between efficiency and sustainability agendas (Lavy et al., 2024). In response, recent research has focused on developing holistic FM models that integrate LSS methodologies with sustainability principles (Tissir et al., 2023). Sustainable Facility Management in UoTs encompasses energy and water efficiency, waste reduction, green procurement, carbon monitoring, and social inclusion (Simion Luduşanu et al., 2025). However, operationalising these principles is constrained by ageing infrastructure, limited digital capability, and weak strategic alignment (Camilleri, 2023). While frameworks such as ISO 14001 have improved environmental performance, they are often implemented separately from efficiency and quality improvement initiatives (Mabrouk & Ibrahim, 2021).

Lean Six Sigma offers a structured, data-driven approach for bridging this gap. Lean targets non-value-adding activities such as delays, excess movement, and underutilised space, while Six Sigma reduces defects and process variability through DMAIC (Samanta & Gurumurthy, 2023). In UoT FM environments, LSS has been shown to improve maintenance response times, optimise space usage, and enhance energy management across multiple service streams (Gomaa, 2023; Farrukh et al., 2022). A holistic FM model for UoTs must integrate LSS with sustainability and digital technologies. Lean tools such as Value Stream Mapping can be adapted to map energy flows, water use, and carbon emissions, linking process improvement directly to environmental outcomes (Saleh et al., 2024). Digital platforms, including BIM, smart sensors, analytics, and digital twins, further support predictive maintenance, lifecycle planning, and data-driven sustainability reporting (Alghuried et al., 2024). Successful implementation depends on leadership commitment, cross-departmental collaboration, digital capability, and continuous skills development. Persistent challenges such as fragmented decision-making, resistance to change, and weak performance monitoring highlight the need for integrated planning and capacity-building approaches (Camilleri, 2022). A holistic LSS-based SFM model offers a viable

pathway for UoTs to achieve operational excellence while advancing institutional sustainability.

2.15 LEAN TOOLS FOR FACILITIES MANAGEMENT AT UoT

Lean tools such as 5S, Value Stream Mapping (VSM), Kaizen, Total Productive Maintenance (TPM), Pareto analysis and Fishbone diagrams are increasingly recognised as effective mechanisms for improving Facilities Management (FM) performance within Universities of Technology (UoTs). Operating under constrained budgets, ageing infrastructure, and significant maintenance backlogs, UoTs require process-oriented, efficiency-driven management approaches (Schultz & Klungseth, 2022). When applied as part of an integrated system rather than as isolated interventions, lean tools provide complementary value by enhancing operational efficiency, sustainability, and service quality. VSM supports the identification of inefficiencies in work-order flows and response times; 5S enhances workplace organisation and safety; Kaizen promotes participatory improvement; TPM improves asset reliability; and Pareto and Fishbone tools support prioritisation and root-cause analysis (Fernandes et al., 2024; Shabeen & Krishnan, 2022).

Evidence indicates that the effectiveness of lean tools in FM depends not only on their technical application but also on organisational enablers such as leadership commitment, staff capability, data availability, and institutional culture (Dragone et al., 2021; Polin et al., 2024). Increasingly, lean tools are being integrated with digital FM platforms, including Computerised Maintenance Management Systems (CMMS) and Building Information Modelling (BIM), to enhance performance visibility, decision accuracy, and lifecycle planning (Fernandes et al., 2024; Marzouk & Abdelkader, 2023). Despite these advances, empirical evidence on the coordinated deployment of lean tools within integrated Lean Six Sigma-based sustainable FM frameworks in UoTs remains limited, reinforcing the need for a structured and context-specific improvement framework (Opoku et al., 2023).

2.15.1 5S for Facilities Management (FM) at UoT

5S is a foundational lean tool that has gained traction in Facilities Management within Universities of Technology as a structured approach to workplace organisation and efficiency. Originating from Japanese manufacturing, the methodology—Sort, Set in Order, Shine, Standardise and Sustain—provides a practical framework for improving housekeeping, safety and operational discipline (Gómez-Molina & Moyano-Fuentes, 2022). In higher education FM environments, 5S is particularly applicable to maintenance workshops, storage facilities and administrative areas that often suffer from clutter and inefficient layouts (Shabeen & Krishnan, 2022). Recent empirical studies demonstrate that implementing 5S in UoT FM departments improves productivity, reduces maintenance response times and extends asset lifespan (Fernandes et al., 2024; Alshahrani et al., 2023). Organised workspaces enable quicker access to tools and spare parts, thereby reducing downtime during repairs. When embedded into daily FM routines, 5S fosters discipline and accountability among staff and campus users, supporting sustainability objectives through waste reduction and improved space utilisation (Schultz & Klungseth, 2022; Olawumi et al., 2024). Sustaining 5S benefits requires continuous auditing, skills development and alignment with complementary lean practices such as Kaizen and digital monitoring tools (Dragone et al., 2021; Polin et al., 2024).

2.15.2 Value Stream Mapping for FM at UoT

Value Stream Mapping (VSM) is a core lean tool used to visualise and analyse the flow of information and materials required to deliver services. By distinguishing value-adding from non-value-adding activities, VSM supports waste reduction, process streamlining and performance improvement (Ghosh et al., 2021). Although developed in manufacturing, VSM has been successfully applied in service sectors, including education, due to its effectiveness in identifying bottlenecks and reducing cycle times (Kovács, 2020). Recent research highlights the evolution of VSM through integration with digital technologies and sustainability frameworks. Digital VSM, enabled by Industry 4.0 technologies such as IoT and cyber-physical systems, allows real-time

process monitoring and data-driven decision-making (Kovács, 2020; Tortorella et al., 2023). In parallel, Green VSM has emerged as an approach for identifying environmental waste, including excessive energy and water consumption, aligning lean initiatives with sustainability goals (Andreazza de Freitas et al., 2025; Chiarini & Kumar, 2024). In UoT FM environments, VSM provides a valuable mechanism for improving maintenance planning and service delivery when supported by cross-functional collaboration and reliable data (Nshirim & Nwagwu, 2023; Woldemicael et al., 2024).

2.15.3 Total Productive Maintenance in FM at UoT

Total Productive Maintenance (TPM) is a lean methodology focused on maximising asset effectiveness through proactive and preventive maintenance involving all stakeholders. In Universities of Technology, TPM supports a shift away from reactive maintenance towards shared responsibility for asset care, addressing challenges associated with ageing infrastructure and constrained budgets (Dragone et al., 2021; Shabeen & Krishnan, 2022). Recent studies show that TPM implementation in campus FM operations extends asset life cycles, improves reliability and enhances safety across facilities such as HVAC systems, laboratories and utilities (Fernandes et al., 2024; Ahuja & Khamba, 2023). Integrating TPM with CMMS and condition-based monitoring systems strengthens data-driven decision-making and supports sustainability objectives by reducing energy waste and the need for emergency repairs (Schultz & Klungseth, 2022; Muchiri et al., 2024). Successful TPM adoption requires structured training programmes, performance measurement and leadership support to sustain long-term benefits.

Kaizen, meaning “continuous improvement”, promotes incremental change driven by employees at all organisational levels. In UoT FM contexts, Kaizen offers a practical approach to addressing challenges such as delayed maintenance, inefficient space utilisation, and escalating operational costs (Gómez-Molina & Moyano-Fuentes, 2022). Its participatory nature aligns well with the collaborative governance culture of higher education institutions (Polin et al., 2024). Empirical studies indicate that Kaizen workshops and suggestion systems contribute to improved energy efficiency, streamlined work-order processing, and reduced turnaround times in FM operations

(Dragone et al., 2021; Schultz & Klungseth, 2022; Sreedharan et al., 2023). When integrated with tools such as 5S and VSM, Kaizen supports sustained waste reduction and service quality improvement (Fernandes et al., 2024). Effective Kaizen implementation requires ongoing training, recognition mechanisms and feedback loops to institutionalise improvements and reinforce a continuous improvement culture (Bortolotti et al., 2022).

2.15.4 Pareto Tools for FM at UoT

The Pareto principle is widely applied in lean FM to identify the critical few issues responsible for the majority of maintenance problems. In UoT environments, Pareto analysis supports prioritisation of maintenance activities and resource allocation under financial and staffing constraints (Dragone et al., 2021). Studies indicate that analysing historical maintenance data enables FM teams to focus on high-impact assets and recurring faults, improving service reliability and cost control (Shabeen & Krishnan, 2022; Gijo & Antony, 2023). Fishbone (Ishikawa) diagrams complement Pareto analysis by facilitating structured root-cause analysis of persistent FM problems. Research shows that Fishbone tools are increasingly applied in higher education FM to address equipment failures, safety incidents and service inefficiencies through multidisciplinary collaboration (Fernandes et al., 2024; Polin et al., 2024; Santos et al., 2023). When integrated with CMMS and Kaizen initiatives, these tools support evidence-based decision-making and sustainable problem resolution (Schultz & Klungseth, 2022).

2.15.5 Ishikawa Fishbone for FM at UoT

The Fishbone diagram, also known as the Ishikawa or Cause-and-Effect diagram, is a widely used lean tool for root cause analysis. In Facilities Management (FM) at Universities of Technology (UoTs), it enables FM teams to systematically identify, categorise and analyse the underlying causes of recurring facility problems, including equipment failures, maintenance backlogs and safety incidents (Dragone et al., 2021). By visually mapping contributing factors across categories such as manpower, methods, materials, machinery, measurement and environment, the Fishbone tool

supports structured, data-driven decision-making and encourages FM teams to move beyond short-term fixes towards sustainable solutions (Shabeen & Krishnan, 2022). Recent studies indicate that Fishbone diagrams are increasingly applied in higher education FM to address persistent challenges such as ageing infrastructure breakdowns, poor energy efficiency and frequent user complaints (Fernandes et al., 2024). When used alongside Pareto analysis, the tool assists FM managers in prioritising critical issues and collaboratively investigating root causes with maintenance staff and other stakeholders (Polin et al., 2024). This integrated approach supports continuous improvement while strengthening preventive maintenance planning, budget allocation and sustainability initiatives aligned with UoT operational objectives (Schultz & Klungseth, 2022).

The effectiveness of Fishbone analysis in UoT FM environments depends on reliable data, multidisciplinary collaboration and organisational openness to change. However, empirical evidence shows that poor record-keeping, limited staff training and resistance to root-cause-focused approaches can undermine its impact (Gómez-Molina & Moyano-Fuentes, 2022). To address these limitations, researchers recommend integrating Fishbone analysis with Computerised Maintenance Management Systems (CMMS) and Kaizen practices to support actionable and sustained improvements (Shabeen & Krishnan, 2022). The literature demonstrates that Lean tools, including 5S, VSM, Kaizen, TPM, Pareto analysis and Fishbone diagrams, can significantly enhance FM performance in Universities of Technology. However, most studies examine these tools in isolation, with limited empirical evidence on their coordinated deployment within an integrated improvement framework. Combined with persistent organisational constraints such as weak leadership commitment, skills shortages and fragmented digital systems, this gap highlights the need for a structured Lean Six Sigma-based framework that integrates Lean tools coherently to address FM challenges in a sustainable and context-specific manner.

Table 2.2: Synthesis matrix on lean tools for FM at UoT

Theme / Sub-topic	Fernandes <i>et al.</i> (2024)	Gómez-Molina, & Moyano-Fuentes (2022)	Dragone <i>et al.</i> (2021)	Polin <i>et al.</i> (2024)	Shabeen & Krishnan (2022)	(Schultz & Klungseth (2022)
5S application	Emphasises 5S for improving FM workshops, safety and asset life	Proposes 5S as a core lean tool in FM framework for UoT	Observes limited but growing use of 5S in building maintenance	Identifies lack of staff training as barrier to 5S adoption	Supports 5S as part of lean practices in the campus FM case study	Recommends 5S to eliminate waste in FM processes
VSM usage	Highlights VSM for process mapping of maintenance workflows	Suggests VSM helps visualise inefficiencies in FM	Finds VSM useful for diagnosing frequent defaults	Notes, VSM faces barriers due to poor data	Presents the VSM case study in campus FM: work order flow	Supports VSM for aligning FM with sustainability goals
Kaizen events & culture	Discusses Kaizen for continuous FM improvement	Positions Kaizen as a cultural driver in the lean FM framework	Confirms Kaizen used to address recurring FM issues	Emphasises the need for leadership buy-in forKaizen	Highlights Kaizen as part of improvement cycles in case study	Encourages Kaizen as an enabler for green FM practices
TPM in FM	Analyses TPM for proactive maintenance in Out	Integrates TPM into lean FM conceptual model	Reports show TPM helps reduce breakdowns in university facilities	Finds TPM adoption hindered by staff resistance	Not a primary focus	Supports TPM as a strategy for efficient resource use
Pareto analysis	Suggests Pareto to prioritise critical FM tasks	Mentions Pareto charts for problem prioritisation	Supports Pareto for analysing recurring defects	Reports of poor record-keeping limit Pareto's use	Not discussed	Not discussed directly
Fishbone diagram	Recommends Fishbone for root cause analysis of FM defaults	Recognises Fishbone as a practical RCA tool	Highlights Fishbone as part of the lean toolkit for FM	Not covered	Not covered	Not covered
Barriers & integration with sustainability	Skills gaps, funding, resistance to change; links to sustainability	Limited lean skills, weak leadership commitment	Poor data visibility, low awareness	Major barriers: funding, culture, training	Poor data and manual systems	Notes similar barriers; supports lean FM for sustainability

To develop a robust SFM Framework for a UoT, this study integrates multiple complementary theoretical frameworks that collectively support the principles of operational efficiency, quality improvement and sustainability. Each framework contributes a unique perspective, and their intersection provides a coherent basis for applying the LSS approach in the higher education FM context. Lean Thinking and Six Sigma Quality Management theories are central to the proposed framework. In parallel, Six Sigma introduces a structured, data-driven approach through the DMAIC (Define, Measure, Analyse, Improve, Control) cycle to reduce process variation and enhance service quality (Nshirim & Nwagwu, 2023). Together, Lean and Six Sigma complement each other: Lean improves process flow and speed, while Six Sigma ensures that FM processes are statistically controlled and defects are minimised. To ensure that efficiency gains align with sustainability objectives, the TBL framework is incorporated, emphasising the environmental, social and economic dimensions of campus sustainability (Nazma & Devi, 2023). TBL provides the sustainability benchmarks that FM activities must meet, ensuring that resource savings contribute not only to cost

reduction but also to improved environmental performance and social responsibility (Schultz & Klungseth, 2022). This is supported by Total Quality Management (TQM), which reinforces an organisation-wide quality culture by embedding continuous improvement and customer focus into FM practices, thus aligning all staff and stakeholders with sustainability goals (Gómez-Molina & Moyano-Fuentes, 2022).

Further, the Socio-Technical Systems theory acknowledges that the effectiveness of LSS and sustainability initiatives depends on the interaction between technical systems (maintenance technologies, CMMS) and the people who operate and maintain them. This perspective addresses human factors such as staff training, motivation and resistance to change, which are critical for successful FM implementation (Dragone et al., 2021). The Resource-Based View (RBV) positions well-managed, sustainable facilities as strategic resources that can enhance the university's competitiveness, reputation and long-term resilience. Finally, Institutional Theory explains how external regulatory frameworks, accreditation standards and stakeholder expectations shape FM practices, reinforcing the need for compliance with green campus standards (Polin et al., 2024).

The integration of these frameworks, Lean Thinking, Six Sigma, TQM, TBL, Socio-Technical Systems, RBV and Institutional Theory, provides a comprehensive theoretical basis for a SFM framework using LSS. Together, they ensure that process improvements are not only efficient and high-quality but also environmentally responsible, strategically valuable and supported by organisational culture and external compliance. This interlinked foundation will guide the design, implementation and continuous refinement of sustainable FM practices at UoT.

2.16 THEORETICAL FRAMEWORK AND INTEGRATION

To develop a robust SFM Framework for a UoT, this study integrates multiple complementary theoretical frameworks that collectively support the principles of operational efficiency, quality improvement and sustainability. Each framework contributes a unique perspective, while their intersection forms a coherent basis for applying the LSS approach within the higher education FM context. Lean Thinking and

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responsible, strategically valuable and supported by organisational culture and external compliance. This interlinked foundation will guide the design, implementation and continuous refinement of sustainable FM practices at UoT. Table 2.3 presents the LSS-based theoretical sustainable FM Framework.

Table 2.3: LSS-based Theoretical Sustainable FM Frameworks at UoT.

Theories	Key Focus	Application to FM at Out	Strengths	Recent References
Lean Thinking	Waste elimination, value stream, flow, continuous improvement (Kaizen)	Streamlines FM processes, identifies non-value-adding tasks	Simple tools (5S, VSM), well-aligned with FM operational goals	Fernandes <i>et al.</i> (2024); Shabeen & Krishna (2022)
Six Sigma Quality Management	Process variation reduction, defect control, DMAIC cycle	Provides measurable, statistically controlled FM improvements	Data-driven, robust for complex problems	Nshirim & Nwagwu (2023); Dragone <i>et al.</i> (2021)
Total Quality Management (TQM)	Organisation-wide quality culture, continuous improvement, customer satisfaction	Engage all FM stakeholders, improve service quality	Holistic, integrates well with Lean & Six Sigma	Gómez-Molina, & Moyano-Fuentes (2022)
Triple Bottom Line (TBL)	Sustainability: environmental, social, economic balance	Aligns FM with green campus targets and sustainability policies	Provides sustainability criteria for FM KPIs	Schultz & Klungseth (2022)
Socio-Technical Systems	Interaction of people and technology; human factors	Helps FM integrate technical tools with staff behaviours	Supports staff buy-in, reduces resistance to change	Dragone <i>et al.</i> (2021)
Resource-Based View (RBV)	Strategic use of valuable, rare, inimitable resources	Positions FM as a strategic asset for institutional competitiveness	Highlights FM's value beyond operations	(Apply to show FM as a differentiator)
Institutional Theory	Compliance with norms, regulations and stakeholder expectations	Explains external pressures driving sustainability standards	Useful for green campus certifications and reporting	Polin <i>et al.</i> (2024)

Kaizen (Continuous Improvement)	Incremental daily improvements driven by everyone	Reinforces the sustainability of LSS improvements in FM	Low-cost, staff-driven improvements	Fernandes <i>et al.</i> (2024); Shabeen & Krishnan (2022)
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2.17 GREEN CAMPUS STANDARDS FOR FM AT UoT

Green Campus Standards are increasingly recognised as essential benchmarks for facilities management (FM) at Universities of Technology (UoTs), driven by growing environmental responsibilities and stakeholder expectations for sustainable campus operations. UoTs typically manage large, diverse campuses that consume significant amounts of energy, water, and materials, positioning them as critical sites for implementing sustainability initiatives (Schultz & Klungseth, 2022). Green campus standards provide structured guidelines for improving energy efficiency, waste management, water conservation, and sustainable construction, aligning FM practices with national policies and global sustainability goals (Polin et al., 2024). A key feature of green campus standards is the adoption of internationally recognised frameworks, such as LEED, Green Star, and ISO 14001, for Environmental Management Systems (Fernandes et al., 2024). These frameworks enable UoTs to benchmark sustainability performance, strengthen regulatory compliance, and guide continuous improvement. Empirical studies indicate that universities implementing formal green building standards achieve measurable cost savings through improved energy and water efficiency, while also creating healthier and more productive learning environments (Agyekum et al., 2022). In addition, green certifications enhance institutional reputation and attractiveness to environmentally conscious students, staff, and funding bodies. Effective implementation of green campus standards requires a holistic FM approach that extends beyond infrastructure upgrades. Successful strategies emphasise stakeholder engagement, staff training, and awareness programmes to embed a culture of sustainability across campus operations (Shabeen & Krishnan, 2022). Routine maintenance practices can be aligned with green standards through predictive maintenance approaches that reduce waste and extend asset life. The use of smart building technologies and data-driven energy management systems further enables

real-time monitoring and optimisation of resource use, supporting institutional sustainability targets (Gómez-Molina & Moyano-Fuentes, 2022).

Despite these benefits, UoTs face significant challenges in adopting green campus standards. Common barriers include limited funding, skills shortages, resistance to behavioural change, and the technical complexity of upgrading ageing infrastructure to meet modern sustainability requirements (Dragone et al., 2021). Addressing these challenges requires strong leadership commitment, targeted capacity building, and collaboration with industry and government to access technical expertise and financial support (Polin et al., 2024). Lean tools such as Value Stream Mapping and 5S can further support green campus initiatives by systematically reducing waste and improving resource efficiency within FM processes (Schultz & Klungseth, 2022). Adopting green campus standards provides UoTs with a structured pathway to improve operational efficiency, environmental performance, and campus user experience. While implementation involves financial and organisational challenges, the long-term benefits include reduced carbon emissions, enhanced institutional resilience, and alignment with national and global sustainability objectives (Agyekum et al., 2022). Embedding green campus standards into FM policies, training, and daily practices is therefore critical to positioning FM as a strategic driver of sustainability and continuous improvement within Universities of Technology.

Table 2.4: Synthesis Green Campus FM Standards at UoT

Theme / Sub-topic	Fernandes <i>et al.</i> , (2024)	Gómez-Molina, & Moyano-Fuentes (2022)	Dragone <i>et al.</i> (2021)	Polin <i>et al.</i> (2024)	Schultz & Klungseth, (2022)	Agyekum <i>et al.</i> (2022)
Importance of green campus standards	Highlights lean maintenance as part of sustainable FM in higher education	Conceptual framework links lean thinking to FM sustainability	Reviews lean practice impact on university building maintenance	Identifies the need for sustainability as a driver for lean FM	Proposes a framework combining lean FM and sustainability	Provides bibliometric trends on green buildings, sets a broader context

Frameworks used (LEED, ISO 14001, Green Star)	Mentions integration of lean tools with certification standards	Emphasises policy alignment with ISO 14001 and other standards	Suggests standards are underused in FM practice	Notes lack of formal certification in Botswana UoT	Advocates green FM is aligned with global standards	Summarises trends in green building standards globally
Benefits for FM and campus operations	Cost savings, efficient maintenance, energy savings	Improved asset life cycles, reduced operational waste	Reduced breakdowns, better preventive maintenance	Highlights potential benefits but notes limited uptake	Cost savings, sustainability and improved stakeholder satisfaction	Reinforces broad benefits: cost, health, sustainability
Implementation challenges	Skills gaps, funding, cultural resistance	Lack of staff training, limited leadership support	Poor record-keeping, insufficient data for green FM	Major barriers include funding, behavioural resistance	Barriers and enablers for lean FM adoption	Not focused on FM barriers specifically, but highlights green building gaps
Integration with lean tools	Links lean maintenance with sustainability	Proposal combined the lean and green FM framework	Supports lean tools (5S, VSM) for green outcomes	Suggests lean tools can support green goals, but face barriers	Recommend lean tools as sustainability enablers	Does not address lean tools specifically
Future research/ Recommendation	Calls for integrated lean-green FM models	Suggests further empirical testing in African universities	Recommends capacity building and stakeholder engagement	Recommend s policy support, partnerships and funding models	Propose continuous improvement and digital tools	Suggests future research to close green building knowledge s

2.18 A STRATEGIC FRAMEWORK FOR GREEN FM USING LSS AT UOT

South African universities, such as the UoT, are increasingly challenged to enhance their FM practices in response to climate change, operational inefficiencies and financial constraints. FM departments in these institutions are not only custodians of the built environment but also play a strategic role in enabling sustainable campus operations. To respond effectively to these complex demands, there is a growing interest in developing GFM frameworks that align environmental sustainability with institutional performance. The integration of LSS into GFM offers a structured approach for reducing waste, enhancing efficiency and achieving sustainable outcomes (Yadav *et al.*, 2023; Lavy *et al.*, 2024). This review synthesises recent literature to justify the development of a strategic framework for GFM using LSS tailored to the South African UoT context. Green Facility Management involves the application of environmentally responsible practices to maintain, operate and optimise buildings and infrastructure. In the higher education sector, this includes energy efficiency, water conservation, sustainable procurement, green cleaning, waste management and indoor environmental quality (Simion Luduşanu *et al.*, 2025). UoT operates across multiple campuses in resource-constrained environments; the pressure to manage utility costs and reduce carbon emissions while maintaining service quality is particularly acute (Jimu & Rennkamp, 2024).

Despite the increasing global adoption of sustainability certifications such as LEED and ISO 14001, South African universities often face implementation challenges such as poor stakeholder engagement, lack of data transparency and insufficient integration of sustainability into core FM functions (Radebe & Ozumba, 2021). A strategic framework is therefore needed to institutionalise green principles into FM through a systemic and performance-oriented approach. Lean Six Sigma is a powerful process improvement methodology that combines Lean's focus on waste elimination with Six Sigma's emphasis on defect reduction and statistical quality control. In FM, LSS has proven effective in streamlining maintenance workflows, reducing energy use, improving space utilisation and enhancing service delivery (Samanta & Gurumurthy, 2023). The LSS methodology, particularly the DMAIC cycle, provides a roadmap for continuous improvement by identifying process bottlenecks, setting measurable goals and

implementing solutions that are both cost-effective and quality-driven (Gomaa, 2023). When applied to sustainability initiatives, Lean principles can help eliminate environmental waste such as energy overuse, material waste and emissions, while Six Sigma ensures these improvements are consistent and data-backed (Mabrouk & Ibrahim, 2021). The convergence of LSS and green FM is particularly valuable in universities, where operations span diverse functions and require a standardised yet adaptable framework.

South African UoT present unique operational and cultural contexts that must be considered in the development of a strategic framework. Key strategic dimensions for Green LSS-based FM in UoT should include leadership commitment, stakeholder engagement, digital infrastructure, regulatory compliance and alignment with national sustainability policies such as the Green Building Council South Africa (GBCSA) guidelines and the Department of Higher Education and Training's Infrastructure Management Strategy (DHET, 2022). A strategic framework must also integrate data-driven decision-making through digital technologies such as BIM, IoT and Energy Management Systems (EMS). Saleh *et al.* (2024) argue that the convergence of LSS and digital systems in FM creates a 'smart sustainability loop' where energy data, maintenance logs and occupancy analytics can inform continuous process optimisation. Case studies from comparable contexts suggest that successful implementation of such a framework requires capacity-building for FM personnel, integrated performance dashboards and the creation of interdisciplinary teams to co-lead sustainability and efficiency initiatives (Alghuried *et al.*, 2024). In the South African context, LSS can also support compliance with Environmental Impact Assessments (EIAs) and municipal service standards, further embedding environmental accountability within FM operations. Implementing a strategic Green LSS framework in South African UoT is not without challenges. Institutional inertia, fragmented FM structures, low levels of LSS expertise and insufficient funding for sustainability projects have been widely reported (Radebe & Ozumba, 2021). These barriers can be overcome by aligning FM improvements with broader institutional transformation goals, leveraging external funding (from green infrastructure funds) and embedding sustainability performance in staff key performance indicators (KPIs).

Tissir *et al.* (2023) stress the importance of leadership and cultural readiness in embedding LSS in public sector environments. Within the South African UoT, executive-level support and cross-functional integration are critical for embedding the proposed framework and ensuring long-term success. The integration of Lean Six Sigma into Green Facility Management provides a comprehensive and adaptable approach for the South African University of Technology to enhance its operational sustainability. A strategic framework that fuses LSS rigour with environmental principles may support UoT to reduce costs, improve service quality and align with national and global sustainability commitments. Future research should explore framework validation through pilot projects, sector-specific performance metrics and digital transformation enablers.

In an era of heightened environmental consciousness and constrained public funding, the South African UoT is under increasing pressure to modernise its FM systems. These institutions operate expansive, multi-campus environments that demand consistent maintenance, energy use optimisation and resource efficiency. FM functions in UoT remain reactive and fragmented, leading to inefficiencies and unsustainable practices (Radebe & Ozumba, 2021). In response, a strategic framework that integrates LSS and GFM has been proposed as a solution to align operational excellence with environmental sustainability in the higher education sector. GFM refers to the application of sustainable principles in the planning, operation and maintenance of buildings and infrastructure. Within the South African higher education context, this includes reducing greenhouse gas emissions, improving energy and water efficiency, implementing waste minimisation practices and ensuring compliance with environmental regulations (Jimu & Rennkamp, 2024). UoT, by their nature, are technologically oriented institutions with opportunities to lead in sustainable innovation. Challenges such as outdated infrastructure, weak regulatory enforcement and limited sustainability literacy among FM professionals have hindered progress (Radebe & Ozumba, 2021).

A growing body of literature advocates for the institutionalisation of green practices through frameworks such as ISO 14001, LEED and the Green Building Council of South Africa (GBCSA) standards (Simion Luduşanu *et al.*, 2025). Despite the adoption of such frameworks in pockets of the sector, a lack of integration with performance

improvement tools has limited their full impact. Therefore, a holistic approach is needed that combines environmental objectives with operational efficiency and service quality.

2.19 INSTITUTIONAL FACTORS AND SUSTAINABILITY DIMENSION

Effective implementation of SFM in HEIs is significantly influenced by strategic alignment and leadership commitment. Beshara and Abdelhamid (2025) emphasise that aligning facility management practices with the SDGs requires robust institutional policies and dedicated leadership to overcome adoption challenges. Similarly, Opoku and Lee (2022) highlight that organisational support at the strategic level is crucial for the successful adoption of sustainable FM practices, ensuring that sustainability is embedded into the core business decisions of institutions. These studies suggest that without strong leadership and strategic alignment, efforts to develop and implement SFM frameworks may lack direction and efficacy.

Organisational culture and the capacity for change are pivotal in adopting sustainable practices within FM. Radebe and Ozumba (2021) identify that a lack of knowledge, insufficient senior management commitment and limited capabilities are major barriers to implementing SFM in higher education settings. The integration of advanced technologies is a critical institutional factor in developing sustainable FM frameworks. Studies by Mahmoud *et al.* (2024) underscore the importance of adopting smart campus technologies, BIM and sustainability assessment tools to enhance operational efficiency and environmental sustainability in HEIs. These technological innovations enable institutions to monitor and manage their facilities more effectively, contributing to the overall goals of sustainability and resource optimisation. Engaging stakeholders and establishing robust governance structures are essential for the successful implementation of SFM. Mahmoud *et al.* (2024) emphasise the need for inclusive governance structures that involve various stakeholders in decision-making processes, ensuring that sustainability initiatives are comprehensive and effectively implemented across the institution. Environmental sustainability is a cornerstone in the development of SFM frameworks within HEIs. Institutions are increasingly adopting practices aimed at reducing their ecological footprint, such as energy-efficient building designs, waste reduction programs and sustainable resource utilisation. Dragone *et al.* (2021) emphasise the importance of sustainable retrofitting of existing university buildings to

enhance energy efficiency and reduce carbon emissions. Their framework outlines various phases of retrofitting, offering choices for optimising energy consumption within different systems of university buildings. Mahmoud *et al* (2024) discuss the utilisation of sustainability assessment tools in higher education institutions to evaluate and implement sustainable practices effectively.

2.19.1 Economic Sustainability and Resource Optimisation

Economic sustainability in facility management involves the strategic allocation and utilisation of resources to ensure long-term financial viability. HEIs are exploring cost-effective solutions that align with sustainability goals, such as investing in technologies that offer long-term savings and efficiency. Opoku and Lee (2022) highlight the shift in facilities management towards practices that consider the economic benefits of business decisions, emphasising the adoption of maintenance and operation practices that contribute to sustainable development. Furthermore, the integration of BIM and smart campus technologies has been shown to improve operational efficiency and environmental sustainability, as noted by recent studies.

2.19.2 Social Sustainability and Stakeholder Engagement

Social sustainability in facility management focuses on creating inclusive, safe and healthy environments for all stakeholders within HEIs. Engaging students, faculty and staff in sustainability initiatives fosters a culture of environmental responsibility and collective action. Radebe and Ozumba (2021) identify the lack of knowledge and senior management commitment as significant barriers to implementing sustainable facilities management practices. Addressing these challenges through education and stakeholder involvement is crucial for the successful adoption of SFM frameworks. The implementation of programs like the Green Office Model enables students and staff to actively participate in sustainability efforts, enhancing social engagement and institutional commitment to sustainability.

2.19.3 Institutional Governance and Policy Integration

Effective governance and policy integration are vital for embedding sustainability into the core operations of HEIs. Developing clear policies, setting measurable goals and establishing accountability mechanisms ensures that sustainability objectives are systematically pursued. The DHET (2022) examines how the Sustainable Development Goals (SDGs) serve as a transformative framework in higher education, highlighting the role of strategic planning and policymaking in overcoming challenges related to institutional disintegration and resource scarcity.

2.19.4 Integration of Lean and Six Sigma for Sustainable Practices

The integration of Lean Manufacturing and Six Sigma methodologies, often referred to as LSS, has become a pivotal approach for driving continuous improvement and sustainability in production systems. Both methodologies focus on enhancing efficiency, reducing waste and improving quality, but each provides unique tools and strategies to achieve these goals. Lean Manufacturing emphasises waste reduction and process flow, while Six Sigma concentrates on reducing process variation and improving quality. The interaction of these approaches enables organisations to systematically identify inefficiencies, implement corrective actions and sustain improvements over time, thereby contributing to long-term sustainability goals.

2.19.5 Role of Digital Transformation in Continuous Improvement

Digital transformation plays a critical role in supporting continuous improvement and achieving sustainable quality. The adoption of advanced technologies such as AI, the IoT and cloud computing facilitates real-time data analysis, predictive maintenance and enhanced decision-making processes. These technologies enable organisations to monitor operations more effectively, identify areas for improvement and implement changes swiftly, leading to improved performance, reduced costs and enhanced customer satisfaction. Furthermore, digital tools support environmental sustainability by optimising resource consumption and minimising waste.

2.19.6 Total Quality Management and Corporate Sustainability

TQM is a comprehensive approach that focuses on continuous improvement, customer satisfaction and employee involvement. The implementation of TQM practices has been shown to have a positive and significant impact on corporate sustainability performance. By improving operational efficiency, reducing waste and increasing customer satisfaction, TQM contributes to the economic, social and environmental dimensions of sustainability. Organisations that embrace TQM principles are better equipped to adapt to changing market conditions and stakeholder expectations, ensuring long-term success and sustainability.

2.19.7. Sustainability in Higher Education Quality Processes

In the context of higher education, the sustainability of quality processes is essential for continuous improvement and institutional development. Establishing flexible and robust quality procedures that can adapt to shifting educational demands is crucial for maintaining academic standards and enhancing student outcomes. Strategies such as outcome-based education, student-centric learning and inclusive practices support an environment where quality is continuously maintained and improved. Leadership plays a vital role in fostering a culture of continuous improvement, ensuring that quality becomes an integral part of institutional operations and contributes to the overall sustainability of higher education institutions.

2.19.8 Challenges and Prospects of Continuous Improvement

Implementing continuous improvement (CI) in the private sector involves various approaches, including Lean Manufacturing, Six Sigma, TQM and Kaizen. Organisations often face challenges such as resistance to change, limited resources and a lack of top management support. Overcoming these barriers requires a strategic focus, effective communication and a commitment to fostering a culture of continuous improvement. Looking ahead, the integration of advanced technologies like IoT and AI is expected to play a significant role in enhancing CI efforts, driving efficiency and promoting environmental sustainability. This literature review underscores the importance of integrating methodologies like Lean Six Sigma, embracing digital

transformation and fostering a culture of continuous improvement to achieve sustainability across various sectors. By addressing challenges and leveraging technological advancements, organisations can enhance their operational efficiency and contribute to long-term sustainable development.

Lean Six Sigma is a hybrid methodology that combines the waste-reduction focus of Lean with the variation control of Six Sigma. The Lean component seeks to eliminate non-value-adding activities (unnecessary inspections or excessive downtime), while Six Sigma utilises the DMAIC (Define, Measure, Analyse, Improve, Control) cycle to minimise defects and process variability. Within the context of university facility management, this dual approach enables the identification of root causes of service delivery failures, such as delayed repairs, poor user satisfaction and high maintenance costs. Tools such as Pareto analysis, process mapping and control charts can be employed to capture and analyse data on these failures, supporting empirical decision-making. The framework also embeds the principles of sustainability, incorporating environmental, social and economic dimensions into the facility management strategy. Environmentally, sustainable FM entails reducing energy consumption, promoting green maintenance practices and improving resource efficiency (Opoku & Lee, 2022). Socially, the focus shifts to stakeholder satisfaction, health and safety standards and inclusive infrastructure. Economically, cost efficiency is addressed through lifecycle costing, predictive maintenance and performance-based budgeting. By integrating these dimensions into the LSS process, the framework ensures that FM improvements are not only efficient but also sustainable in the long term. Institutional factors such as leadership support, availability of resources, skills development and policy alignment act as enablers or barriers to the implementation of the proposed framework. The success of LSS in FM settings relies on cross-functional collaboration, top-down commitment and staff training (van Beers *et al.*, 2022). Therefore, the framework emphasises institutional readiness, capacity building and the adoption of performance metrics aligned with university strategic objectives. Ultimately, the outcome of this conceptual framework is the development of a Sustainable Facility Management Framework tailored to the University of Technology, grounded in process improvement, stakeholder value and long-term viability.

2.20 STRATEGIES USED IN FM AND SUSTAINABILITY

Figure 2.4 illustrates a maturity model for Facility Management (FM), showing how organisations can progress from basic operational FM to a fully integrated strategic FM approach. The vertical axis represents the level of service, while the horizontal axis moves from managing physical resources 'Place' towards integrating 'People' and 'Processes'. This progression indicates that effective FM must evolve beyond simply maintaining physical assets to aligning with organisational goals and stakeholder needs. As Aliu *et al.* (2025) argue, maturity models help institutions benchmark their FM capabilities and identify gaps for strategic improvement. At the base level, FM operates in a reactive, operational mode, focusing on maintaining assets in a workable condition. This reflects the typical challenges faced by universities with ageing infrastructure and limited budgets. The next level introduces tactical FM, which emphasises planned maintenance and cost reduction, leading to assets in excellent condition. Recent research highlights how moving from reactive to preventive maintenance significantly improves asset performance and cost-efficiency (Ahmed, 2020). As organisations progress, the model shows that FM must incorporate management-level functions to achieve better performance. This requires alignment with institutional objectives, policies and performance measures. A shift towards management FM includes lifecycle costing, risk management and resource optimisation. According to van der Voordt and Jensen (2021), embedding management FM practices helps institutions move from cost-focused maintenance to value-driven FM, creating long-term benefits for both users and the institution. At the highest levels, the figure emphasises the need for integrative and strategic work. Strategic FM involves aligning FM with the organisation's core mission, sustainability goals and stakeholder expectations. Integrating people and processes creates interactions that improve service quality and user satisfaction. Polin *et al.* (2023) argue that universities embracing strategic FM see significant improvements in sustainability performance and operational efficiency, particularly when Lean and smart technologies are applied. The goal of this maturity model is to reach 'Best in League' performance through continuous improvement and strategic alignment. The figure underscores that FM excellence requires collaboration across physical assets, people and processes, supported by integrative work such as Lean Six Sigma. As Tampubolon and Purba (2021) noted, higher education institutions that embed Lean FM practices are better

positioned to optimise resources, enhance user experiences and achieve sustainability targets. This model provides a roadmap for UoT aiming to professionalise FM and add strategic value.

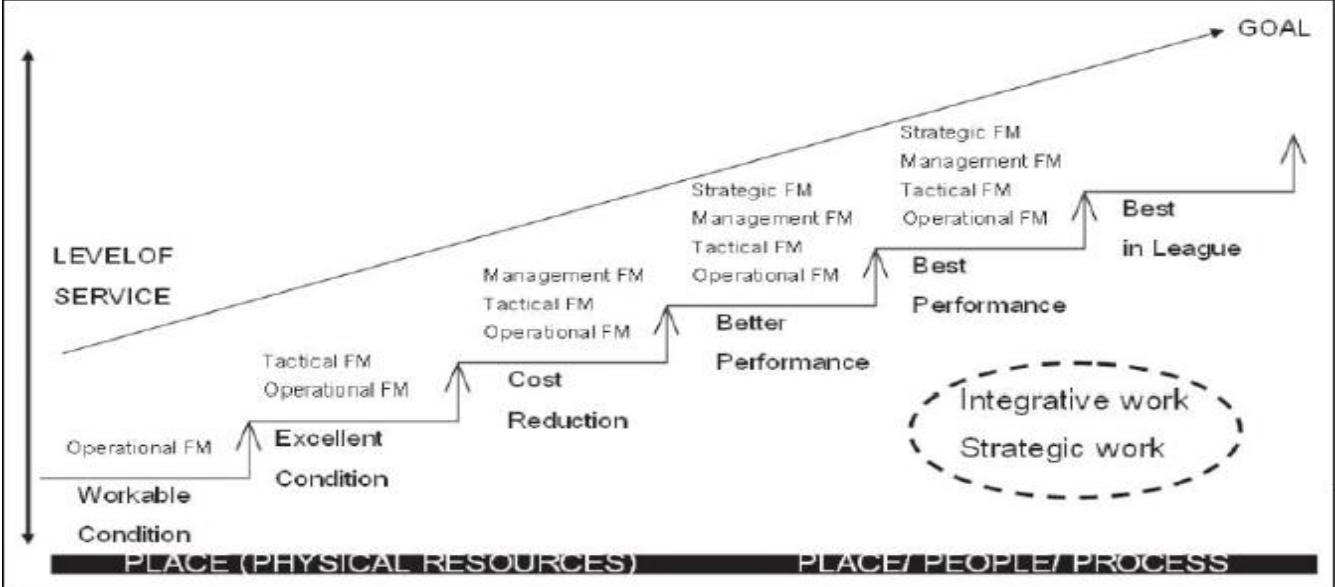


Figure 2.4: Stages of facility management transformation (Bujang, 2025)

The figure 2.5 presents a comprehensive safety framework for facilities management that connects a broader legislative framework with an organisation’s internal safety policy and detailed site-level safety practices. It demonstrates how external standards, codes of practice and guidelines cascade down to inform actionable plans, audits and procedures on the ground. This layered structure is essential in ensuring that legal requirements are translated into practical actions that safeguard people, processes and physical assets. According to Tan *et al.* (2023) clear linkage between legislation and workplace implementation is vital to reduce accidents and improve compliance in complex facility environments. These documents set the minimum requirements and best practices that organisations must follow to comply with occupational health and safety (OHS) regulations. This structure aligns with findings by Pilbeam (2024), who emphasises that strong regulatory frameworks combined with clear codes of practice help organisations interpret and apply safety obligations consistently across diverse facilities.

The safety policy serves as the bridge between legislative requirements and day-to-day operations. It formalises the organisation’s commitment to safety, sets clear

expectations and allocates responsibilities. This policy acts as the backbone for implementing site safety plans, audits, emergency procedures and training initiatives. Pilbeam (2024) notes that a clear safety policy, when well-communicated and reinforced by management, significantly improves worker safety behaviours and reduces incidents in facilities and construction sites. The lower part of the diagram breaks down how the safety policy is operationalised through a structured Site Safety Plan, Safety Audit, Emergency Evacuation Plan and OHS Procedures. Each component contains clear action points such as hazard analysis, employee inductions, fire safety and manual handling procedures. This ensures that all aspects of physical conditions, human factors and process safety are addressed. Systematic frameworks are crucial for higher education institutions and large facilities to proactively manage diverse risks and create a strong culture of safety compliance.

Figure 2.5 demonstrates how a robust safety framework integrates legislation, policy and operational procedures, forming a closed loop of compliance, monitoring and improvement. This holistic approach helps institutions like the UoT to safeguard staff, students, contractors and visitors while maintaining facilities sustainably. As highlighted by Pilbeam (2024), integrating OHS frameworks within broader FM systems, including Lean and digital tools, enhances safety outcomes and supports continuous improvement in line with sustainability goals.

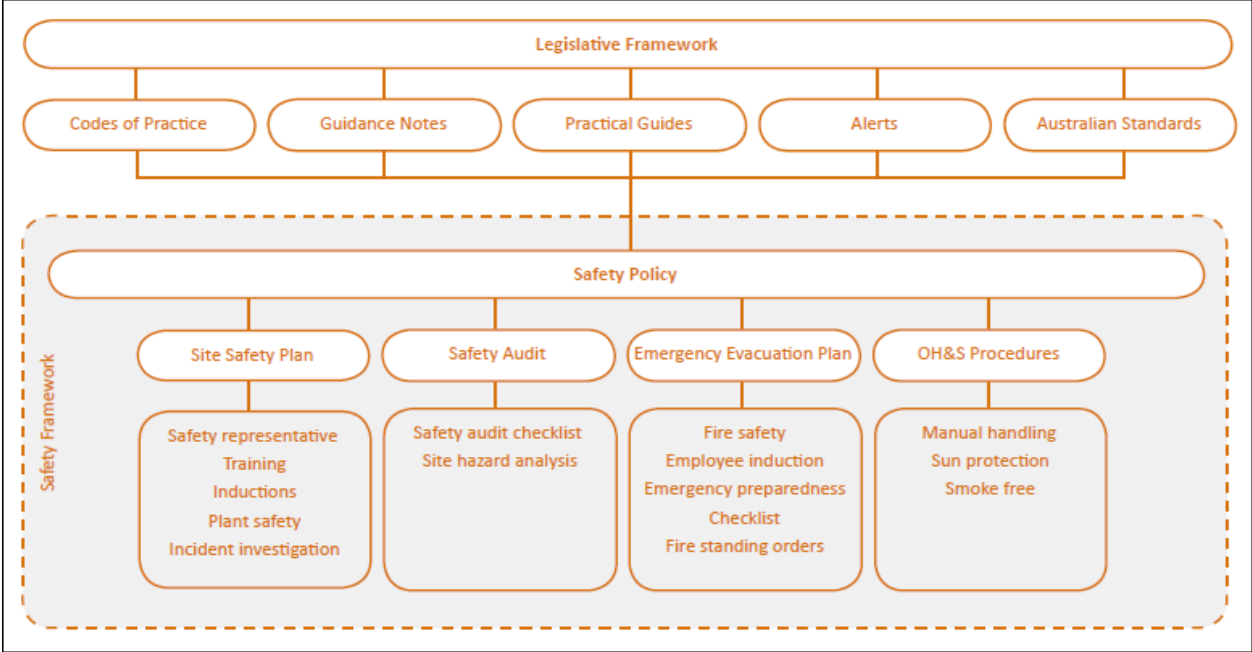


Figure 2.5: Legislative framework (Safe Work Australia, 2024)

One effective strategy is the adoption of LSS methodologies tailored to facility management. Ratvasky and Furterer (2024) demonstrated that applying LSS principles to university facility services, particularly in design and construction workflows, significantly reduced waste, rework and administrative bottlenecks. By employing DMAIC, FM teams can systematically identify inefficiencies, streamline processes and improve service reliability (Ratvasky & Furterer, 2024). Integrating sustainability goals into each DMAIC phase further helps embed energy efficiency and waste reduction measures in infrastructure workflows (Detyna, 2023). Abdelalim et al. (2025) further showed how combining AI-driven Digital Twins with IoT sensors can shift FM from reactive to proactive strategies, achieving consistent energy savings and reducing maintenance costs in large facilities (Abdelalim *et al.*, 2025). Developing robust asset and performance information systems is essential. Sporseem *et al.* (2021) argue that FM departments must transition from fragmented paper- or spreadsheet-based systems to unified digital platforms. Accurate asset registers and historical maintenance data enable predictive scheduling, cost forecasting and KPI tracking. Such systems underpin long-term strategy by providing transparency and data-driven insights, thereby shifting FM culture toward proactive and preventive maintenance (Sporseem *et al.*, 2021).

Strengthening leadership commitment and governance is crucial. Detyna (2023) found that universities embedding Lean and sustainability objectives within strategic plans saw more effective implementation of FM innovations. Similarly, LSS literature emphasises that cross-functional leadership engagement, supported by structured governance and stakeholder forums, is critical to success (Whisker, 2024). Empowered FM teams with executive backing can coordinate resources, enforce standards and integrate FM into institutional objectives more effectively. Another effective strategy is implementing human-centric service models and inclusive stakeholder engagement.

Facilities management futures 2025 recommendations advocate integrating FM software with user-facing apps to streamline maintenance requests, room bookings and feedback loops, thereby aligning operations with end-user needs (Infraspeak, 2024). Creating continual feedback loops with students, lecturers and staff ensures FM remains responsive, transparent and user-focused, a critical factor in improving overall

institutional satisfaction. Finally, fostering a culture of continuous improvement and capacity building can enable long-term FM excellence. Training FM staff in Lean, data analytics and sustainability empower them to identify incremental improvements and reduces reliance on consultants. Mannino *et al.* (2021) pilot studies highlight how performance information models supported staff in tracking building KPIs and planning maintenance tasks, resulting in better internal capabilities. Promoting continuous improvement through daily Kaizen exercises and employee-led innovation ensures FM remains adaptive and responsive in changing contexts.

2.21 FACTORS IN POOR FM IN HIGHER EDUCATION

One of the most persistent factors contributing to poor FM in higher education institutions, particularly in Africa, is insufficient funding and budget prioritisation. Across countries such as South Africa, Nigeria and Ghana, chronic underfunding has resulted in the rapid deterioration of physical infrastructure, overcrowding and service inefficiencies (Chikafalimani *et al.*, 2021; Polin *et al.*, 2024). These financial limitations constrain both capital development and preventive maintenance, forcing FM teams into reactive practices that are costlier in the long term (Wuni *et al.*, 2018). Without stable financial allocations and forward-looking investment, universities struggle to ensure the safety, functionality and longevity of their built environment, thereby undermining the quality of education and institutional reputation. A closely linked challenge is the shortage of skilled and capable FM personnel. Many FM departments in public universities lack professionals with training in critical areas such as sustainability integration, asset lifecycle management and digital tools like Building Information Modelling (BIM) (Chikafalimani *et al.*, 2021; Mewomo *et al.*, 2022). The deficit in technical, managerial and innovation-oriented skills inhibits the adoption of modern FM practices and reinforces reactive maintenance cultures (Moayed *et al.*, 2023). Radebe and Ozumba (2021) emphasise that such skills gaps not only reduce operational effectiveness but also form a major barrier to embedding long-term sustainability in institutional infrastructure strategies. Equally significant is the lack of leadership commitment and strategic alignment.

Poor FM outcomes are often rooted in weak executive support and the absence of integrated institutional policies that prioritise facilities management (Radebe &

Ozumba, 2021). Studies by Mewomo *et al.* (2022) confirm that time constraints, poor communication and top-level disengagement result in fragmented execution and low accountability. FM departments that are excluded from strategic decision-making normally receive inadequate recognition and resourcing, which limits their capacity to plan, innovate, or align with sustainability and service delivery goals. Inadequate information systems and poor data management remain major contributors to FM inefficiency. Many FM teams lack access to accurate asset registers, maintenance histories and performance dashboards, relying instead on paper-based or fragmented digital systems (Sporssem *et al.*, 2021). This lack of real-time, reliable data hinders effective planning, risk management and resource allocation. Without a digital backbone to support performance monitoring, FM processes become invisible, reactive and inconsistent, particularly in older institutions with legacy systems.

Another key issue is the persistence of a reactive maintenance culture and fragmented operational processes. Hou (2023) observed that FM teams in both South African and Nigerian universities predominantly operate under a fix-on-failure model, which drives up costs and increases downtime. Furthermore, inadequate coordination between construction, design and FM units leads to poor project handovers, loss of institutional knowledge and operational inefficiencies (Wuni *et al.*, 2018). When FM is not embedded early in the facility lifecycle, continuity and documentation gaps undermine the implementation of proactive and preventive strategies. The limited stakeholder engagement and collaboration significantly weaken FM performance. Stakeholders such as students, academic staff and administrators are often excluded from decision-making processes, leading to misaligned service priorities and a lack of accountability (Wuni *et al.*, 2018; Sedhom *et al.*, 2023). The absence of defined maintenance policies and feedback mechanisms reduces transparency and responsiveness. Furthermore, poor collaboration between internal FM staff and outsourced service providers exacerbates performance gaps, impeding coordination, innovation and service quality improvements.

2.22 ROOT CAUSES OF POOR FM IN HIGHER EDUCATION

One fundamental root cause of poor facility management in higher education institutions is the chronic lack of financial resources and prioritisation in capital and

maintenance budgets. Public universities across Africa often face political and economic pressures that allocate limited funds to facilities, resulting in deferred maintenance, overcrowding and dilapidated infrastructure (Chikafalimani *et al.*, 2021). This underfunding undermines long-term planning and forces facilities teams into reactive, stopgap solutions rather than proactive strategies (Chikafalimani *et al.*, 2021), further exacerbating facility degradation over time.

Another critical factor is the deficiency in skilled human capital within FM departments. Research indicates that many institutions lack personnel trained in key FM competencies, especially in sustainability, data systems and technical maintenance (Mewomo *et al.*, 2022; Chikafalimani *et al.*, 2021). Without qualified staff to plan, execute and manage facilities effectively, processes become inefficient, systems remain antiquated and innovation is stifled (Mewomo *et al.*, 2022). This skills imbalance directly hinders FM responsiveness and adaptability in evolving operational contexts. A lack of clear policy frameworks and strategic leadership commitment also significantly undermines FM performance. Mewomo *et al.* (2022) highlight the absence of formal FM policies and guidance in public buildings, hampering accountability and consistency. Moreover, senior leadership often fails to integrate FM goals into institutional strategies (Radebe & Ozumba, 2021), leaving departments to operate in isolation. This absence of strategic alignment results in fragmented operations, limited stakeholder engagement and poor visibility of FM as a core institutional function. The absence of robust information and asset management systems further hampers FM effectiveness. Sporseem *et al.* (2021) describe how institutions rely on incomplete documentation, a lack of maintenance history and missing asset registers, which make data-driven planning impossible. As a result, FM teams struggle to make informed decisions, schedule preventive interventions and track performance improvements. This chronic data deficiency institutionalises inefficiency and operational opacity, perpetuating maintenance setbacks and budget overruns.

A culture of reactive maintenance and fragmented processes remains prevalent. Hou (2023) and partially echoed by Chikafalimani *et al.* (2021), found that institutions predominantly respond to breakdowns rather than adopting preventative strategies or predictive maintenance tools. FM teams are often excluded from construction and handover planning, leading to documentation gaps and poor continuity (Chikafalimani

et al., 2021). This siloed approach results in redundancy, unclear responsibilities and increased lifecycle costs. The insufficient adoption of innovation and sustainability practices is a major impediment. Konanahalli *et al.* (2020), supported by Radebe & Ozumba (2021), argued that low innovation and enforcement of sustainability policies hinder FM progress. Institutions fail to integrate green technologies or sustainability criteria in FM planning, missing opportunities for energy, water and operational efficiencies. This gap is both cultural, as sustainability is not embedded in FM training and structural, in that FM goals are rarely included in strategic planning or budgetary reviews.

2.23 IFMA STRATEGIES

IFMA (2021) defined a strategic facility plan process model that includes interaction between the strategic facility plan and the relevant stakeholders, namely, staff, facility manager and top management, as represented in Table 2.5. They added that organisational analysis is predominantly required to ensure efficiency increases through the definition and implementation of financial analysis, systematic layout planning, SWOT analysis, scenario planning, modelling and an integrated facility planning framework. For facility managers in particular, the SPF process model emphasises on benchmarking Key Info identification, Analysis and synthesis, Scenario development and forecast and SFP implementation as depicted in the following table.

Table 2.5: Strategic Facility Planning (SFP) Process Model (IFMA, 2021)

	Understanding	Analysis	Planning	Acting
Staff	Data gathering	Data management	Input into operational requirements and feasibility constraints	Monitor Tactical facility plan implementation
Facility Managers	Benchmarking Key Info identification	Analysis and synthesis	Scenario development and forecast	SFP implementation Reporting Tactical facility plan development

Top Management	Strategic business planning Team organisation SFP project implementation	Strategic alignment analysis (facilities vs institutional goals); financial and risk appraisal	Review Approval and recommendations	Benefits evaluation
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One of the reporting strategies includes the tactical facility plan development, whereby facility managers should understand the difference between strategic, master and tactical plans, as indicated in Table 2.5 by IFMA (2021). The Strategic Facility Plan, Master Plan and Tactical Plan, the table effectively illustrates the structured hierarchy of facility planning, which spans from strategic to tactical levels. This alignment reflects best practices in facility management (FM) for ensuring that physical assets support organisational goals while optimising cost and performance over their lifecycle (Opoku & Lee, 2022). At the strategic level, plans focus on broader organisational needs such as condition analysis, life cycle cost projections and capacity analyses, which ensure that facilities align with the institution’s long-term objectives.

The master plan level bridges the gap between strategic intent and operational execution by detailing site-specific physical plans, infrastructure layouts, building aesthetics and phasing strategies. Scholars highlight that master planning plays a critical role in managing growth and ensuring cohesive campus or site development, especially in higher education and healthcare sectors (Al-Humaiqani & Al-Ghamdi, 2022). It integrates design, environmental sustainability and social considerations to support resilient and adaptive infrastructure. At the tactical plan level, the focus shifts to operational execution through detailed maintenance schedules, operating budgets and floor plans. This level translates strategic and master plans into actionable tasks, ensuring day-to-day efficiency and service quality (Lai *et al.*, 2022). Routine operational planning is crucial for maintaining facility performance, occupant safety and cost control. As Lai *et al.* (2022) argue, effective tactical FM reduces operational risks and enhances user satisfaction, thereby supporting overall organisational productivity.

The integration of gap analyses, cost projections and engineering assessments across these levels ensures a data-driven approach to facility investment decisions. Recent research underscores the importance of incorporating life cycle costing and predictive analytics to optimise total cost of ownership (Mannino *et al.*, 2021). This approach aligns capital expenditure with operational realities, promoting sustainable facility management practices.

This structured table highlights the interdependence of strategic, master and tactical plans in contemporary facility management. It reinforces the view that a multi-layered approach supports sustainable, resilient and cost-effective facilities that align with organisational goals (Opoku & Lee, 2022). As the built environment evolves in response to sustainability, digitalisation and stakeholder demands, integrated facility planning frameworks remain critical for long-term value creation.

Table 2.6: IFMA Plans (Source: IFMA, 2021)

STRATEGIC FACILITY PLAN	MASTER PLAN	TACTICAL PLAN
Existing condition analysis	Site-specific physical plan for buildings	Maintenance schedules/plans
Organizational needs statement (linking FM to strategy)	Infrastructure and systems within the site	Operational plans
Gap analysis	Aesthetics of buildings and grounds	Building floor plans/stacking plans
Recommendations for new spaces/buildings	Phasing plans for building	Architectural design/configurations
Facility cost projections/life cycle cost analysis	Construction estimates	Operating budget
Capacity analysis and use recommendations	Engineering assessments	Floor plans or occupancy charts

2.24 FACILITY MANAGEMENT AND FINANCIAL PERFORMANCE

One of the main organisational objectives is to be profitable and sustainable in the long run through continuous and upgraded strategic and financial management. IFMA (2021) argued that a strategy applied in facility management is efficient if it includes FM objectives, feasibility analysis, FM risk analysis and financial analysis that involves operating costs/benefits, return on investment, balanced scorecard and sustainability. Figure 2.6 displays suppliers' categorisation for facility managers, where a difference should be made between leverage, strategic, routine and bottleneck suppliers for better facility management (IFMA, 2021).

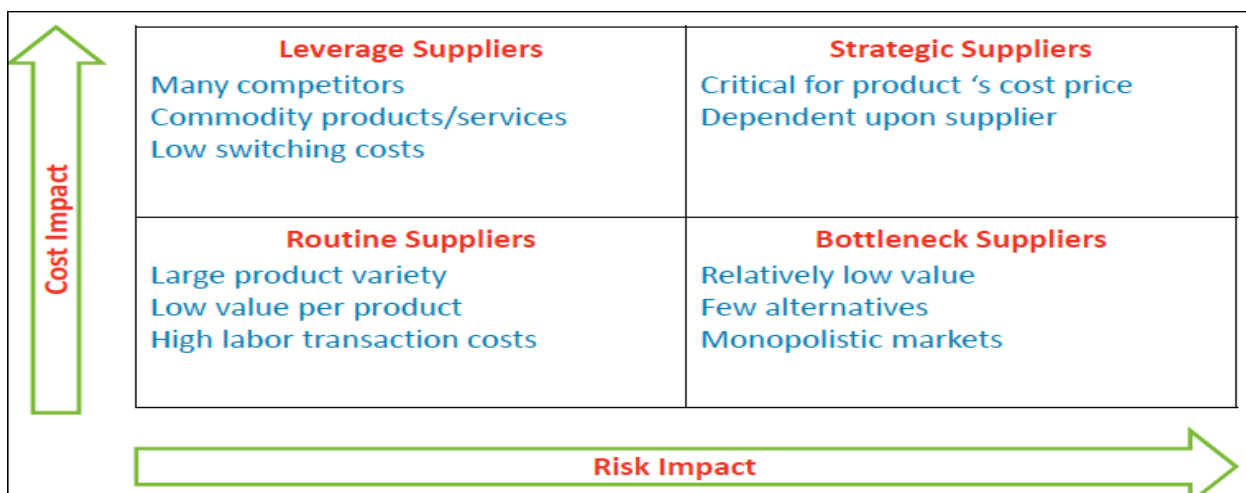


Figure 2.6: Suppliers' categorisation for facility managers (Source: IFMA)

Specific procurement strategies should be identified by facility managers depending on the type of suppliers as internally classified. For strategic and leverage suppliers, partnership and competitive bidding should be suitable for facility management improvement compared to blanket PO and secure supply strategies. The diagram illustrates a classic Kraljic Portfolio Matrix, which categorises suppliers based on their relative cost and risk impact. This strategic supply management framework helps procurement professionals develop differentiated sourcing strategies to maximise value and minimise supply chain vulnerabilities (Yalcin *et al.*, 2024). The matrix plots suppliers along two axes: cost impact (vertical) and risk impact (horizontal). Each quadrant suggests a tailored sourcing approach aligned with the nature of the supplier relationship.

In the top-left quadrant, leverage suppliers provide products or services with high cost impact but low supply risk due to a competitive market with many alternatives. Competitive bidding and e-sourcing are appropriate strategies here because organisations can use their buying power to negotiate favourable terms (Perdana & Mulyono, 2021). This approach leverages low switching costs and market competition to drive cost savings. The top-right quadrant focuses on strategic suppliers, whose goods or services are critical to an organisation's cost structure and performance. These suppliers often operate in a less competitive environment, leading to higher dependency (Khan *et al.*, 2022). Long-term partnerships and collaborative relationships are recommended to mitigate risk and secure a stable supply, as well as to drive innovation through closer integration. Routine suppliers, in the bottom-left quadrant, provide low-value, low-risk items that often involve high transaction costs due to product variety and order volume. To reduce administrative burden and improve efficiency, procurement teams can use blanket purchase orders and e-procurement systems, which standardise ordering and payment processes (Hallikas *et al.*, 2021). Automation in this area frees up resources for more strategic tasks. Bottleneck suppliers occupy the bottom-right quadrant. These suppliers have a relatively low-cost impact but pose a high supply risk due to limited alternatives or monopolistic market conditions.

2.25 THEORETICAL FRAMEWORK

This section of the literature presents the theory that guides facility management techniques applied in this study. Kanan *et al.* (2023) argued that Lean manufacturing comprises efficient management tools and process methodologies enabling waste reduction and delivery of quality products and services to customers. The above theory stipulates that Lean Six Sigma (LSS) management includes sub-elements as depicted in Figure 2.7 below.

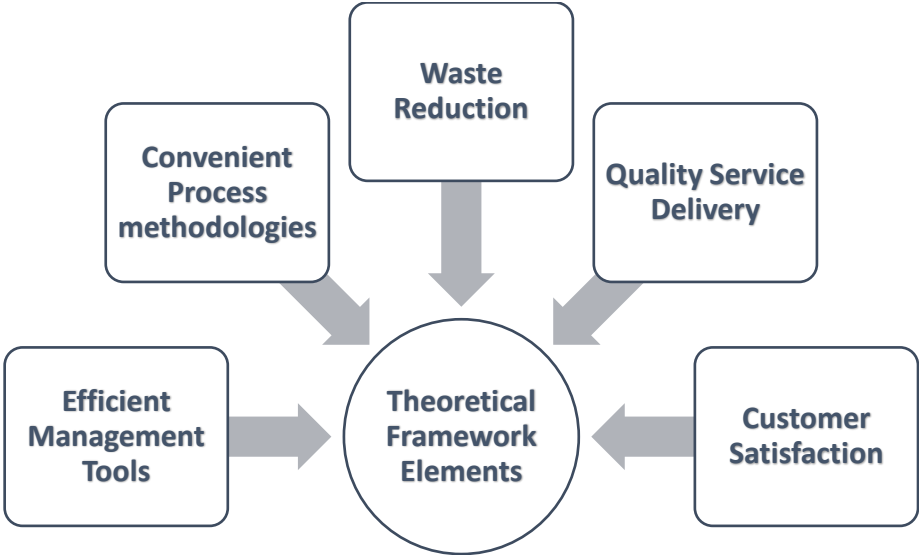


Figure 2.7: Theoretical framework elements (Author,2025)

2.26 DIGITALISATION IN FACILITY MANAGEMENT

The fourth industrial revolution (4IR) has transformed the traditional or domestic ways of operating. da Silva and Cardoso (2024) showed that adopting innovative technologies contribute to business optimisation through cost reduction and customer satisfaction. This suggests that management of facilities equally requires digital transformation for performance improvement and sustainability. According to Al-Qudah *et al.* (2024), six stages, namely business as usual, present and active, formalised, strategic, converged, innovative and adaptive stages, should be followed to achieve a complete digital transformation as presented in Figure 2.8.

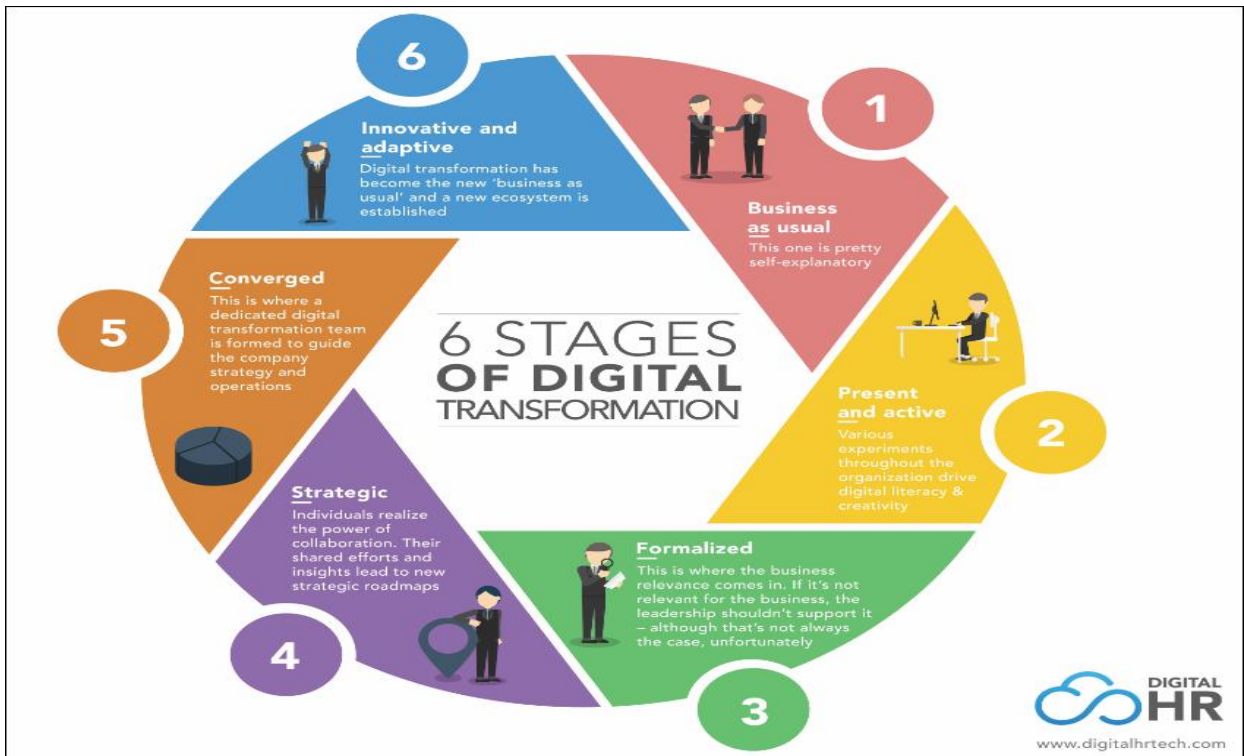


Figure 2.8: Stages of digital change (Digital HR, 2017)

Digital adoption should be handled by the IT department to ensure continuous upgrades. Awareness should be raised on the importance of numerical data for effective operations. Kostakis & Kargas (2021) stated that digital innovation starts with the management, analysis, availability, security and storage of digital data as displayed in Figure 2.9.

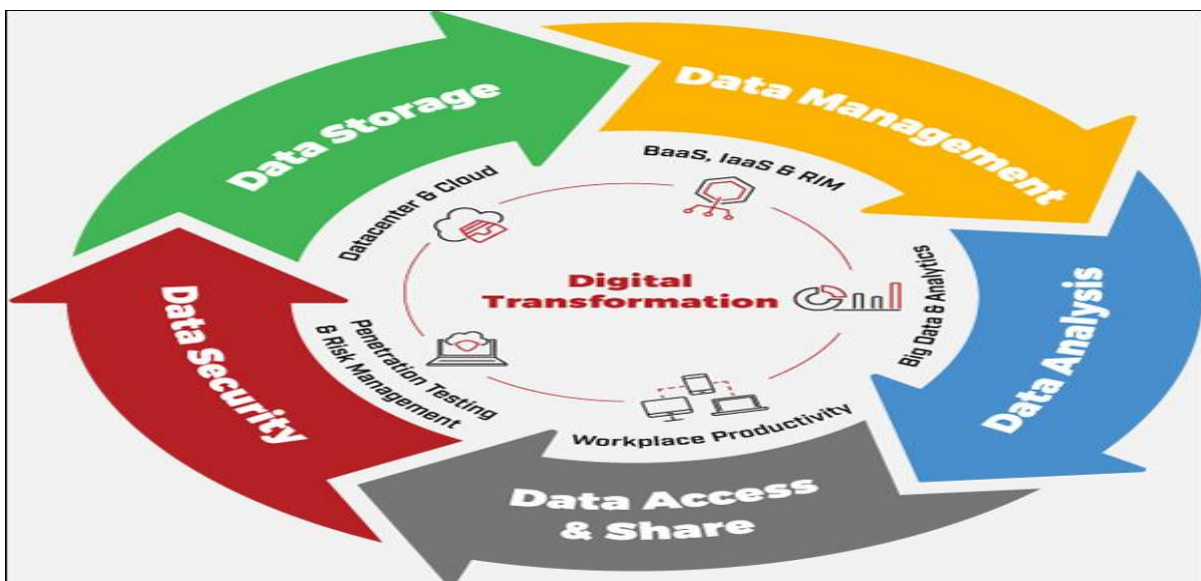


Figure 2.9: Digital data transformation diagram (Digital HR, 2017)

For WSO2 (2021), becoming starts with a successful management of devices involved in the digital process since applications are hosted in specific devices. Figure 2.10 shows that IT facilities such as IoT server and device bindings are the core elements for digital integration and reporting.

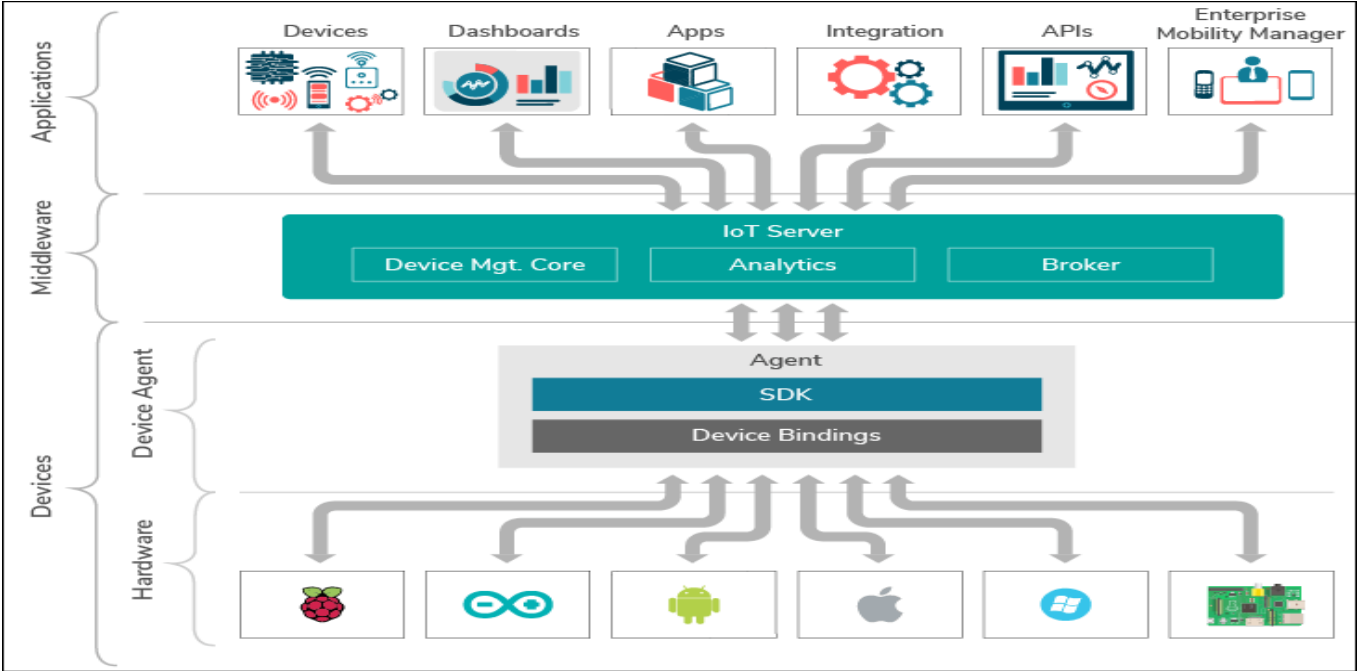


Figure 2:10: Devices and digital transformation (Microsoft, 2018; Relevant Software, 2025)

Figure 2.11 below shows interactions between digital devices and the internet of things (IoT) connectivity in completing business operations and achieve long term goals.

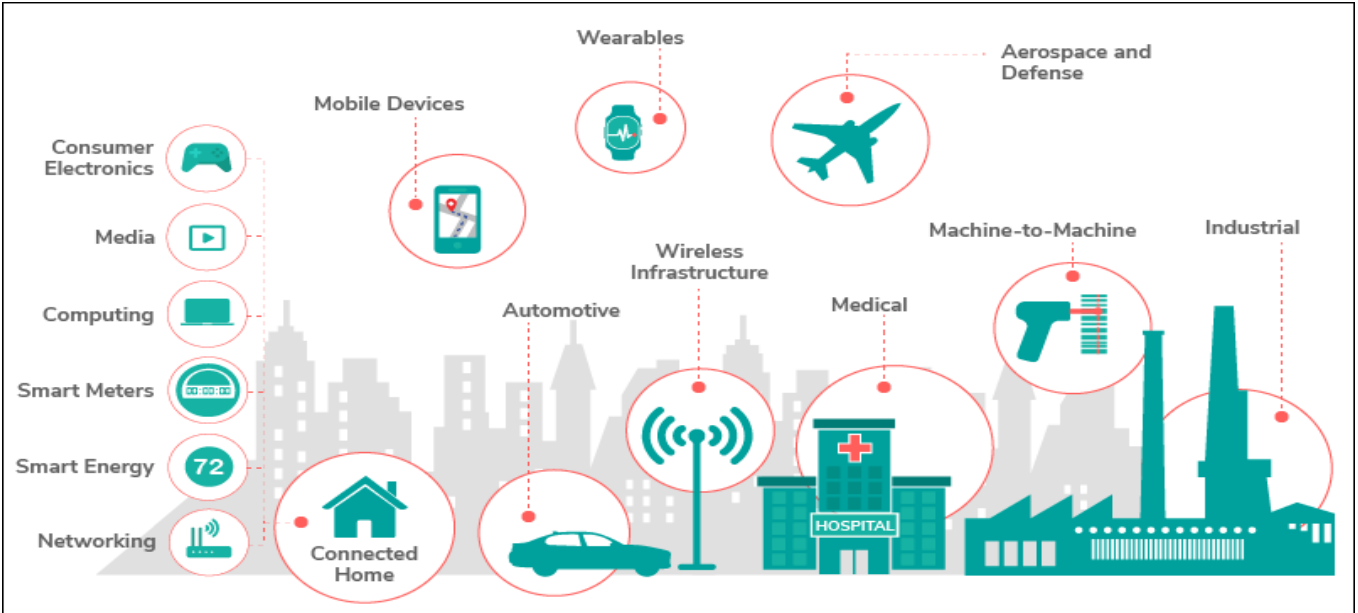


Figure 2.11: Device transforming businesses (Source: WSO2, 2021)

2.27 SYSTEM INTEGRATION IN FACILITY MANAGEMENT

Besides integrating all related systems, the main facility management system should ensure automation of facilities procurement, management of assets, automation of maintenance workflows, decrease repair and maintenance costs, together with the management of suppliers, contractors and other stakeholders (Smartsense, 2021). Figure 2.12 shows that integration between operational systems involved in the facility management process is important for the optimisation of physical resources utilisation. A unique network system platform enables remote system management, real-time location services and instant communication. Also, the system security is managed at many levels through the system detecting potential intrusion while ensuring constant security control over the integrated platform.

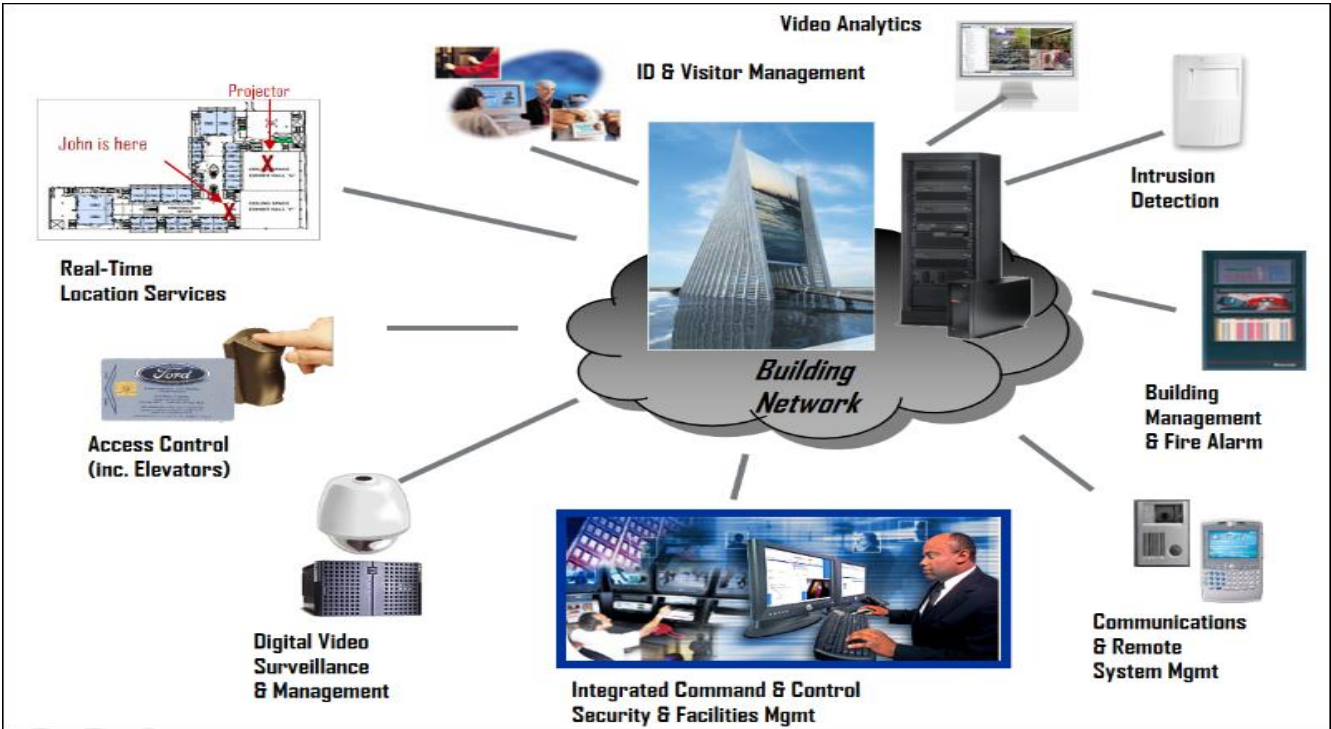


Figure 2.12: System integration (Source: Aikon Solutions .com)

Figure 2.13 illustrates an integrated framework for Enterprise Infrastructure Management (EIM), which unifies Facility Management, Property Management, Operations Management and Technology Management functions. This

multidimensional model reflects the growing recognition that built environment assets must be optimised, allocated, preserved and enabled through a holistic approach (Opoku & Lee, 2022). As highlighted by Opoku and Lee (2022), integrating these domains ensures that infrastructure assets are not only cost-effective but also sustainable and resilient to disruptions.

In the domain of FM, activities such as space management, strategic master planning, furniture and equipment control and workplace services represent efforts to optimise the use of physical assets. Effective space management has been linked to improved operational efficiency and user satisfaction (Jensen & Voordt, 2020). These practices ensure that facilities align with organisational strategy and evolving workforce needs, especially in the post-pandemic era of hybrid work models. The allocate function, as shown in the Property Management segment, focuses on real property and lease management, project management and capital budgeting. These activities are critical for managing the financial performance of real estate portfolios and ensuring that resources are distributed effectively. Al-Humaiqani and Al-Ghamdi (2022) argued that strategic capital allocation and project management underpin sustainable development, risk management and long-term value creation for organisations with extensive property assets.

Preservation is emphasised within Operations Management, which includes environmental sustainability assessment, condition assessment, emergency preparedness and building operations. Research by Al Mughairi *et al.* (2022) demonstrates that continuous condition monitoring and proactive maintenance significantly reduce life cycle costs and enhance building performance. Moreover, environmental sustainability assessment aligns EIM practices with global ESG goals, reinforcing the importance of operational practices that support decarbonisation and climate resilience. Finally, technology management underpins the enable function, ensuring that critical systems such as telecom, cable management, asset control and service desks operate efficiently. IoT-enabled building systems and digital help desks have become vital in improving asset visibility and service response times (Ahmad & Alshurideh, 2025). As Sulaiman *et al.* 2021 pointed out, the digitalisation of infrastructure management enables predictive maintenance, improves user experience and supports data-driven decision-making. The figure presents a

comprehensive model that demonstrates how interconnected management domains can deliver strategic, operational, financial and technological value to organisations. The shift towards integrated infrastructure management aligns with best practices for creating sustainable, resilient and agile built environments in the face of evolving challenges.



Figure 2.13: Enterprise infrastructure management

In the South African context, the UoT benefits from the interaction between facility management on one side and technology and operations management on the other side. Figure 2.14 presents the facility management in the University, emphasising three (3) critical pillars, namely, facility management, operations Management and technology management.

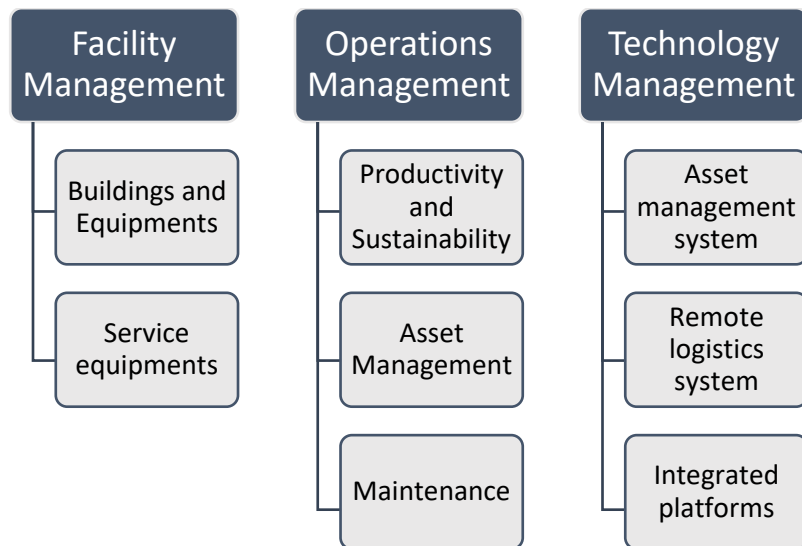


Figure 2.14: Facility management in universities (International Organization for Standardization, 2021)

2.28 CHANGE MAINTENANCE PROCESS

Process of change maintenance involves continuous training and upgrading of employees who are the custodians of facilities, license certification offered by the facility producers, together with the direct involvement of vendors. Modifications can be required before installation and use for aeration, wall support and so on. Sources of changes, whether drastic or smooth in the long term, can be triggered by government regulations, IT innovations, amended service-level agreements between universities and vendors or contractors. Key performance indicators should be managed for universities to identify when consistency affects reliability and thus upgrade traditional ways of handling both internal and external operations. All processes are to be formalised and documented for traceability of effective results and identification of improvement areas. Figure 2.15 displays characteristics of the facility management process during the digital era. The figure illustrates a linear progression that connects key organisational and systems capabilities: Flexibility, Adaptability, Versatility and Diversity, culminating in Resilience. This conceptual chain highlights how these interrelated attributes function together to build robust, sustainable and future-ready organisations. Scholars argue that resilience is not an isolated trait but an emergent outcome of these underlying capacities (Malik *et al.*, 2022). Flexibility, for instance, enables organisations to adjust workflows and reallocate resources in response to changing circumstances, which has been especially critical during crises

such as the COVID-19 pandemic (Ho *et al.*, 2021). Adaptability extends this idea by encompassing the capability to learn, evolve and thrive amid uncertainty. As Luo *et al.* (2021) noted that adaptable organisations embrace feedback loops and continuous improvement, which strengthens their ability to pivot in volatile environments. When combined with flexibility, adaptability allows organisations to address both predictable and unforeseen disruptions in real time. Versatility, the third element in the figure, refers to the multi-functionality and cross-competency of teams, systems and infrastructure. Versatile organisations develop diverse skill sets, redundant systems and multi-use spaces that can be reconfigured as needs shift (Tonetto *et al.*, 2024). This attribute adds a practical layer to adaptability by ensuring that resources can be repurposed without significant downtime, further reinforcing resilience. Diversity plays a crucial role in enhancing system resilience by introducing varied perspectives, skills and problem-solving approaches. Research shows that diverse teams are more innovative and better equipped to manage complex challenges because they avoid groupthink and broaden the range of potential solutions (Lai *et al.*, 2022). Diversity in supply chains, building systems and stakeholder relationships reduces dependency risks and enhances an organisation’s capacity to bounce back from disruptions.

The figure’s directional flow underscores that resilience is not a static goal but an outcome of cultivating flexibility, adaptability, versatility and diversity. This aligns with current thinking in facilities management and organisational design, which advocates for integrated, multi-dimensional strategies to navigate future uncertainties (Opoku & Lee, 2022). As the built environment continues to face climate change, pandemics and technological disruption, this conceptual progression remains vital for sustaining high performance and organisational continuity.

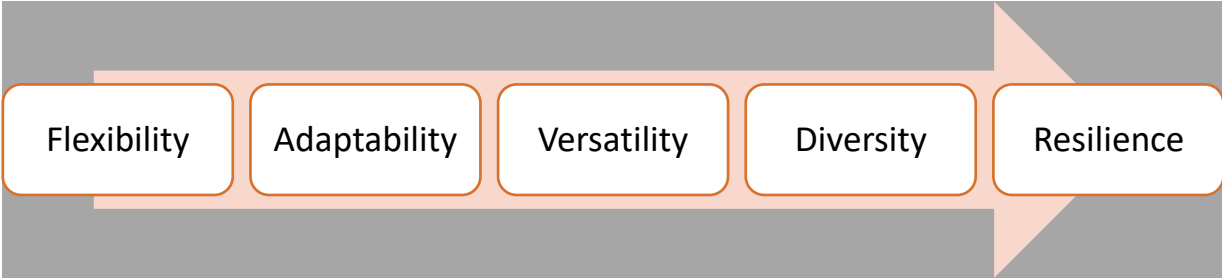


Figure 2.15: Facility management characteristics (Hollnagel, 2020)

2.29 FACILITY MANAGEMENT DURING THE PANDEMIC

The COVID-19 pandemic profoundly transformed the role and scope of FM globally. FM teams were tasked with balancing operational continuity and health safety, requiring unprecedented agility and resilience (Ho *et al.*, 2021). According to Ho *et al.* (2021), FM functions evolved from purely operational roles to strategic roles, involving crisis response planning, real-time risk assessment and stakeholder communication to ensure safe building occupancy. This shift highlighted FM's critical contribution to organisational resilience during public health emergencies.

One of the key areas of adaptation was the implementation of enhanced health, safety and hygiene protocols. Research by Tan *et al.* (2022) demonstrated that FM teams rapidly adopted touchless technologies, air purification systems and reconfigured spaces to comply with physical distancing guidelines (Tan *et al.*, 2022). This technological integration not only ensured safer workspaces but also underscored the increasing convergence of FM and digital transformation. These interventions helped maintain trust among building occupants, which is essential for business continuity during disruptive events.

Occupancy management and space utilisation strategies were also reshaped. In many sectors, FM had to accommodate flexible work arrangements and hybrid occupancy models, which required new space planning and resource allocation approaches (Modgil *et al.*, 2022). Modgil *et al.* (2022) argue that FM played a pivotal role in monitoring occupancy levels, tracking contact tracing data and optimising building services to reduce operational costs under fluctuating occupancy. Such dynamic management demonstrates FM's expanding role as an enabler of safe and adaptive workplaces. Furthermore, the pandemic accelerated the adoption of smart and data-driven FM practices. IoT sensors, building management systems and predictive maintenance became integral for real-time monitoring of indoor air quality, cleaning frequencies and equipment performance (Ahmad & Alshurideh, 2025).

Sulaiman *et al.* (2021) highlighted that these digital tools enhanced the capacity of FM to respond proactively to health threats and minimise service interruptions. These innovations not only addressed immediate pandemic challenges but also laid the

groundwork for smarter, healthier facilities in the long term. The pandemic has redefined FM from a cost-centred function to a strategic driver of organisational resilience, occupant well-being and operational continuity. The lessons learned during COVID-19 have prompted FM professionals to embed flexible, technology-enabled and health-focused practices into standard operations (Tonetto *et al.*, 2024). Tonetto *et al.* (2024) assert, the FM sector must continue to evolve by integrating lessons from the pandemic into future planning to withstand future disruptions. The concept of mobility has striven to address the phenomenon of telework, considering less social inclusion as one of the key COVID-19 protocols to stop the spread of the virus. At the university level, students' buses will be less used due to online learning classes with students off campus. Universities have to invest in buying ergonomic IT and office devices to completely achieve work from home. Less need for parking spaces and fewer parking spaces. Revision of remuneration package, including company car. The above-mentioned comments and critical analysis suggest that the core management of facilities is losing its value-added in improving operational activities in companies. It will not disappear over time, whatever the level of mobility, but its role might drastically shift from operational to strategic level as suggested by da Silva and Cardoso (2024).

For Canon (2022), improving facility management is based on the delivery of convenient facility support applied to specific areas in combination with continuous performance measurement and proactivity. The definition of facility management applications remains the main target for long-term survival in the current unprecedented environment. Figure 2.16 outlines the Facility management approach. The figure presents an integrated framework highlighting four key components: Approach, Tools, Methods and Targets, which collectively shape an effective facility management strategy. A proactive approach with quick response time and compliance with safety regulations aligns with recent research emphasising the critical role of preventative strategies in enhancing operational resilience and risk management (Rezvani *et al.*, 2023).

Proactive facility management enables organisations to anticipate potential issues, reducing downtime and ensuring continuity of services (Lin *et al.*, 2022). Compliance with safety policies not only mitigates legal liabilities but also fosters a culture of safety that supports sustainable operations. The Tools section includes the adoption of

advanced technologies such as FM applications, Six Sigma models and warehouse management systems, which are essential in driving data-driven decision-making. The integration of digital tools and tracking devices is increasingly recognised as vital for optimising asset performance and achieving lean facility operations (Ghansah, 2024). Six Sigma methodologies have been widely applied to reduce process variability, improve quality and enhance overall productivity in facility management contexts (Rosa *et al.*, 2023). This technological advancement enables real-time monitoring, which supports the methods outlined in the figure, such as asset management and on-time delivery.

Recent studies highlight that meeting these targets requires a combination of strategic alignment, effective communication and robust support systems (Opoku & Lee, 2022). Staff satisfaction and student commitment, in particular, are interrelated with support services and programmes that foster a collaborative and productive work environment (Rosa *et al.*, 2023). Thus, the framework illustrated in the figure aligns with contemporary facility management practices aimed at achieving operational excellence and sustainable performance outcomes.

Approach	Tools	Methods	Targets
<ul style="list-style-type: none"> • Proactive • Quick response time • Compliance with safety policies and regulations 	<ul style="list-style-type: none"> • Communication devices • FM applications • Six Sigma model • Warehouse management systems • Tracking devices 	<ul style="list-style-type: none"> • Asset management • Support services • Support programmes • on-time delivery • adequate inventory level • effective reporting and analysis 	<ul style="list-style-type: none"> • Customer satisfaction • Staff satisfaction • Student commitment • met budgets targets

Figure 2.16: FM approach (Canon 2022)

2.30 REVIEW OF CONCEPTUAL MODELS

According to Jensen *et al.* (2012), facility management can add value to the company and societies if and only if facility management and corporate real estate management strategy levels meet green requirements, as indicated in Figure 2.17 below.

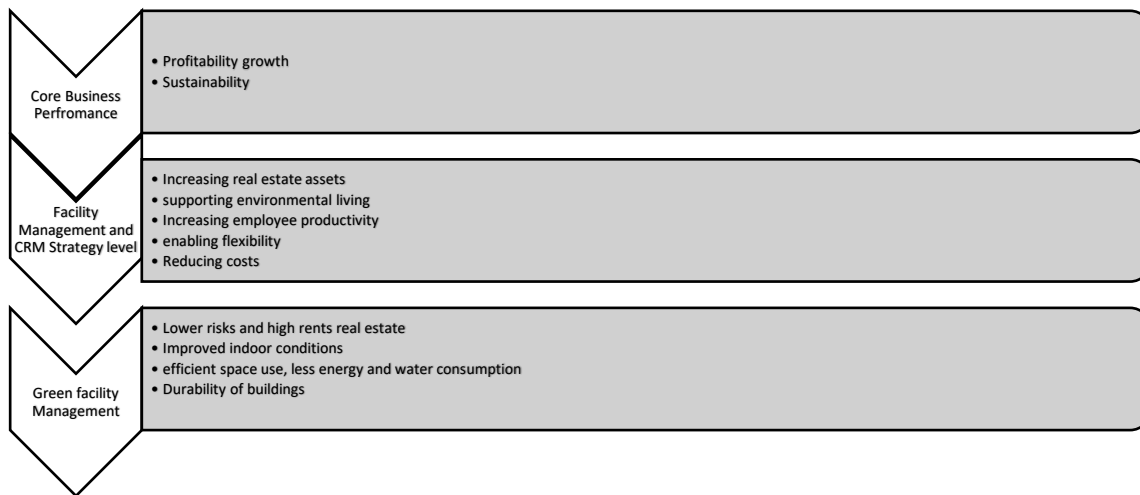


Figure 2.17: FM Values (Eichholtz, Kok & Quigley, 2020)

Stages of Facility Management Process, Figure 2.18 below represents a successful facility management model that comprises three stages, namely facility expectations, Performance evaluation of facilities and Facility management process design as defined by the government of South Australia (2022). The figure presents a structured three-stage model for effective facility management (FM), comprising Facility Expectations, Performance Evaluation of Facilities and Facility Management Process Design. This staged approach aligns with best practices in FM by ensuring that operational processes are continuously informed by stakeholder needs and performance data (Opoku & Lee, 2022).

Stage 1, Facility Expectations, focuses on articulating the requirements and aspirations of stakeholders. This stage is critical because misalignment between user expectations and service delivery often results in dissatisfaction and underperformance. Clearly defining expectations provides a baseline for subsequent measurement and informs the development of realistic and responsive management strategies (Jensen & Voordt, 2020).

Stage 2, Performance Evaluation of Facilities, emphasises the need for systematic measurement of facility conditions, functionality and service quality. This aligns with post-occupancy evaluation (POE) principles, which assess whether facilities meet user needs and deliver value throughout their lifecycle (Al Mughairi *et al.*, 2022). Research shows that robust performance evaluation frameworks, incorporating key performance indicators (KPIs) and feedback loops, are essential for continuous improvement and sustainability in FM.

Stage 3, Facility Management Process Design, uses insights from the performance evaluation to design or refine FM processes. This ensures that service delivery mechanisms are tailored to meet stakeholder expectations effectively and efficiently. As Mannino *et al.* (2021) argue, integrating performance data into FM design enables proactive maintenance, resource optimisation and alignment with broader organisational objectives. By structuring FM as an iterative process that begins with stakeholder expectations, evaluates actual performance and then adjusts management processes, organisations can create resilient and sustainable facilities. This staged approach echoes the continuous improvement cycle inherent in total quality management and life cycle costing principles, which are increasingly recognised as vital for modern FM practices (Lai *et al.*, 2022).

The figure illustrates a practical and evidence-based approach for aligning facilities with evolving user needs, thereby enhancing operational effectiveness, user satisfaction and sustainability performance.

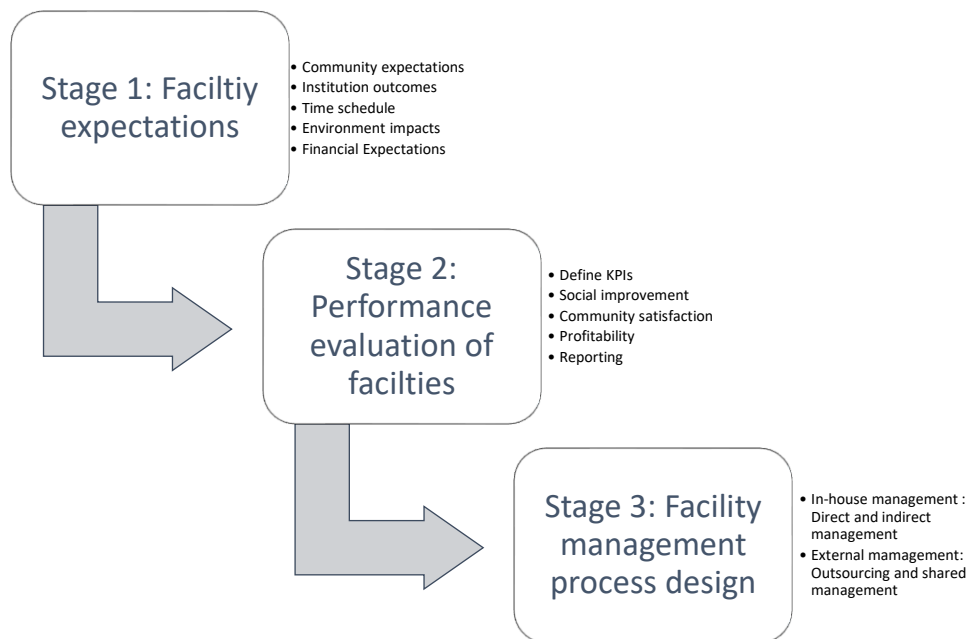


Figure 2.18: FM model (ISO, 2018)

The conceptual framework diagram illustrates seven critical components that influence an integrated approach to organisational development and resilience: stakeholders' experience, system integration, change maintenance process, COVID-19 change, ISO principles, sustainability and digitalisation. At its core, the framework underscores the interdependence of these elements in shaping effective management and operational strategies within contemporary contexts. Stakeholders' experience is increasingly recognised as pivotal to the co-creation of value and successful implementation of frameworks, as evidenced by Gordo-Gregorio *et al.* (2025), who argued that stakeholder involvement fosters shared understanding and continuous improvement.

System integration is another essential component highlighted in the diagram. In an era of digital transformation, seamless integration of systems enhances operational efficiency, data-driven decision-making and adaptability (Salman & Ahmad, 2025). Integrating diverse IT systems allows organisations to respond swiftly to market dynamics and stakeholder needs while minimising redundancy and errors. This aspect aligns closely with the digitalisation dimension shown in the framework, which emphasises the adoption of digital tools and processes to drive innovation and resilience. The diagram also positions change maintenance processes and COVID-19 change as vital components. The pandemic has accelerated the need for dynamic

change management approaches to ensure organisational sustainability during crises (Modgil *et al.*, 2022).

Effective change maintenance processes provide mechanisms for continuous monitoring, feedback and adaptation, which are critical in responding to unprecedented disruptions like COVID-19. Sustainability and adherence to ISO principles are equally central to this conceptual framework. Sustainability initiatives are increasingly embedded in strategic management to meet environmental, social and governance (ESG) goals, which enhances corporate reputation and operational longevity (Oyelakin & Johl, 2022). ISO principles offer standardised guidelines that strengthen governance structures, promote best practices and ensure compliance with global benchmarks.

The integration of digitalisation within this framework points to its transformative impact across all other components. Digital tools facilitate stakeholder engagement, system interoperability and real-time monitoring of sustainability metrics and compliance with ISO standards. As Lok *et al.* (2023) note, digitalisation is not merely a technological upgrade but a strategic enabler for process innovation and organisational agility (Lok *et al.*, 2023). This conceptual framework diagram in Figure 2.19 presents a holistic view of the interconnected drivers that shape resilient and sustainable organisational ecosystems in a rapidly changing global environment.

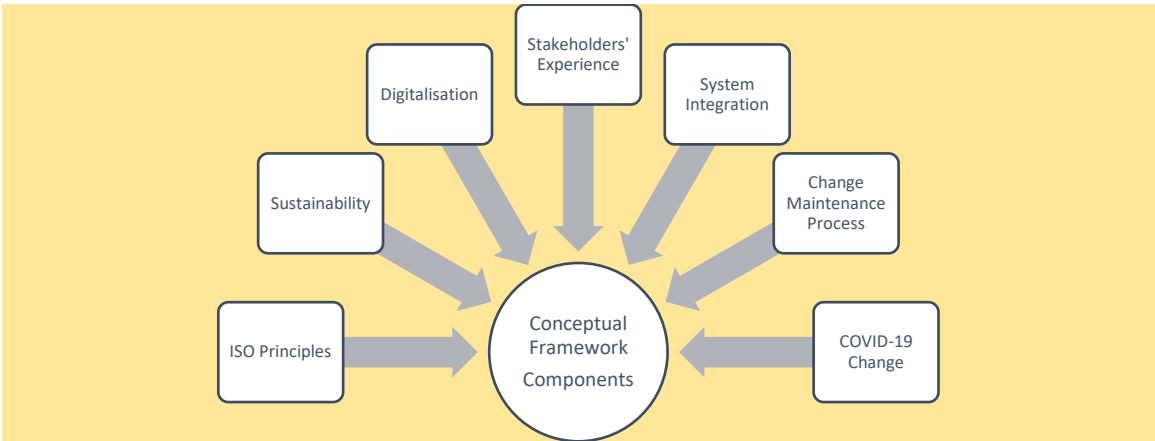


Figure 2.19: Conceptual framework components (Author’s 2025, ISO 41001, ISO, 2018)

2.31 FACILITY MANAGEMENT THEORY SUPPORTING THE STUDY

2.31.1 Systems Theory in Integrated FM for Higher Education

Systems Theory, as conceptualised by Ludwig von Bertalanffy in the 1940s and formally articulated in his seminal work *General System Theory* in 1968, provides a valuable lens through which the complexity of organisations, including universities, can be understood. The theory views organisations as open systems composed of interrelated and interdependent components that interact continuously with their internal and external environments. Within the context of integrated facilities management (FM) in higher education, Systems Theory highlights the need to manage physical assets, people, processes and technologies as a cohesive whole rather than as isolated functions.

It posits that an organisation is composed of interrelated subsystems that must function cohesively to achieve the broader goals of the institution (Skyttner, 2022). In FM, Systems Theory is instrumental in promoting a holistic view where all components, people, processes, technologies and physical infrastructure are managed as part of an interconnected whole. This systems-based thinking is particularly relevant to higher education institutions, where diverse FM functions must support academic excellence, student welfare and regulatory compliance.

Integrated Facility Management (IFM) embodies Systems Theory by unifying multiple FM services such as maintenance, cleaning, security and energy management within a single strategic and operational framework. Sedhom *et al.* (2024) highlighted that universities, due to their complex and decentralised environments, benefit significantly from integrated FM models. These models encourage coordination among departments, ensure accountability and optimise resources by leveraging shared data and collaborative processes. Systems Theory helps university FM teams anticipate how changes in one area, such as deferred maintenance, can impact others with regard to student satisfaction or safety, allowing for more informed and systemic decision-making.

The integration of digital technologies such as BIM, Geographic Information Systems (GIS) and Building Automation Systems (BAS) further reinforces the application of Systems Theory in higher education FM. Congiu *et al.* (2024) developed a bidirectional BIM-GIS framework that allows facility managers to move fluidly between spatial and operational views, improving planning, energy efficiency and emergency response. Similarly, Quinn *et al.* (2022) demonstrate that the integration of BAS data into BIM models enables real-time monitoring and predictive maintenance. These technological systems, when interlinked, reflect Systems Theory by enabling cross-functional visibility and responsive infrastructure management in multi-campus university settings. A critical dimension of Systems Theory in FM is its sociotechnical orientation, which considers the interaction between human actors and technical systems. In higher education, this is evident in the collaboration between academic staff, students, maintenance workers and external service providers. Kaswan and Rathi (2021) argued that effective FM depends not only on technological tools but also on aligning stakeholder responsibilities, governance structures and communication channels. This alignment ensures that the FM system is both technically efficient and socially responsive, important qualities in university environments where stakeholder expectations and service standards are high.

Systems Theory also offers a pathway for universities to strengthen sustainability and resilience within their FM strategies. Caldera *et al.* (2021) advocate for the application of Critical Systems Thinking (CST) to address complex challenges such as climate change adaptation, infrastructure ageing and financial constraints. By using systemic tools like feedback loops, stakeholder mapping and scenario modelling, FM teams can shift from reactive to proactive planning. This evolution positions IFM not just as an operational necessity but as a strategic enabler for sustainable campus development. In the South African context, where the University of Technology face pressing needs for efficiency, cost control and green compliance, Systems Theory provides a robust foundation for designing and managing integrated, future-ready facility systems as outlined in Figure 2.20.

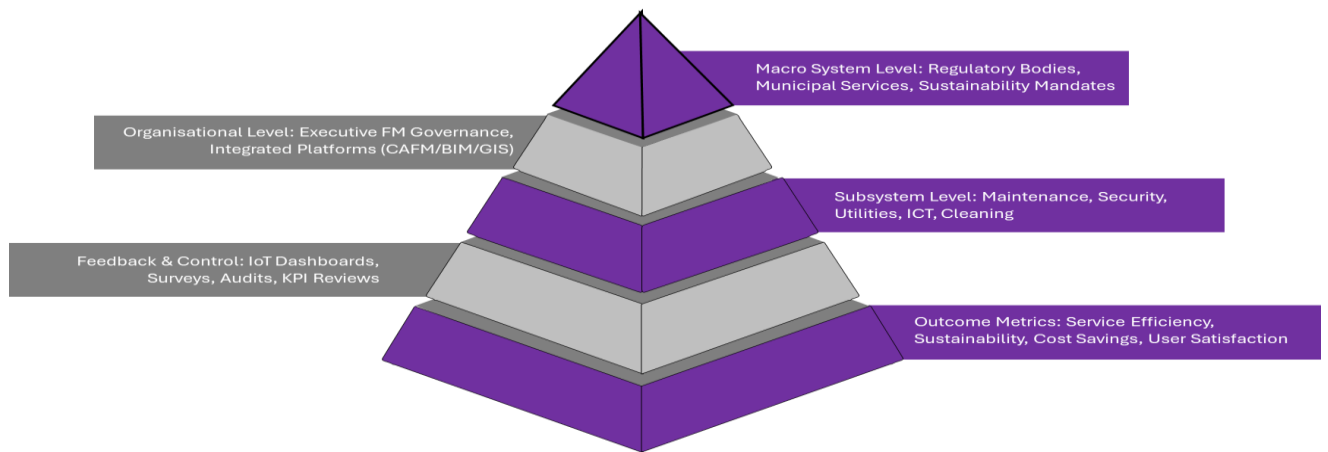


Figure 2.20: System Theory for integrated FM in higher education (Author 2025, ISO 41001,ISO, 2018)

2.31.2 Continuous improvement theory on FM in higher education

Continuous Improvement (CI) is a foundational concept in quality and operations management, widely applied through cycles such as Plan-Do-Check-Act (PDCA). In the context of higher education facility management (HE-FM), CI offers a structured approach to iteratively improving service delivery, infrastructure performance and stakeholder satisfaction. He (2024) emphasises that embedding PDCA in university operations enables early anomaly detection and more agile problem-solving, which are critical in the dynamic environments of higher education institutions. Technological advancement has further enhanced the application of CI in FM. Mahmoud *et al* (2024) conducted a comprehensive review highlighting how BIM and IoT sensors are increasingly integrated into FM systems to facilitate real-time feedback and data-driven adjustments. Their findings show that smart CI practices improve operational reliability, energy efficiency and overall responsiveness to user needs in campus settings. Incorporating CI strategies into FM also supports broader institutional objectives such as sustainability and social inclusion. A recent case study in South Africa found that applying continuous improvement principles through routine performance audits, stakeholder consultations and inclusive design workshops led to measurable improvements in both facility performance and student well-being (Moghayedi *et al.*, 2023). This suggests that CI is not only a technical tool but also a vehicle for aligning FM practices with the social mission of universities. Despite its advantages, implementing CI in HE-FM is not without challenges. EAB (2024) notes that many universities still operate with siloed departments, outdated legacy systems and limited

data infrastructure, all of which hinder the success of continuous improvement initiatives. Overcoming these barriers requires institutional commitment, integrated digital platforms and a culture of accountability among FM teams and leadership. To institutionalise CI effectively, higher education institutions must adopt maturity models and KPIs that align with sustainability goals, digital transformation and service excellence. Mahmoud *et al.* (2024) recommend embedding continuous feedback loops within digital FM platforms to enable proactive maintenance, strategic asset planning and long-term optimisation. As universities evolve into complex, service-oriented ecosystems, CI becomes an indispensable strategy for ensuring resilient and adaptive facility operations. Figure 2.21 presents the continuous improvement theory on FM in higher education.

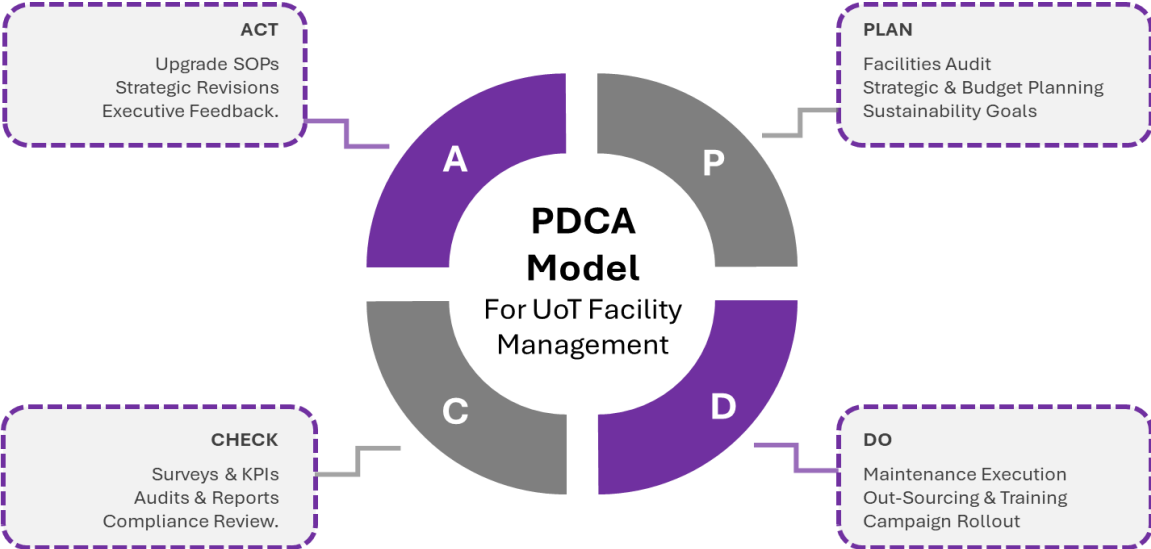


Figure 2.21: PDCA model for UoT FM (Antony, 2021)

2.31.3 Sustainable Development Theory on FM in UoT

Sustainable Development Theory (SDT) emphasises the integration of environmental, social and economic goals to ensure long-term development without compromising future generations. In the context of FM at South African UoT, this theory provides a guiding framework for aligning infrastructure operations with institutional sustainability mandates. According to Opoku and Lee (2022), FM plays a critical role in institutionalising the Sustainable Development Goals through responsible campus planning, green procurement and inclusive space management. Sustainable Facilities Management (SFM) builds on this theoretical foundation by embedding sustainability

principles into FM activities such as energy management, waste reduction and lifecycle asset planning. Radebe & Ozumba (2021) argue that while higher education institutions often embrace sustainable construction standards, the operationalisation of sustainability within FM remains inconsistent. This gap between design and practice reflects a failure to translate sustainable intentions into actionable strategies, a shortcoming SDT directly addresses by promoting systemic, long-term thinking.

Recent empirical research highlights the growing relevance of integrated FM approaches for advancing sustainability in higher education. Opoku and Lee (2022) conducted a bibliometric review revealing a shift toward smart, data-enabled FM strategies that balance cost control and ecological performance. Technologies such as BIM and IoT sensors allow FM teams to track building usage, emissions and maintenance patterns in real time, enabling more sustainable decision-making. Molloy and Adewunmi (2025) further support this perspective, showing how FM standards aligned with SDGs can enhance institutional sustainability reporting and benchmarking. Social sustainability also features prominently within Sustainable Development Theory as applied to FM. Gwabavu and Shakantu (2024) found that the condition of facilities, accessibility and maintenance responsiveness significantly affect student well-being and equity outcomes in South African universities. Their findings affirm that FM is not just about infrastructure; it is instrumental in shaping inclusive, safe and empowering learning environments. This reflects SDT's focus on the "people" dimension of sustainability, urging institutions to consider the human impact of facility operations.

Despite these promising directions, several barriers continue to inhibit the full application of Sustainable Development Theory in FM at UoT. These include limited institutional capacity, outdated infrastructure, insufficient data integration and low prioritisation of FM in strategic planning (Okoro, 2023). To overcome these challenges, scholars advocate for FM maturity models, cross-functional governance structures and enhanced performance measurement systems tailored to sustainability goals. By institutionalising SDT within FM, UoT can improve environmental outcomes, foster student success and align more closely with national and global development frameworks. Figure 2.22 presents the Sustainable Development Theory as applied to FM in UoT.

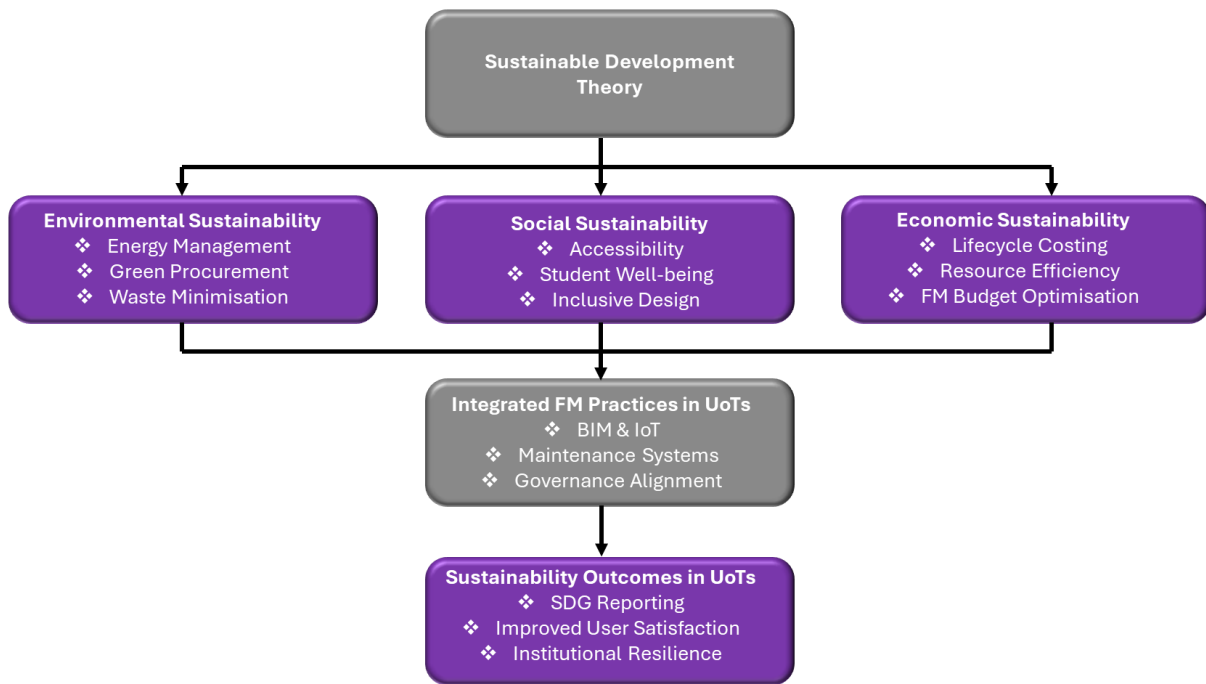


Figure 2.22: Sustainability theory applied to FM in UoT (Darko and Chan, 2023)

2.31.4 Technology Acceptance Model in UoT Facility Management

The Technology Acceptance Model (TAM), originally proposed by An *et al.* (2023), provides a theoretical framework for understanding user behaviour regarding the adoption of new technologies. It centres on two key constructs, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), which jointly influence users' intention to adopt technology. In the context of FM at the South African UoT, TAM is increasingly used to understand the uptake of digital tools such as BIM, Computer-Aided Facility Management (CAFM) systems and Internet of Things (IoT) platforms (Nortey *et al.*, 2025). Recent research highlights that both PU and PEOU are significantly affected by factors such as system functionality, interface design and training. Nortey (2024), in a study involving FM professionals across tertiary institutions, found that FM personnel were more likely to adopt digital FM platforms when they perceived them as improving efficiency and when the systems were easy to navigate. Furthermore, availability of ongoing technical support positively influenced users' confidence, reinforcing the importance of institutional readiness for FM digitalisation. IoT-based applications in FM, such as leak detection, smart lighting and air quality sensors, present valuable innovations, but their adoption depends on user trust and digital competence. Negrin

(2023) shows that technology readiness and trust in automation significantly mediate the TAM constructs in FM settings. This is particularly relevant in UoT where FM staff may vary in technical exposure. Training, awareness campaigns and user engagement are therefore critical to strengthening technology acceptance and mitigating resistance to change.

TAM has been extended through the inclusion of contextual constructs such as compatibility, observability and awareness, especially in relation to BIM-based FM systems. Nortey *et al.* (2025) developed the BIM-FM Innovation Acceptance Framework, demonstrating that awareness of standards and system interoperability strongly influence PU and adoption intentions. For UoT this implies that without foundational training and policy alignment, even well-funded FM systems may experience underutilisation due to low user acceptance. While TAM provides a foundational lens, its integration with other models like the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Task-Technology Fit (TTF) framework has been recommended to improve predictive power. Granić (2024) argues that including organisational, social and behavioural factors offers a more comprehensive understanding of technology adoption. South African UoT, such as hybrid models, can guide leadership in designing more effective change management strategies that align technological implementation with FM capabilities and user expectations.

2.31.5 LSS-Based SFMF Conceptual Framework for UoT

The proposed conceptual framework guides the development of a Sustainable Facility Management (SFM) framework for South African Universities of Technology by applying Lean Six Sigma (LSS). It integrates three core domains facility management, sustainability, and LSS to improve operational efficiency, service quality, and environmental performance within higher education infrastructure. Facility management forms the foundation of the framework, as it encompasses both operational and strategic activities required to maintain and enhance the university-built environment. In the UoT context, this includes infrastructure maintenance, utilities management, campus safety, and space utilisation. FM departments commonly face challenges such as ageing infrastructure, budget constraints, reactive maintenance

practices, and stakeholder dissatisfaction, underscoring the need for a structured, performance-driven improvement approach aligned with long-term institutional goals. To ensure long-term relevance, sustainability principles are embedded at the core of the framework. Guided by the Triple Bottom Line approach, the framework promotes FM practices that balance economic efficiency, environmental responsibility, and social well-being. Sustainable FM contributes to cost savings through energy efficiency, reduces environmental impacts through improved waste management, and enhances stakeholder satisfaction by providing safe and functional learning environments.

Lean Six Sigma serves as the methodological driver of the framework. Lean focuses on eliminating non-value-adding activities, while Six Sigma reduces process variation and improves quality. The DMAIC cycle provides a structured pathway for identifying FM inefficiencies, diagnosing root causes, implementing targeted interventions, and sustaining performance improvements. The framework is further underpinned by Total Quality Management and Systems Thinking. TQM reinforces continuous improvement and stakeholder focus, while Systems Thinking enables a holistic view of FM by recognising interdependencies between infrastructure, institutional policies, and user behaviour. Although LSS applications in FM remain limited, existing studies offer valuable insights. Case evidence shows that applying LSS in university facilities can reduce rework, approval delays, and operational costs, particularly when efficiency and sustainability objectives are aligned (Ratvasky & Furterer, 2024; Detyna, 2023). Sustainability-oriented waste management frameworks also demonstrate how Lean tools can improve resource efficiency and reduce FM operating costs in public-sector environments (Klein et al., 2021). South African studies further confirm the relevance of LSS in resource-constrained settings. Evidence from manufacturing and laboratory environments highlights improvements in service quality and efficiency, with leadership commitment identified as a critical success factor (Mabotja & Mavutha, 2024; Mbita & Swartz, 2024). These findings underscore the importance of governance and management support in implementing an LSS-based FM framework within UoTs. By integrating international and local evidence, the proposed framework combines LSS process optimisation, sustainability alignment, and context-specific governance considerations. The conceptual framework presented in Figure 2.23 aligns DMAIC phases with FM performance outcomes and sustainability gains, providing a structured

foundation for developing an integrated SFM framework for South African Universities of Technology.

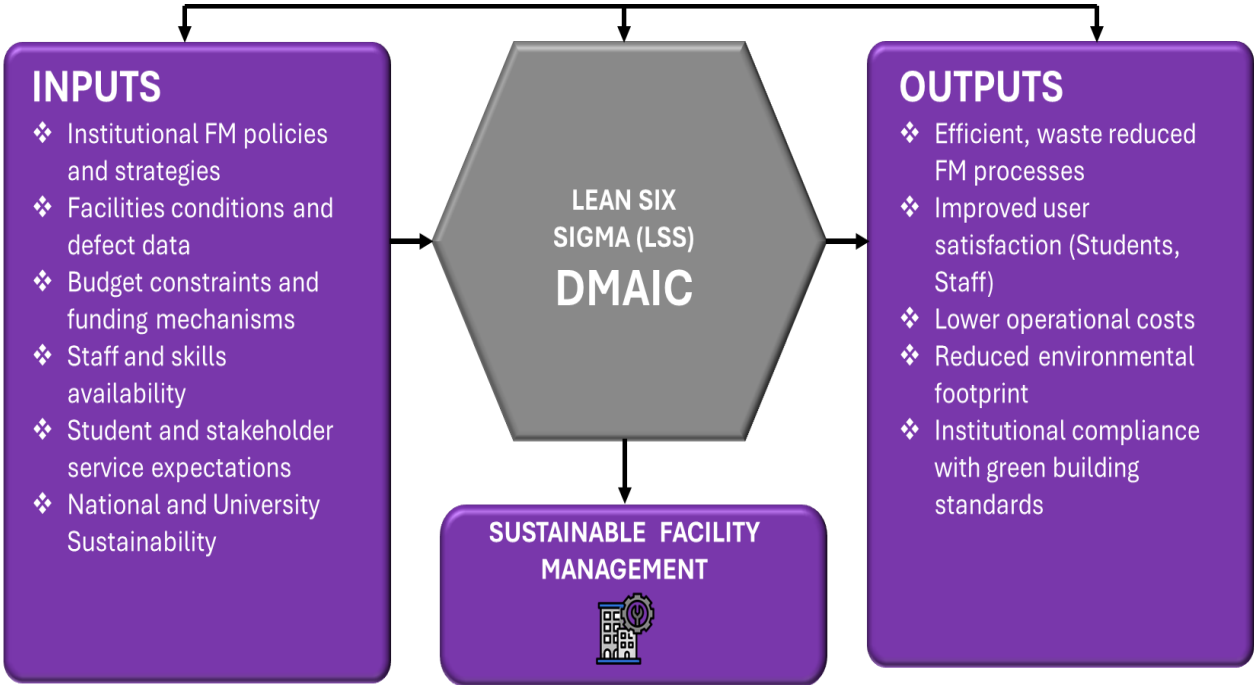


Figure 2.23: Conceptual framework (Antony et al., 2021; Ghasemibojd et al., 2025)

2.31.6 FM Change Framework (Kotter’s 8 Steps)

- ***Creating Urgency through Benchmarking Inefficiencies***

The first step involves establishing a compelling need for change within the FM context. Benchmarking tools can identify inefficiencies such as excessive energy use, high maintenance backlog, poor space utilisation, or non-compliance with sustainability regulations. Research shows that quantifying these gaps using KPIs significantly motivates stakeholders to acknowledge the necessity for transformation (Carreño, 2024). In FM, this could involve energy audits, maintenance response time analysis, or comparing operational costs to industry best practices to highlight the risks of inaction and benefits of change (Picado Argüello & González-Prida, 2024).

- ***Forming an FM-Wide Guiding Coalition***

Kotter's second step focuses on assembling a diverse and influential coalition to champion change. In facility management, this coalition should include technical teams (maintenance and engineering), sustainability officers, finance representatives and end-user delegates including academic or office occupants. Literature suggests that multidisciplinary coalitions enhance commitment and reduce resistance by ensuring all operational perspectives are represented (Majnoor, 2024). Leadership within this coalition is essential to align departmental goals and provide the authority needed to overcome entrenched operational silos.

- ***Developing a Vision Aligned with Corporate Sustainability Strategy***

A clear and actionable vision for change is critical to success (Kotter, 2012). In FM, this vision should integrate broader corporate sustainability goals, such as net-zero emissions, energy efficiency and occupant well-being, with facility-level operational targets. Studies on integrated FM systems highlight that aligning vision statements with strategic sustainability frameworks, including ESG and ISO standards, increases top management support and resource allocation for initiatives like green building upgrades or smart technology adoption (Carman *et al.*, 2019).

- ***Communicating the Vision via Town-Halls and CAFM Interfaces***

Effective communication transforms strategic visions into shared understanding. Literature on change communication shows that consistent, transparent and multi-channel messaging significantly enhances adoption rates (Santos de Souza & Chimenti, 2024). In FM, leaders can use town hall meetings to engage directly with staff and end users, explain the benefits, and address concerns. Additionally, CAFM (Computer-Aided Facility Management) platforms can disseminate updates, project dashboards and real-time metrics, fostering a continuous dialogue that reinforces urgency and commitment throughout the change journey.

- ***Generating Short-Term wins***

Research consistently emphasises that visible early successes are crucial for maintaining momentum in organisational change (Carreño, 2024). In FM initiatives, short-term wins may include a measurable reduction in energy consumption after deploying building automation systems or noticeable improvements in maintenance request turnaround times through workflow digitisation. These results should be publicly celebrated within the organisation to validate the change effort and build confidence among sceptical stakeholders (Picado Argüello & González-Prida, 2024).

- ***Consolidating Achievements by Upskilling Facilities Staff***

Kotter's model warns against declaring victory too soon; instead, it advocates consolidating gains and driving further change. In FM, sustained improvement requires ongoing staff training and competency development in areas like energy management, IoT-enabled maintenance and sustainability reporting. Studies in change management demonstrate that organisations investing in workforce development post-implementation achieve higher long-term performance and adaptability to emerging challenges (Majnoor, 2024). This step strengthens internal capabilities to sustain and expand on initial improvements.

- ***Standardising New Procedures through Documented Protocols***

For changes to endure, they must be embedded in organisational processes. FM literature highlights that standard operating procedures (SOPs), digital maintenance manuals and documented workflows help institutionalise new practices (Kerzner, 2018). For example, newly introduced energy efficiency measures or predictive maintenance routines should be codified in ISO-compliant documents, ensuring consistent application even as staff or leadership changes occur. This formalisation also supports regulatory audits and certification requirements such as ISO 41001 for facility management systems.

- ***Anchoring Change via Leadership Endorsement and ISO 41001 Integration***

Finally, lasting transformation requires anchoring the new approaches within organisational culture and leadership frameworks (Kotter, 2012). In FM, executive leaders must continuously endorse the changes, integrating them into corporate policies, performance reviews and strategic planning. Aligning operations with ISO 41001 further legitimises the changes, embedding best practices for efficient and sustainable facility management (Carman *et al.*, 2019). This institutionalisation phase ensures that improvements in sustainability, technology adoption and service delivery become part of the institutional fabric. Based on the holistic view of facility management theories enforce the following:

- i. **Sustainable Development Theory** is the most appropriate primary FM theory because it directly underpins the sustainability goals of your LSS-based framework, ensuring alignment with TBL principles (economic efficiency, environmental stewardship and social well-being), policy mandates and the long-term resilience of UoT infrastructure. SDT aligns your framework with national and global sustainability mandates, such as the UN SDGs and ISO 41001, making your research more policy-compliant and academically robust.
- ii. **Systems Theory** should act as the secondary theoretical pillar, providing the integrative, holistic view that will allow LSS process improvements to function effectively within the university's interconnected FM system. Leadership effectiveness, Digital readiness and Cultural adaptability are vital components in system theory. Systems Theory reinforces integration of FM activities (maintenance, energy, safety) into one cohesive operational ecosystem, which LSS can then optimise.
- iii. **Kotter's 8-Step Change Model** becomes critical and relevant for implementation and change management, but not the overarching theoretical lens.

Across the facility management theories applied to higher education, three cross-cutting dimensions emerge as central enablers of effective practice: leadership effectiveness, organisational digital readiness and cultural adaptability. Systems Theory, Lean Six Sigma frameworks and Kotter's Change Model all highlight the pivotal role of leadership in aligning subsystems, mobilising resources and sustaining change through governance and vision. Organisational digital readiness is reflected in Systems

Theory, Continuous Improvement and the Technology Acceptance Model, where the integration of tools such as BIM, IoT and CAFM platforms demonstrates the need for institutions to invest in infrastructure, training and support to unlock efficiency and responsiveness. Cultural adaptability, meanwhile, is emphasised in Systems Theory's sociotechnical orientation, Sustainable Development Theory's focus on inclusivity and equity and Kotter's model of anchoring change into institutional culture. Collectively, these dimensions show that sustainable facility management in the University of Technology requires more than technical solution depends on committed leadership, digitally mature systems and an adaptive culture that embraces innovation and inclusivity.

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2.31.7 Construct Underpinning Development of the Sustainability FM Scheme

The hypothesised structural model in Figure 2.24 illustrates the proposed relationships among the key constructs underpinning the development of a sustainable facility management scheme within the UoT. Drawing from LSS principles and facility management literature, the model posits five (5) constructs direct relationships:

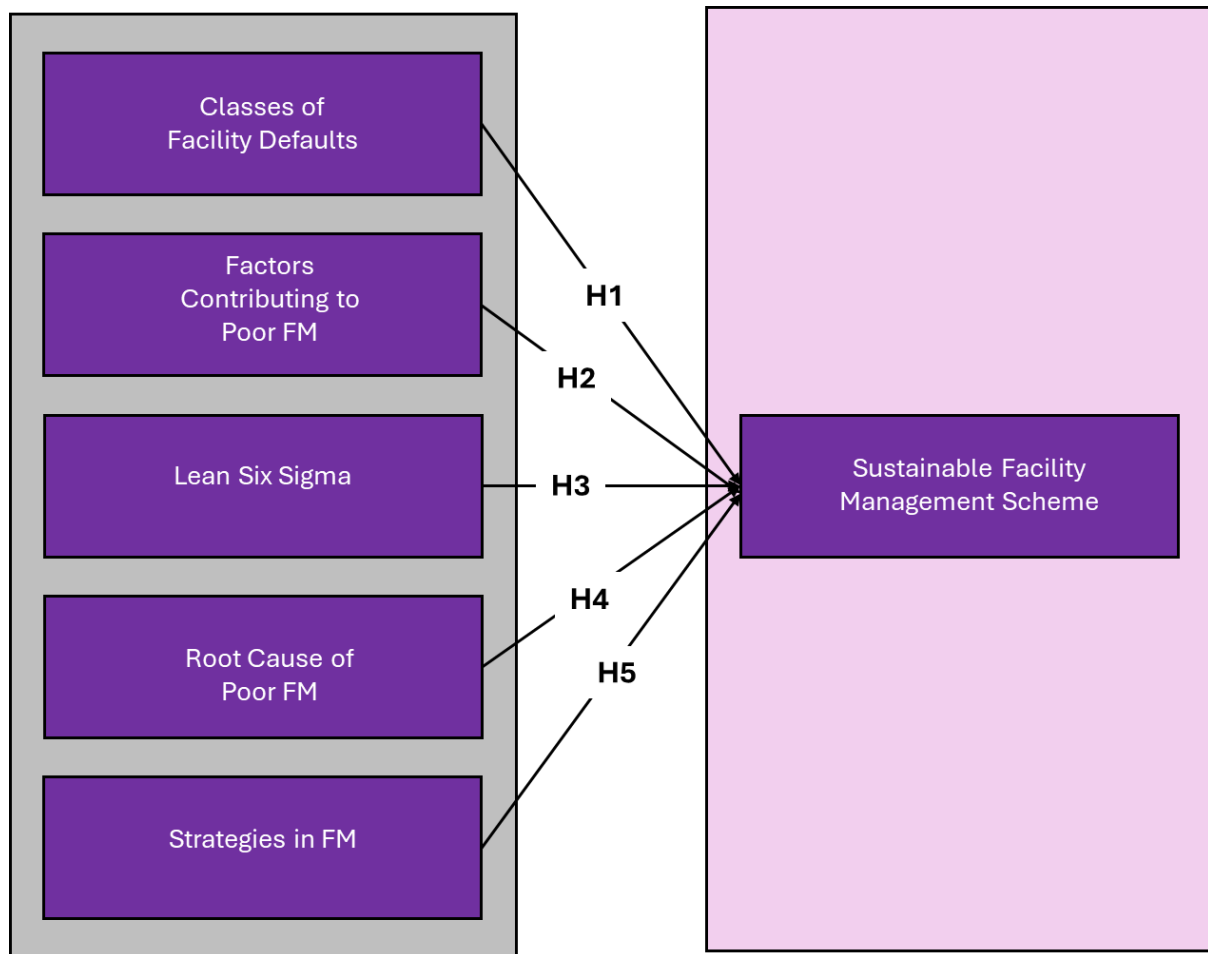


Figure 2.24: Conceptual model (Antony et al., 2021; Ghasemibojd et al., 2025)

H1: Classes of facility defaults are negatively associated with sustainable facility management schemes. Prior studies suggest that persistent structural and operational defects compromise the long-term sustainability of facilities (Olanrewaju, 2025).

H2: Factors contributing to poor facility management negatively influence sustainable facility management schemes. This aligns with findings identified organisational inefficiencies and inadequate resource allocation as significant barriers (Durdyev *et al.* 2022).

H3: Lean Six Sigma practices positively impact sustainable facility management schemes. Evidence indicates that adopting process optimisation and waste reduction methodologies can significantly enhance operational sustainability (Alemde, 2025).

H4: Root causes of poor facility management negatively affect sustainable facility management schemes. As highlighted by Albakri and Wood-Harper (2025), unresolved systemic issues and management deficiencies hinder sustainable practices

H5: Strategies employed in facility management positively influence sustainable facility management schemes. Effective strategic planning and maintenance protocols have been shown to foster sustainable facility outcomes (Okoro, 2023).

The framework establishes a theoretically grounded basis for empirical testing. Each hypothesised path reflects a causal proposition informed by the facility management and sustainability literature, supporting the conceptualisation of Lean Six Sigma as an enabling mechanism for overcoming management deficiencies and promoting sustainable practices.

2.32 CHAPTER SUMMARY

This literature review chapter moves beyond a descriptive account by synthesising prior studies to establish a coherent theoretical and conceptual foundation for the study. Lean Six Sigma (LSS) DMAIC is positioned not only as a process improvement methodology, but as an integrative mechanism through which operational efficiency, sustainability and service quality in facility management can be systematically aligned. The reviewed literature demonstrates that persistent facility management challenges in higher education, such as reactive maintenance, resource inefficiencies, fragmented systems, and weak stakeholder coordination, are interrelated rather than isolated, thereby necessitating a holistic, systems-based intervention. In synthesising facility sustainability frameworks with Lean Six Sigma principles, the chapter reveals how root causes, managerial strategies, and implementation barriers converge around institutional capacity, leadership commitment, digital maturity, and change readiness. These insights informed the development of the study's conceptual framework, which integrates institutional factors, ISO-aligned sustainability principles, digitalisation, FM processes, stakeholder experience, change management, and system integration as mutually reinforcing dimensions influencing FM performance in universities of technology.

The theoretical alignment is further strengthened by demonstrating how each theory underpins a specific component of the framework. Systems Theory provides the overarching lens for understanding FM as an interconnected socio-technical system within higher education institutions. Continuous Improvement Theory supports the iterative application of DMAIC in diagnosing and improving FM processes. Sustainable Development Theory anchors the environmental, economic and social dimensions of facility management outcomes. Kotter's Eight-Step Change Framework explains the dynamics of implementing FM transformation within institutional contexts, while the Technology Acceptance Model elucidates the adoption of digital FM systems by stakeholders. Collectively, these theories are not treated as standalone perspectives, but are integrated to justify the structure, logic and operationalisation of the proposed Lean Six Sigma based sustainable facility management framework for Universities of Technology.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 CHAPTER OVERVIEW

This chapter explained the research methodology adopted for this study. A detailed description of the research methodology and design helped provide the researcher with insight into how the research was conducted. The process involved the description of the approach, paradigm, and strategies that were used, the data collection tools that were utilised, the population and sampling techniques that were employed, as well as the data analysis techniques that were applied. The measures were put in place to ensure reliability and trustworthiness, and the ethical considerations of the study were explained. Facilities management (FM) was an essential aspect of ensuring the smooth operation of any institution, particularly within the UoT. Effective FM practices directly impacted the learning environment, operational efficiency, and cost management. Challenges such as inadequate funding, obsolete assets, poor maintenance policies, and resource constraints often undermined FM efforts. Within this framework, the DMAIC methodology was used to address these challenges and to develop a sustainable FM framework.

3.2 RESEARCH METHODOLOGY

Research methodology refers to the systematic plan for conducting research, including the underlying philosophical assumptions, research approach, data collection techniques, and analytical procedures used to address the research objectives. It provides a blueprint for selecting appropriate tools and strategies for gathering and interpreting data. According to Saunders et al. (2019), research methodology encompasses the overall research process, including the logic of inquiry (whether deductive or inductive), and integrates research design, methods, and procedures into a coherent framework aligned with the research purpose. Alghamdi and Li (2021) emphasise that an effective research methodology ensures the validity, reliability, and ethical integrity of research, particularly when investigating complex social phenomena.

In this study, the chosen methodology was tailored to the nature of the research problem, whether it involved qualitative insights, quantitative measurement, or mixed-methods integration.

3.3 RESEARCH DESIGN

This study adopts a convergent parallel mixed-methods design, which integrates both quantitative and qualitative approaches to develop a comprehensive understanding of facilities management (FM) challenges and sustainable practices at the Tshwane University of Technology (TUT). The quantitative component focuses on assessing student leaders' perceptions using structured questionnaires, while the qualitative component explores staff members' insights through semi-structured interviews. These approaches were conducted sequentially, and the results were integrated during the interpretation phase (Creswell & Plano Clark, 2018).

3.4 RESEARCH APPROACH

The quantitative component employs a positivist paradigm, aiming to objectively measure FM-related variables using structured instruments. It relies on statistical methods to identify trends and relationships. The research process begins with quantitative data, then transitions to qualitative data, followed by integration, as shown in Figure 3.1.

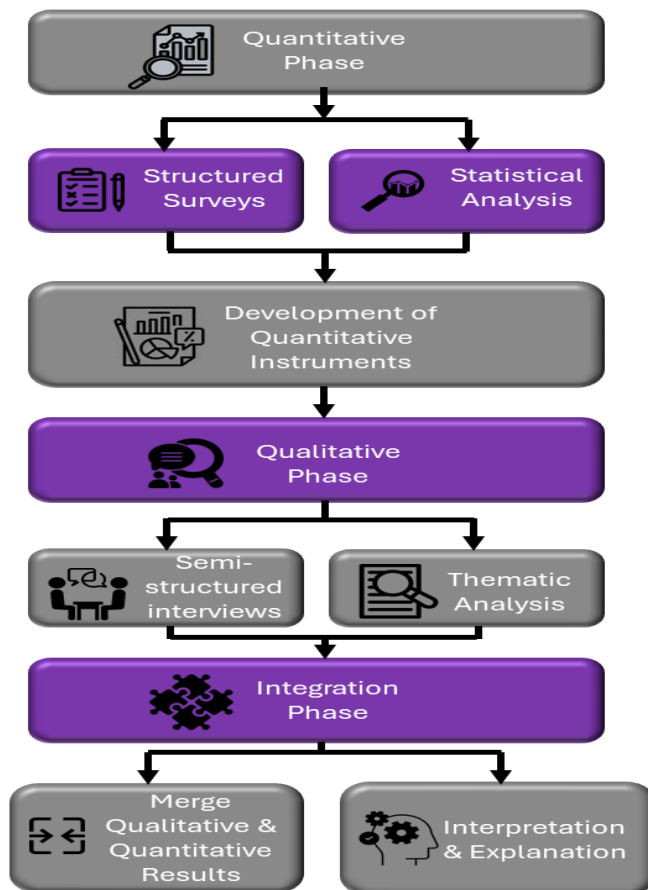


Figure 3.1: Research process (Creswell & Plano Clark, 2021)

The qualitative aspect is grounded in an interpretivist paradigm that focuses on understanding the subjective experiences and institutional dynamics that influence facilities management (FM). Equal priority was given to both methods to enrich the findings (Saunders, Lewis & Thornhill, 2019).

3.5 RESEARCH PARADIGM

There are four (4) main research philosophies adopted by researchers, namely pragmatism, positivism, interpretivism, and realism (Saunders, Lewis & Thornhill, 2019).

3.5.1 Pragmatic Research Philosophy

The pragmatic research philosophy focuses on the practical application of research methods to address specific problems, rather than being restricted to a singular philosophical viewpoint. Pragmatism adopts an abductive reasoning approach,

allowing researchers to oscillate between inductive and deductive reasoning to best solve the research problem (Hampson & McKinley, 2023). This paradigm advocates for methodological pluralism, enabling the use of both qualitative and quantitative methods depending on the context. Pragmatism emphasizes outcomes and actions, making it well-suited to applied research, particularly in fields such as operations management and educational leadership, where solutions must be feasible and implementable (Creswell & Creswell, 2022).

3.5.2 Positivist Research Philosophy

The positivist paradigm asserts that reality is objective and can be measured and known through empirical observation and scientific methods. It emphasises hypothesis testing, generalisability, and statistical reliability, typically favouring quantitative methods (Alharahsheh & Pius, 2020). Within positivism, the researcher maintains independence from the phenomena being studied to minimise bias and subjectivity. This philosophy is widely used in the natural and social sciences, where precision, prediction, and causality are crucial (Glogowska, 2020). Positivist studies often yield laws and theories that explain patterns of behaviour or observable facts.

3.5.3 Interpretivist Research Philosophy

The interpretivist philosophy holds that reality is socially constructed and can be understood only through subjective interpretation. It emphasises the importance of understanding participants' lived experiences, social contexts, and cultural backgrounds (Thanh & Thanh, 2015). Interpretivist research typically employs qualitative methods, including interviews, ethnography, and case studies, to explore meaning, context, and depth. This approach is common in sociology, anthropology, and education research, where the goal is to understand how individuals interpret their social world (Merriam & Tisdell, 2016). Researchers using this paradigm are considered integral to the research process and often reflect on their roles and potential biases.

3.5.4 Realist Research Philosophy

The realist paradigm is a blend of positivism and interpretivism, acknowledging that while objective reality exists, our understanding of it is mediated by human interpretation. Critical realism, a branch of this philosophy, posits that structures and mechanisms operate independently of human perceptions but can be understood through a combination of observation and theory (Fletcher, 2017). Realism supports mixed-methods research and is valuable in complex settings such as health sciences, education, and policy evaluation, where both observable phenomena and underlying causes must be explored (Zachariadis, Scott & Barrett, 2013). It facilitates multi-layered analysis and is often used in case studies and programme evaluations. Table 3.1 provides a summary of the different research paradigms.

Table 3.1: Summary of research paradigms

Research Paradigm	Key Characteristics	Typical Methods	Recent Sources
Pragmatism	Focuses on practical solutions; uses both qualitative and quantitative methods; abductive reasoning.	Mixed methods (surveys, interviews, case studies)	Hampson & McKinley (2023); Creswell & Creswell (2022)
Positivism	Objective reality; uses quantitative data; hypothesis testing and statistical analysis.	Surveys, experiments, statistical models	Alharahsheh & Pius (2020); Glogowska (2020)
Interpretivism	Subjective reality; uses qualitative data; explores social constructs and meaning.	Interviews, ethnography, focus groups	Thanh & Thanh (2015); Merriam & Tisdell (2016)
Realism	Combines objectivity and subjectivity; uses mixed methods; explains observable and underlying mechanisms.	Case studies, mixed methods, and realist evaluation	Fletcher (2017); Zachariadis <i>et al.</i> (2013)

For the purposes of this research, the researcher adopted a pragmatic (mixed-methods) approach. Mixed-methods research is guided by philosophical assumptions that enable the use of both qualitative and quantitative approaches throughout the research process. The study moved beyond debates surrounding quantitative and qualitative approaches and focused on recognising the usefulness of both paradigms and on identifying how these approaches can be used together within a single study to maximise their strengths and minimise their respective weaknesses.

3.6 RESEARCH POPULATION AND SAMPLING

3.6.1 Research Population

The target population refers to the complete group of individuals relevant to a research study from which a sample is drawn. In this study, the population comprised registered student leaders and staff members at Tshwane University of Technology (TUT) who were directly involved in or affected by facilities management (FM) processes. This group included student leaders who represented the broader student community's voice on facilities matters, as well as staff members responsible for operational, administrative, and strategic decisions regarding FM services.

The population comprised both registered students and staff members of TUT. The interview population consisted of staff members from the selected university of technology. The quantitative population comprised N = 3 000 registered students, mainly student leaders residing in university residences. The research was conducted in the Gauteng Province at the Tshwane University of Technology, where five of its eight learning sites were located.

3.6.2 Sampling Method/Technique

There are two types of sampling techniques, namely probability and non-probability sampling methods (Malhotra, 2010), which were applied in this study.

3.6.3 Probability Sampling

The sampling technique requires knowledge of the population and employs some form of random selection (Pope & Stanistreet, 2018). According to Alvi (2016), this sampling technique reduces errors, minimizes the likelihood of sampling bias, and provides a more representative sample.

Table 3.2: Probability Sampling Techniques (Pope & Stanistreet, 2018)

Sampling Technique	Description
Simple Random Sampling	The research participants are selected at random, with every member of the target population having an equal probability of selection.
Stratified Random Sampling	Within a target population, elements or individuals are stratified based on characteristics of interest to the researcher, such as gender, age, or employment status. A representative sample is then randomly selected from each stratum.
Systematic Random Sampling	Respondents are selected using a sampling frame, such as conducting research at a supermarket and selecting every fourth or eleventh individual who enters the store to be included in the sample.
Cluster Random Sampling	The study population is divided into heterogeneous sub-groups depending on specified criteria, such as districts, cities, or provinces, and the sample is drawn at random from these clusters.

The current study employs simple random sampling, as the quantitative sample was randomly selected, providing an equal probability of selection for students across all learning sites. The sample size was selected from the five (5) Tshwane University learning sites in the Gauteng province, namely Arcadia, Ga-Rankuwa, Pretoria West, Arts and Soshanguve.

3.6.4 Non-probability Sampling

Non-probability sampling is also referred to as non-random sampling. This type of sampling requires the researcher to intentionally select a specific sample to serve the purpose of the study (Malhotra, 2010). The selection requires some subjective judgment (Bryman, 2019) in alignment with the targeted objectives. According to

Gravetter and Forzano (2018), non-probability sampling methods include quota, purposive, snowball, and convenience sampling, as presented in the table below.

Table 3.3: Non-Probability Sampling techniques (Gravetter & Forzano, 2018)

Sampling Technique	Description
Quota Sampling	It entails selecting participants from a pre-set group who meet the research's needs.
Purposive Sampling	The researcher has prior knowledge of the study population's characteristics and selects participants or elements that best meet the research's needs.
Snowball Sampling	A few participants are selected, and they propose additional individuals who might be suitable for the research.
Convenience Sampling	Also known as haphazard sampling, this method involves choosing research participants who are conveniently available.

Purposive sampling was used for the qualitative component to select facilities management–related professionals, specifically facilities managers, maintenance managers, technical supervisors and sustainability or infrastructure officers, who are directly involved in FM operations and decision-making at the university. A total of approximately 20 interviews was targeted, with the final sample size guided by data saturation, whereby interviews ceased once no new themes or insights emerged

3.6.5 Sample Selection

3.6.5.1 Qualitative sampling selection

The sample size included individuals from senior, middle, and lower management, as well as artisans and technicians. Sample size refers to the subset of individuals selected from the population to participate in a research study. For this study, the quantitative strand included 353 student leaders who completed a structured questionnaire. This number was deemed statistically sufficient to allow for generalisable findings. For the qualitative component, 21 staff members were purposively selected to participate in semi-structured interviews. This number was considered sufficient to achieve thematic saturation and to capture a diversity of perspectives on facilities management (FM) issues. The final qualitative sample size

was determined once saturation was reached, with a maximum of 20 respondents, comprising two senior managers selected from Building and Estate, Facilities Management, and Residences, eight middle- and lower-level management staff; and ten artisans and technicians.

The study aimed to reach a representative sample of the population, which will constitute the sample size, calculated as follows.

$$n = \frac{N}{1 + N(e)^2}$$

Where: n = the random sample size, N = the respondent size and e = margin of error, the significance level is estimated at 5% (Antoro, 2024).

Based on the Slovin formula, the sample size, n for this research is:

$$\begin{aligned} n &= N / (1+Ne^2)^2 \\ &= 3000 / [1+(3000)(0.05)^2] \\ &= 353 \end{aligned}$$

The sampling population comprises 353 student leaders from 5 learning sites, as shown in Table 3.3: Arcadia, Pretoria West, Soshanguve, Arts, and Ga-Rankuwa.

Table 3.4: UoT learning Sites

No	Learning sites	Students
1	Arcadia	55
2	Pretoria West	90
3	Soshanguve	100
4	Arts	53
5	Ga-Rankuwa	55
Total	5	353

The study was based on a sample size of 353 participants that include student leaders from all the Tshwane-based learning sites comprising of the 10 Local SRC, Residence Committees from 26 residences made from 10 committee members of each residence (260), 1 residence mentor of each residence (26) and 7 Institutional SRC members that are mainly part of student governance within the university and student accommodation.

3.6.5.2 Sampling justification

The sampling strategies adopted in this study are aligned with the research design and the overarching objective of developing a comprehensive, evidence-based framework for sustainable facilities management (FM) within South African universities of technology. The study employed a mixed-methods approach, which necessitated distinct yet complementary sampling techniques for the quantitative and qualitative components. For the quantitative strand, stratified random sampling was employed, with campus location serving as the primary stratification variable. The student leadership population at the Tshwane University of Technology (TUT) is distributed across five learning sites in the Gauteng Province, namely Arcadia, Ga-Rankuwa, Pretoria West, Arts and Soshanguve. The use of stratification by campus was necessary to ensure that each learning site was adequately represented, given that facilities conditions, service delivery experiences, and infrastructure challenges may differ across campuses. This approach is consistent with the stratified sampling framework illustrated in Figure 3.2 and ensures coherence between the sampling strategy and the study design.

Following stratification, proportional allocation was applied, whereby the sample drawn from each campus was proportionate to the size of the student leadership population at that campus. This method prevents over- or under-representation of smaller or larger campuses and enhances the external validity and generalisability of the findings. Within each campus stratum, respondents were selected using simple random sampling to minimise selection bias and ensure that all eligible student leaders had an equal probability of inclusion. Stratified random sampling is particularly appropriate where subgroup differences are anticipated, as it increases precision and representativeness across heterogeneous populations (Etikan & Bala, 2017). A total sample size of 353 student leaders was determined using standard sample size calculation techniques for large populations, assuming a 95% confidence level and a 5% margin of error. This sample size provides sufficient statistical power to support inferential analyses, including analysis of variance (ANOVA), correlation and regression modelling, thereby strengthening the robustness and reliability of the quantitative findings (Creswell & Creswell, 2018).

For the qualitative component, purposive sampling was adopted to select participants with direct involvement in facilities management operations and decision-making. This approach ensured the inclusion of staff members possessing relevant knowledge and experience necessary to provide rich, context-specific insights into FM practices and challenges. A total of 20 staff members were interviewed, a sample size consistent with qualitative research conventions that prioritise depth and information richness over numerical representation. This number was adequate to achieve thematic saturation, whereby no new themes emerged from additional interviews (Guest, Bunce & Johnson, 2006; Palinkas et al., 2015). The combined use of stratified random sampling for the quantitative strand and purposive sampling for the qualitative strand, as depicted in Figure 3.2, enhances the methodological rigour of the study. It ensures balanced representation across campuses while capturing expert perspectives from FM practitioners, thereby strengthening the credibility, transferability and dependability of the findings. Collectively, these sampling decisions support the development of a sustainable, Lean Six Sigma-driven FM framework grounded in both user and provider perspectives.

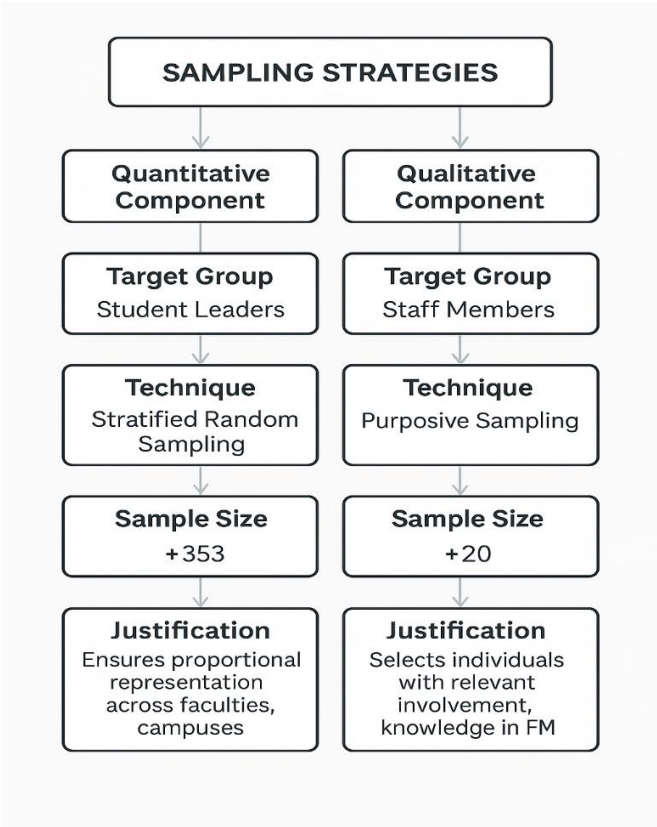


Figure 3.2. Sampling strategies (Creswell and Plano Clark, 2018)

3.6.5.3 Sampling Techniques

Sampling techniques define how participants are selected from the population. In the quantitative phase, stratified random sampling is used. This probability sampling method divides the population into subgroups (campuses or faculties) and then randomly selects participants from each group, ensuring balanced representation (Etikan & Bala, 2017). For the qualitative phase, purposive sampling is a non-probability method applied to identify staff members who have relevant knowledge and experience in FM policy or operations. This technique ensures information-rich data collection (Palinkas *et al.*, 2015).

3.7 DATA COLLECTION METHODS

This study adopted a mixed-methods approach and utilised both quantitative and qualitative data collection techniques to comprehensively examine facilities management practices and sustainability challenges within universities of technology in South Africa.

3.7.1 Quantitative Data Collection

Quantitative data were collected using a structured questionnaire designed to obtain standardised responses from registered student leaders across the various campuses and faculties of the Tshwane University of Technology. The questionnaire comprised closed-ended items measured on a five-point Likert scale, capturing respondents' perceptions of key facilities management (FM) constructs, including service quality, maintenance effectiveness, leadership responsiveness and sustainability initiatives. The use of a Likert scale enabled the quantification of subjective perceptions in a manner suitable for statistical analysis (Boone & Boone, 2012). Prior to full-scale data collection, the questionnaire was pilot tested with a small group of student leaders at the Tshwane University of Technology who were not included in the main study. The pilot study was conducted to assess the clarity, relevance and sequencing of the questions, and to identify any ambiguities or inconsistencies. Feedback from the pilot phase informed minor revisions to wording and structure, enhancing the instrument's

overall reliability. Internal consistency was evaluated using Cronbach's alpha, with coefficients of 0.70 and above considered acceptable (Creswell and Creswell, 2018). Following pilot refinement, the final questionnaire was administered either electronically or in hard copy, depending on participant accessibility. Completed questionnaires were coded and analysed using IBM SPSS Statistics, enabling the application of descriptive and inferential statistical techniques for quantitative interpretation (Pallant, 2020).

3.7.2 Qualitative Data Collection

Qualitative data were collected through semi-structured interviews with purposively selected staff members who were directly involved in facilities management (FM) operations, policy development and strategic oversight at the Tshwane University of Technology. This approach was appropriate for this study, as it enabled the exploration of institution-specific challenges, governance issues and sustainability practices influencing the implementation of a Lean Six Sigma-driven FM framework within a university of technology context. Interviews were conducted either face-to-face or virtually, depending on participant availability and ethical considerations. All participants provided informed consent prior to participation. Each interview was audio recorded and subsequently transcribed verbatim to ensure accurate representation of participants' views. The interview guide was structured around key themes aligned with the study objectives, including FM operational challenges, institutional constraints, policy gaps, the application of Lean Six Sigma principles and strategies for achieving sustainable FM outcomes.

To enhance the validity and trustworthiness of the qualitative instrument, the interview guide was reviewed by academic supervisors and FM experts to ensure content relevance, clarity and alignment with the research objectives. During data collection and analysis, credibility was strengthened through the use of verbatim transcription and consistent questioning across interviews, while dependability was supported by maintaining a clear audit trail of interview procedures and analytical decisions.

Qualitative data were analysed thematically using Atlas.ti software. An inductive coding process was applied to identify recurring patterns and themes, followed by a constant

comparative method to refine and validate emerging categories. This analytical approach enhanced rigour by systematically comparing data across participants and ensuring that interpretations were grounded in the empirical evidence (Nowell et al., 2017). The qualitative findings complemented the quantitative results by providing deeper insight into the institutional realities and professional perspectives shaping sustainable FM implementation at the university.

3.8 QUANTITATIVE DATA ANALYSIS

Quantitative data collected from student leaders using structured questionnaires were analysed using IBM SPSS Statistics (version 30). The analysis was conducted to address the study objectives and test the hypothesised relationships underpinning the proposed Lean Six Sigma–driven sustainable facilities management (FM) framework at the Tshwane University of Technology. Descriptive statistics, including frequencies, means, and standard deviations, were computed to summarise respondents' demographic characteristics and their perceptions of key FM constructs, namely facility defaults, causes of poor facilities management, leadership responsiveness, maintenance effectiveness, sustainability practices, and Lean Six Sigma application. These statistics provided an initial understanding of trends and central tendencies in student leaders' experiences of FM service delivery across campuses and faculties. Exploratory factor analysis (EFA) was conducted prior to hypothesis testing to assess the dimensionality, construct validity and reliability of the measurement scales. This step ensured that the observed variables adequately represented their underlying latent constructs and were suitable for subsequent multivariate analysis. Reliability was further assessed using Cronbach's alpha coefficients.

Inferential analysis included analysis of variance (ANOVA) to examine whether statistically significant differences existed in FM perceptions across campuses and faculties. Pearson correlation coefficients were then computed to assess the strength and direction of relationships between key constructs related to FM performance and sustainability outcomes. To test the hypothesised relationships among latent variables, Structural Equation Modelling (SEM) was employed. SEM was appropriate given the study's theoretical framework, sample size and the presence of multiple interrelated constructs. The technique enabled simultaneous examination of relationships between

observed indicators and latent variables, thereby supporting validation of the proposed FM framework. Multiple linear regression (MLR) analysis was conducted to identify the most influential predictors of student satisfaction with FM services. While SEM alone would have been sufficient for hypothesis testing, the inclusion of MLR provided additional explanatory clarity and practical insight by quantifying the relative contribution of individual predictors. The combined use of SEM and MLR strengthened the robustness of the findings through methodological triangulation and enhanced confidence in the consistency of results across analytical techniques.

3.9 Qualitative Analysis

Thematic analysis is conducted on the interview transcripts using Atlas.ti software. This involves coding text segments to identify recurring themes and categories related to FM governance, operational barriers, strategic planning and sustainability. A constant comparative method is used to refine themes and ensure analytical rigour. This approach provides nuanced insights into FM practices and their alignment with Lean Six Sigma principles (Nowell *et al.*, 2017).

3.10 RELIABILITY AND VALIDITY

In mixed-methods research, ensuring reliability and validity across both quantitative and qualitative strands is essential for producing credible, consistent and transferable findings. As this study combined quantitative survey data from student leaders with qualitative interview data from facilities management staff, appropriate procedures were applied to ensure the trustworthiness of both components. This section presents the approaches used to assess the study's reliability and validity.

3.10.1 Reliability

Reliability refers to the consistency and stability of a research instrument, indicating the extent to which it produces similar results under consistent conditions. In this study, reliability was assessed for the quantitative questionnaire administered to student leaders. Internal consistency reliability was evaluated using Cronbach's alpha. This statistic measures the degree to which items within a construct are interrelated. Cronbach's alpha coefficients of 0.70 and above were considered acceptable, indicating satisfactory internal consistency (Daniel & Cross, 2018). Reliability testing was conducted after the pilot study and confirmed during the main data analysis phase, ensuring that the measurement scales used in the study were dependable.

3.10.2 Validity

Validity concerns the extent to which a research instrument accurately measures what it is intended to measure. Several forms of validity were addressed in this study to strengthen the credibility of the quantitative findings.

a) Internal Validity

Internal validity relates to the accuracy of inferences drawn from the data. In this study, internal validity was enhanced through the use of stratified random sampling of student leaders, which reduced selection bias and ensured representativeness across campuses. In addition, careful questionnaire design and alignment of items with the study objectives supported the examination of relationships between Lean Six Sigma practices and facilities management outcomes

b) External Validity

External validity refers to the extent to which the findings can be generalised beyond the immediate study context. External validity was strengthened by sampling student leaders from multiple campuses of the Tshwane University of Technology and by ensuring proportional representation across learning sites. This approach supports the applicability of the findings to other universities of technology with similar institutional characteristics.

c) Construct Validity

Construct validity concerns whether the instrument accurately captures the theoretical constructs under investigation. In this study, construct validity was supported through the development of questionnaire items based on an extensive literature review and established facilities management and Lean Six Sigma frameworks. Exploratory factor analysis was conducted as part of the quantitative analysis to confirm that items loaded appropriately onto their intended constructs.

d) Content Validity

Content validity addresses whether the instrument adequately covers all relevant dimensions of the concepts being measured. Content validity was ensured through expert review, including feedback from academic supervisors and professionals knowledgeable in facilities management and sustainability. This process confirmed that the questionnaire sufficiently represented key aspects of sustainable facilities management, Lean Six Sigma practices and service delivery within a university of technology context.

3.11 TRUSTWORTHINESS OF THE STUDY

In qualitative research, trustworthiness is essential for ensuring that findings are credible, dependable and grounded in participants' experiences. In this study, trustworthiness was addressed using the criteria of credibility, transferability, dependability, confirmability, and reflexivity, as proposed by Lincoln and Guba (1985) and supported by subsequent qualitative research scholars (Nowell et al., 2017; Creswell & Poth, 2018).

3.11.1 Credibility

Credibility refers to the confidence that can be placed in the truth of the research findings. In this study, credibility was enhanced by semi-structured interviews, which enabled participants to provide detailed and authentic accounts of facilities management practices. Interviews were audio-recorded and transcribed verbatim, ensuring that the analysis remained closely grounded in participants' original statements. In addition, prolonged engagement with the data during the thematic analysis process enabled careful interpretation and reduced the risk of misrepresentation (Lincoln & Guba, 1985; Nowell et al., 2017).

3.11.2 Transferability

Transferability concerns the extent to which the findings may be applicable to other contexts. This study enhanced transferability by providing thick descriptions of the research context, participant roles, and institutional setting of the University of Technology. Detailed contextual information allows readers to determine the relevance of the findings to similar higher education or facilities management environments (Creswell and Poth, 2018).

3.11.3 Dependability

Dependability refers to the consistency and stability of the research process. In this study, dependability was ensured through the use of a systematic and transparent data analysis procedure, including clearly documented steps for data collection, transcription, coding and theme development. The use of Atlas.ti software further supported consistency in coding and theme refinement. An audit trail was maintained to document methodological decisions and analytical steps, enabling the research process to be traced and reviewed (Nowell et al., 2017).

3.11.4 Confirmability

Confirmability addresses the extent to which the findings are shaped by participants' responses rather than researcher bias. In this study, confirmability was strengthened through the maintenance of an audit trail, including interview transcripts, coding records and analytic memos. Findings were supported by direct participant quotations,

ensuring that interpretations were grounded in empirical evidence rather than personal assumptions (Lincoln & Guba, 1985).

3.11.5 Reflexivity

Reflexivity involves the researcher's critical awareness of their role, assumptions and potential influence on the research process. Throughout the study, the researcher engaged in ongoing reflexive reflection, acknowledging personal perspectives and actively seeking to minimise their influence during data collection and analysis. This reflective practice supported ethical rigour and reinforced the integrity of the qualitative findings (Creswell & Poth, 2018).

3.12 ETHICAL CONSIDERATIONS

Ethical considerations were central to maintaining the integrity of the research and ensuring the protection of participants throughout the study. Prior to data collection, ethical clearance was obtained from the Tshwane University of Technology (TUT) Research Ethics Committee. Participation in the study was voluntary, and informed consent was obtained from all participants. Anonymity and confidentiality were strictly maintained throughout the research process. In line with the Tshwane University of Technology ethics policy and established research ethics guidelines (Israel & Hay, 2006; Resnik, 2020), the study upheld high standards of academic integrity, participant welfare, and data protection. All sources were appropriately acknowledged using the Harvard Referencing style to prevent plagiarism and intellectual property infringement. Detailed ethical procedures were provided in the participant information leaflet, which is included in the Appendix.

3.12.1 Informed Consent

Informed consent was obtained from all participants prior to their involvement in the study. Participants were provided with clear information regarding the purpose of the research, data collection procedures, potential risks and anticipated benefits. Consent forms were signed to indicate voluntary participation. This process ensured respect for

participant autonomy and informed decision-making, consistent with the principles outlined in the Belmont Report (National Commission, 1979).

3.12.2 Participant Protection

The safety and well-being of participants were prioritised throughout the research process. The study was designed to ensure that no participant was exposed to physical, psychological or emotional harm. All data collection activities were conducted in non-threatening environments, and care was taken to avoid distress or discomfort. Ethical clearance granted by the TUT Research Ethics Committee further ensured that potential risks were identified and appropriately managed (Moriña, 2021).

3.12.3 Confidentiality

Participant confidentiality was rigorously protected. Personal identifiers, including names, contact details and institutional affiliations, were not included in any reports or publications arising from the study. Data were anonymised and securely stored, with access restricted to the researcher only. These measures ensured that participants' privacy was respected and that data were handled responsibly (Babbie, 2021).

3.12.4 Voluntary participation and a right to withdraw

Participation in the study was entirely voluntary. Participants were informed of their right to decline participation or to withdraw from the study at any stage without penalty or negative consequences. In cases where participants chose to withdraw, their data were removed from the dataset and securely destroyed in accordance with ethical research protocols (Creswell and Poth, 2018).

3.12.5 Research Benefits

The study provided evidence-based insights and recommendations aimed at improving facilities management performance at the Tshwane University of Technology. The findings were shared with relevant institutional stakeholders and made accessible to students to support institutional development and enhance student support services.

3.13 CHAPTER SUMMARY

This chapter presented the methodological framework used to investigate sustainable facilities management (FM) practices at the Tshwane University of Technology (TUT) through a convergent parallel mixed-methods design. The chapter defined the research methodology and justified the integration of qualitative and quantitative approaches to explore and measure FM challenges. Data were collected concurrently through semi-structured interviews with FM staff members and structured questionnaires administered to student leaders, with findings triangulated and integrated during analysis. The data collection instruments included a Likert-scale questionnaire and a semi-structured interview guide. Quantitative data were analysed using IBM SPSS Statistics through descriptive and inferential techniques, including analysis of variance (ANOVA), correlation analysis, regression analysis, and potential Structural Equation Modelling (SEM). Qualitative data were analysed using thematic coding in Atlas.ti, guided by a constant comparative method. Ethical principles, including informed consent, confidentiality, and voluntary participation, were strictly upheld throughout the research process. Methodological triangulation enhanced the validity, reliability, and trustworthiness of the findings, thereby providing a robust foundation for the development of a Lean Six Sigma-aligned facilities management framework aimed at advancing operational excellence and sustainability within South African universities of technology.

CHAPTER FOUR

QUANTITATIVE DATA ANALYSIS AND FINDINGS

4.1 CHAPTER OVERVIEW

To achieve the objectives of this study, this chapter presents the empirical findings derived from a questionnaire consisting of 57 items. The instrument included five demographic questions and 52 items measuring latent variables such as facility defaults, causes of poor facility management, strategies, sustainability, Lean Six Sigma (LSS), value stream mapping (VSM), and a sustainable facility management (FM) scheme tailored for South African universities of technology. The Partial Least Squares Structural Equation Modelling (PLS-SEM) approach, implemented using SmartPLS 4, was employed to develop and evaluate the proposed framework.

Data analysis was conducted using IBM SPSS (version 30) and involved descriptive statistics, comprising frequencies, tables, means, and standard deviations, followed by exploratory factor analysis, reliability testing, correlation analysis, and structural equation modelling (SEM). In addition, multiple regression analysis was performed to examine the influence of facility defaults, poor FM factors, root causes, LSS, and FM strategies on the sustainable facility management scheme.

4.2 THE RESPONSE RATE

A total of 353 questionnaires were distributed and 333 returned giving a total response of 95.1%. Out of a total of 333 questionnaires returned 326 were found valid for the analysis, yielding a valid response rate of 97.9% whereas the rest of the questionnaires were not used due to missing information.

4.3 DEMOGRAPHIC INFORMATION

Descriptive statistics summarise and organise the characteristics of a data set. It enables data to be presented in a meaningful and understandable way, thereby facilitating simplified interpretations of the dataset in question (Cooksey, 2020). In this study, descriptive statistics were presented as frequencies, custom tables, means, and standard deviations. Frequencies were conducted to analyse the study's biographical

details, such as campus, age, and level of education. Custom tables, means and standard deviations were used to understand the participants` perceptions of the study constructs.

4.3.1: Campus

Table 4.1: Campus

		Frequency	Valid Percent
Valid	Arcadia	47	14,4
	Art	37	11,3
	Pretoria West	85	26,1
	Soshanguwe	97	29,8
	Ga_Rankuwa	60	18,4
	Total	326	100,0

The campus distribution of the respondents presented in Table 4.1 depicts Arcadia 47 (14.4%), Art 37 (11.3%), Pretoria West 85 (26.1%), Soshanguwe 97 (29.8%) and Ga-Rankuwa 60 (18.4%). This campus distribution of respondents is relatively consistent with the size of the campuses and that most students who took part in the survey are between Pretoria West and Soshanguwe.

4.3.2: Age

Table 4.2: Age

		Frequency	Valid Percent
Valid	Less than 25 years	266	81,6
	Between 25 and 40 years	59	18,1
	Between 41 and 55 years	1	0,3
	Total	326	100,0

Table 4.2 above reflects the age distribution of the study participants. The majority of participants, 266 (81.6%), are under 25 years old, followed by those between 25 and 40 years, 59 (18.1%), and the least, 1 (0.3%), were between 41 and 55 years.

4.3.3: Level of Education

Table 4.3: Level of Education

		Frequency	Valid Percent
Valid	Less than Matric	6	1,8
	Matric	214	65,6
	Bachelor's degree or Equivalent	50	15,3
	Honours Degree or Equivalent	9	2,8
	Master's degree or Equivalent	1	,3
	Other	46	14,1
	Total	326	100,0

Table 4.3 illustrates the highest education level of respondents, indicating that 6 (1.8%) did not complete matric level, 214 (65.6%) of the respondents had matric, 50 (15.3%) hold bachelor's degrees, 9 (2.8%) hold honours degrees, 1 (0.3%) hold masters degrees and 46 (14.1%) hold other qualifications such as diplomas.

4.4 DESCRIPTIVE ANALYSIS

The purpose of the descriptive analysis was to examine student leaders' perceptions regarding key facilities management (FM) dimensions within a South African university of technology. Specifically, the analysis sought to assess perceptions of classes of facility defaults, factors contributing to poor FM, root causes of ineffective facility management, FM strategies, sustainability practices, and the application of Lean Six Sigma (LSS) within a sustainable FM scheme. To achieve this, custom tables, means and standard deviations were computed based on responses recorded on a five-point Likert scale. For ease of interpretation, the two lower response categories (Strongly Disagree and Disagree) and the two upper categories (Agree and Strongly Agree) were combined during analysis (Morgan, Reichert and Harrison, 2017).

Table 4.4: Facility Default Classes at UoT

		Strongly Disagree/ Disagree	Not Sure	Strongly Agree/ Agree	Mean	Standard Deviation
CFD1: Processes are a class of Facility defaults in the UT.	Count	52	86	188	3.45	1.077
	Row N %	16%	26,4%	57.7%		
CFD2: Procedures are a class of Facility defaults in the UT.	Count	42	85	199	3.58	.950
	Row N %	12.9%	26,1%	61.1%		
CFD3: Systems are a class of Facility defaults in the UT.	Count	51	77	198	3.53	1.028
	Row N %	15.6%	23,6%	60.7%		
CFD4: Policies are a class of Facility defaults in the UT.	Count	53	80	193	3.54	1.015
	Row N %	16.3%	24,5%	59.2%		
CFD5: Roles and responsibilities are a class of Facility defaults in the UT.	Count	53	66	207	3.60	1.087
	Row N %	16.2%	20,2%	63.5%		
CFD6: Public finances are a class of Facility defaults in the UT.	Count	62	109	155	3.34	1.039
	Row N %	19%	33,4%	47.5%		
CFD7: Leadership style is a class of Facility defaults in the UT.	Count	49	68	209	3.68	1.079
	Row N %	15%	20,9%	64.1%		
CFD8: Technical defaults (Plumbing, electrical, structural...) are a class of Facility defaults in the UT.	Count	82	54	190	3.46	1.302
	Row N %	25.1%	16,6%	58.2%		
	Row N %	15.9%	36,8%	47.3%		

Table 4.4 summarises the responses of participants regarding the classification of various types of facility defaults in the University of Technology (UT). The respondents were asked to rate whether certain processes, procedures, systems and other factors are considered facility defaults in the UT. Overall, respondents seem to agree that processes (57.7%), procedures (61.1%), systems (60.7%), roles and responsibilities (63.5%) and leadership style (64.1%) are important factors that contribute to facility defaults in the University of Technology, though there is variation in the degree of

agreement across these different categories. Technical defaults and public finances show more mixed opinions. The highest agreement was observed in Leadership style with a mean of 3.68, suggesting that leadership style is considered one of the main facility defaults. Public finances had the lowest mean (3.34), indicating that respondents were less unified in considering public finances a facility default.

Table 4.5: Factors in Poor FM at UoT

		Strongly Disagree/ Disagree	Not Sure	Strongly Agree/ Agree	Mean	Standard Deviation
FCFM1: Inadequate funding contributes to poor FM in the UT.	Count	45	61	220	3,76	1,177
	Row N %	13,8%	18,7 %	67,5%		
FCFM2: Unstable and unskilled resources contribute to poor FM in the UT.	Count	49	61	216	3,79	1,105
	Row N %	15,1%	18,7 %	66,3%		
FCFM3: Lack of maintenance policies contributes to poor FM in the UT.	Count	33	42	251	4,06	1,052
	Row N %	10,2%	12,9 %	77%		
FCFM4: Lack of maintenance systems contributes to poor FM in the UT.	Count	35	41	250	4,02	1,057
	Row N %	10,8%	12,6 %	76,7%		
FCFM5: No budgeting priority contributes to poor FM in the UT.	Count	48	75	203	3,74	1,191
	Row N %	14,7%	23,0 %	62,2%		
FCFM6: Budget assumptions contribute to poor FM in the UT.	Count	32	102	192	3,69	1,019
	Row N %	9,8%	31,3 %	58,9%		
FCFM7: Multiple stakeholders.	Count	40	168	118	3,36	,916
	Row N %	12,2%	51,5 %	36,2%		
FCFM8: No proportionality between facilities and the managing staff contributes to poor FM in the UT.	Count	57	85	184	3,56	1,132
	Row N %	17,5%	26,1 %	56,4%		
FCFM9: No on-time faults reporting contributes to poor FM in the UT.	Count	58	75	193	3,60	1,161
	Row N %	17,8%	23,0 %	59,2%		

FCFM10: No direct responsibility contributes to poor FM in the UT.	Count	48	67	211	3,77	1,103
	Row N %	14,7%	20,6 %	64,8%		
FCFM11: Diverse reporting processes contribute to poor FM in the UT.	Count	67	90	169	3,45	1,148
	Row N %	20,5%	27,6 %	51,8%		
FCFM12: Superficial investigation contributes to poor FM in the UT.	Count	62	102	162	3,46	1,114
	Row N %	19%	31,3 %	49,7%		
FCFM13: An unsuitable system for FM contributes to poor FM in the UT.	Count	42	67	217	3,76	1,052
	Row N %	12,9%	20,6 %	66,6%		
FCFM14: Dependence on the procurement department contributes to poor FM in the UT.	Count	48	106	172	3,55	1,068
	Row N %	14,7%	32,5 %	52,8%		
FCFM15: Lack of property profile contributes to poor FM in the UT.	Count	46	68	212	3,75	1,109
	Row N %	14,1%	20,9 %	65%		
FCFM16: Outsourcing system contributes to poor FM in the UT.	Count	54	97	175	3,55	1,105
	Row N %	16,6%	29,8 %	53,7%		

Table 4.5 lists the variables contributing to inadequate facilities management (FM) in the University of Technology (UoT). Factors related to policies (77%) and systems (76.7%), such as lack of maintenance policies and unsuitable systems for FM, are viewed as considerable contributors to poor FM. Budgeting issues and staffing challenges are also substantial, with many respondents noting that issues like inadequate funding (67.5%) and no budgeting priority (62.2%) are major contributors. Some factors like diverse reporting processes (51.8%) and outsourcing systems (53.7%) seem to be less important but still relevant to respondents.

Table 4.6: Root Causes of Poor FM in UoT

		Strongly Disagree/ Disagree	Not Sure	Strongly Agree/ Agree	Mean	Standard Deviation
RCFM1: Poor state of infrastructural facilities is a root cause of poor FM in the UT.	Count	42	37	247	3,95	1,110
	Row N %	12,9%	11,3%	75,8%		
RCFM2: Obsolete assets is a root cause to poor FM in the UT.	Count	39	96	191	3,67	1,013
	Row N %	12%	29,4%	58,6%		
RCFM3: Policy and regulatory constraints are a root cause of poor FM in the UT.	Count	78	85	163	3,42	1,160
	Row N %	23,9%	26,1%	50%		
RCFM4: Low quality and high price of local products is a root cause to poor FM in the UT.	Count	70	68	188	3,60	1,287
	Row N %	21,5%	20,9%	57,7%		
RCFM5: High energy costs is a root cause of poor FM in the UT.	Count	69	94	163	3,46	1,160
	Row N %	21,1%	28,8%	50%		
RCFM6: Finance instability is a root cause of poor FM in the UT.	Count	36	51	239	3,96	1,040
	Row N %	11,1%	15,6%	73,3%		
RCFM7: No staff training is a root cause of poor FM in the UT.	Count	56	56	214	3,84	1,218
	Row N %	17,2%	17,2%	65,7%		
RCFM8: Intervention delays is a root cause of poor FM in the UT.	Count	31	64	231	3,95	1059
	Row N %	9,5%	19,6%	70,8%		
RCFM9: No maintenance plan is a root cause of poor FM in the UT.	Count	34	45	247	4,09	1,090
	Row N %	10,5%	13,8%	75,7%		

Table 4.6 reflects the root causes of poor facility management (FM) in the University of Technology (UT). The table includes a breakdown of respondents' opinions on different factors contributing to poor FM, along with the associated frequency counts, means and standard deviations. Maintenance planning and infrastructure (RCFM1 and RCFM9) are the most agreed-upon causes of poor FM, with 75.8% and 75.7% of respondents recognising these as major issues. Finance instability (73.3%) and

obsolete assets (58.6%) are also considered key contributing factors, reflected in high agreement and mean scores. Policy constraints (50%), energy costs (50%) and staff training (65.7%) are factors with lower, but still considerable, levels of agreement. This analysis reveals that the universities face substantial challenges in terms of infrastructure, finance and policy constraints, which need addressing for better facility management outcomes.

Table 4.7: Strategies for FM and Sustainability in UoT

		Strongly Disagree/ Disagree	Not Sure	Strongly Agree/ Agree	Mean	Standard Deviation
SFM1: Leadership commitment is a strategy used for FM sustainability at the UT.	Count	33	47	246	3,84	1,022
	Row N %	10,1%	14,4 %	75,4%		
SFM2: Skilled human resources are a strategy used for FM sustainability at the UT.	Count	34	65	227	3,80	,986
	Row N %	10,5%	19,9 %	69,6%		
SFM3: FM planning system is a strategy used for FM sustainability at the UT	Count	46	90	190	3,55	1,054
	Row N %	14,1%	27,6 %	58,3%		
SFM4: Adequate funding is a strategy used for FM sustainability at the UT.	Count	51	94	181	3,53	1,071
	Row N %	15,6%	28,8 %	55,5%		
SFM5: Gap analysis/Planning schedules is a strategy used for FM sustainability at the UT.	Count	54	111	161	3,46	1,039
	Row N %	16,6%	34,0 %	49,4%		
SFM6: A budgetary analysis is a strategy used for FM sustainability at the UT.	Count	47	85	194	3,61	1,063
	Row N %	14,4%	26,1 %	59,6%		
SFM7: Maintenance plans are a strategy used for FM sustainability at the UT.	Count	58	77	191	3,56	1,159
	Row N %	17,8%	23,6 %	58,6%		

Table 4.7 outlines strategies used for Facility Management (FM) sustainability at the University of Technology (UT), along with the respondents' views on their effectiveness. The data suggests that leadership commitment (75.4%) and skilled human resources (69.6%) are the most widely acknowledged strategies for ensuring

FM sustainability at the University of Technology. While other strategies, such as FM planning systems (58.3%), funding (55.5%) and budgetary analysis (59.6%), also play important roles, there is a slightly greater level of uncertainty or disagreement regarding their impact on sustainability. Gap analysis and planning schedules (49.4%) have the least amount of agreement, suggesting that this may not be seen as a key strategy for FM sustainability compared to the others.

Table 4.8: Lean, Six Sigma, VSM & Sustainability in UoT

		Strongly Disagree/Disagree	Not Sure	Strongly Agree/Agree	Mean	Standard Deviation
LSS1: Management values are well defined.	Count	94	62	170	3,26	1,172
	Row N %	28,8%	19,0%	52,2%		
LSS2: FM capacities and business values are well-measured.	Count	80	133	113	3,11	1,003
	Row N %	24,5%	40,8%	34,7%		
LSS3: FM process flows are well analysed.	Count	98	109	119	3,06	1,065
	Row N %	30,1%	33,4%	36,5%		
LSS4: FM process flows are well improved.	Count	117	105	104	2,92	1,091
	Row N %	35,9%	32,2%	31,9%		
LSS5: FM process flows are well-controlled.	Count	102	106	118	3,05	1,079
	Row N %	31,3%	32,5%	36,2%		
LSS6: LSS allows reducing waste and defects.	Count	48	137	141	3,34	,924
	Row N %	14,7%	42,0%	43,2%		
LSS7: FM process is continuously reviewed for efficiency improvement.	Count	69	121	136	3,23	,958
	Row N %	21,2%	37,1%	41,8%		
LSS8: LSS enables a reduction in inventory.	Count	48	166	112	3,23	,847
	Row N %	14,8%	50,9%	34,3%		

Table 4.8 appears to summarise responses to various statements about Lean Six Sigma (LSS) practices, focusing on facilities management (FM) processes, in the University of Technology. The overall trend shows that while respondents generally agree with the effectiveness of LSS practices in improving FM processes (especially waste reduction (43.2%) and continuous review (41.8%)), there is less certainty or confidence in certain aspects, particularly process flow improvements (31.9%) and control (36.2%).

Table 4.9: Sustainable FM Scheme for a South African University

		Strongly Disagree/Disagree	Not Sure	Strongly Agree/Agree	Mean	Standard Deviation
SFMS1: Identifying various classes of facility defaults contributes to designing an appropriate framework for FM in SA universities.	Count	30	80	216	3,70	,986
	Row N %	9,2%	24,5%	66,3%		
SFMS2: Assessing factors contributing to poor FM contributes to designing an appropriate framework for FM in SA universities.	Count	37	75	214	3,72	1,016
	Row N %	11,4%	23,0%	65,7%		
SFMS3: Establishing the root causes of the poor FM contributes to designing an appropriate framework for FM in SA universities.	Count	32	75	219	3,82	1,011
	Row N %	9,8%	23,0%	67,2%		
SFMS4: Establishing suitable strategies and practices for FM contributes to designing an appropriate framework for FM in SA universities.	Count	22	73	231	3,88	,963
	Row N %	6,8%	22,4%	70,9%		

Table 4.9 shows responses from a survey on the design of an appropriate framework for Facility Management (FM) in South African universities. Across all four statements, the majority of respondents (between 65.7% and 70.9%) strongly agree or agree that the factors mentioned (identifying facility defaults, assessing poor FM factors, understanding root causes and establishing strategies and practices) are critical in

designing an FM framework for South African universities. The mean scores for all statements range from 3.70 to 3.88, indicating a high level of agreement. The standard deviations (0.963 to 1.016) are relatively low, suggesting that the responses were fairly consistent across the group of respondents, with less disagreement among the participants. This data indicates a general consensus on the importance of addressing various factors, from identifying facility issues to establishing strategies, in creating an effective and sustainable facility management framework in South African universities.

4.5 EXPLORATORY AND RELIABILITY ANALYSIS

Exploratory factor analysis (EFA) was employed in the study as a factor validity technique. Factor Validity is defined as an analysis that allows us to simplify a set of complex variables or items using statistical procedures to explore the underlying dimensions that explain the relationships between the multiple variables/items (Field, 2012). Before conducting EFA, two statistical measures were conducted to determine the feasibility of the data for factor analysis. These two statistical measures are the Kaiser Meyer Olkin Measure (KMO) of Sampling Adequacy and Bartlett's Test of Sphericity. The KMO test is a measure that is intended to measure the suitability of data for factor analysis. In other words, it tests the adequacy of the sample size (Pallant, 2020).

The KMO measure of sampling adequacy varies from 0 to 1, with a minimum value of 0.6 considered adequate for factor analysis (Field, 2012). Bartlett's Test of Sphericity tests the null hypothesis (H_0) that the variables are orthogonal, the original correlation matrix is an identity matrix, indicating that the variables are unrelated and therefore unsuitable for structure detection (Field, 2012). The alternative hypothesis (H_1) tests that the variables are not orthogonal; they are correlated enough such that the correlation matrix diverges significantly from the identity matrix (Pallant, 2020). The significant value (p -value < 0.05) indicates that a factor analysis may be worthwhile for the data set (Shrestha, 2020). The exploratory analysis results are presented in Table 4.10 below.

Table 4.10: Exploratory and Reliability Analysis Results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.845						
Bartlett's Test of Sphericity's p-value <0.001						
CONSTRUCT CODES AND ITEMS	COMPONENT					
	1	2	3	4	5	6
Factor 1: Strategies used in Facility Management						
SFM7: Maintenance plans are a strategy used for FM sustainability at the UT.	,822	-,020	,105	,138	,056	,111
SFM6: A budgetary analysis is a strategy used for FM sustainability at the UT.	,790	,002	,121	,151	,030	,080
SFM5: Gap analysis/Planning schedules is a strategy used for FM sustainability at the UT.	,731	,114	,094	,186	,127	-,040
SFM4: Adequate funding is a strategy used for FM sustainability at the UT.	,718	,117	,058	,138	,134	-,033
SFM3: FM planning system is a strategy used for FM sustainability at the UT.	,605	,112	,225	,191	,155	,151
Factor 2: Factors contributing to poor Facility Management						
FCFM10: No direct responsibility contributes to poor FM in the UT.	,071	,745	,011	-,033	,211	,023
FCFM12: Superficial investigation contributes to poor FM in the UT.	,009	,718	,133	-,072	-,031	,018
FCFM11: Diverse reporting processes contribute to poor FM in the UT.	,061	,699	,234	,035	,039	-,069
FCFM8: No proportionality between facilities and the managing staff contributes to poor FM in the UT.	,013	,690	,007	,043	,206	,119
FCFM13: An unsuitable system for FM contributes to poor FM in the UT.	-,009	,666	,194	-,132	,172	,078
FCFM14: Dependence on the procurement department contributes to poor FM in the UT.	,080	,583	,139	,031	,217	,173
FCFM9: No on-time faults reporting contributes to poor FM in the UT.	,103	,571	,045	-,036	,216	,172
Factor 3: Sustainable Facility Management Scheme						
SFMS2: Assessing factors contributing to poor FM contributes to designing an appropriate framework for FM in SA universities.	,172	,201	,773	,030	,072	,123
SFMS4: Establishing suitable strategies and practices for FM contributes to designing an appropriate framework for FM in SA universities.	,198	,100	,766	,101	,185	,052
SFMS3: Establishing the root causes of the poor FM contributes to designing an appropriate framework for FM in SA universities.	,157	,182	,738	,090	,180	,085

SFMS1: Identifying various classes of facility defaults contributes to designing an appropriate framework for FM in SA universities.	,224	,194	,680	,102	,131	,137
Factor 4: Lean, Six Sigma (LSS)						
LSS5: FM process flows are well-controlled.	,130	,007	,017	,860	-,058	-,002
LSS3: FM process flows are well analysed.	,179	-,022	-,023	,838	-,079	,047
LSS4: FM process flows are well improved.	,171	,034	,051	,819	-,069	-,005
LSS2: FM capacities and business values are well measured.	,097	-,082	,169	,689	-,036	,132
LSS7: FM process is continuously reviewed for efficiency improvement.	,184	-,082	,068	,586	,065	,083
Factor 5: Root causes to poor Facility Management						
RCFM9: No maintenance plan is a root cause of poor FM in the UT.	,048	,170	,193	-,135	,795	,092
RCFM7: No staff training is a root cause of poor FM in the UT.	,117	,243	,113	,094	,681	,089
RCFM8: Intervention delays is a root cause of poor FM in the UT.	,046	,283	,165	,008	,662	,089
RCFM6: Finance instability is a root cause of poor FM in the UT.	,159	,145	,127	,008	,633	,021
Factor 6: Classes of Facility Defaults						
CFD3: Systems are a class of Facility defaults in the UT.	,125	-,032	-,022	-,017	,073	,773
CFD5: Roles and responsibilities are a class of Facility defaults in the UT.	,029	,095	-,036	,108	,095	,717
CFD2: Procedures are a class of Facility defaults in the UT.	,028	,020	,280	-,024	-,020	,692
CFD4: Policies are a class of Facility defaults in the UT.	,082	,088	-,046	,032	,128	,676
CFD7: Leadership style is a class of Facility defaults in the UT.	-,132	,185	,093	,233	-,040	,591
CFD1: Processes are a class of Facility defaults in the UT.	,099	,100	,260	-,013	,055	,531
Eigenvalues						
Eigenvalues	7,382	4,238	2,536	2,107	1,905	1,586
% of Variance	21,712	12,464	7,458	6,196	5,603	4,666
Cronbach`s Alpha Coefficient	,880	,896	,858	,863	,849	,807
Composite Reliability	,902	,846	,899	,873	,877	,806
Average Variance Extracted (AVE)	,606	,579	,640	,633	,642	,515
Constructs Abbreviations	SFM	FCFM	SFMS	LSS	RCFM	CFD

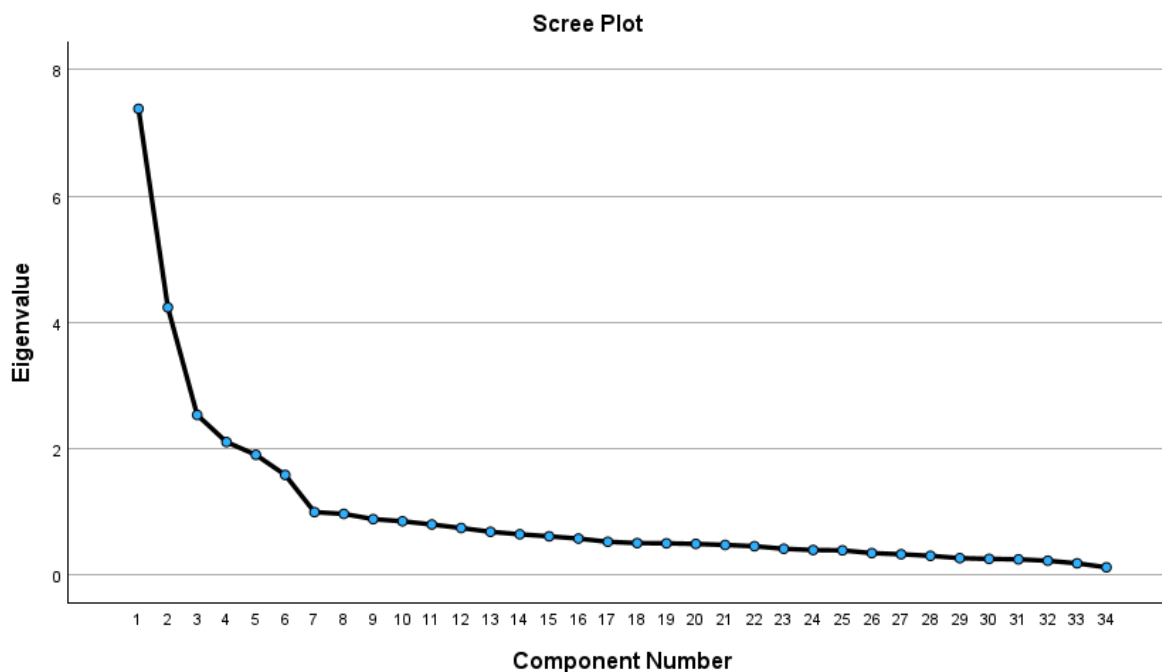


Figure 4.1: Scree Plot

EFA was performed on fifty-two items meant to measure the study constructs addressing issues regarding facility management at South African Universities of Technology. The Principal Components Analysis (PCA) with the varimax rotation method was implemented. The KMO value = 0,845 suggests that the sampling is adequate. The Bartlett's Test of Sphericity's p-value <0.05 level of significance implied that factor analysis is worthwhile for the data set. Using the Kaiser's Eigenvalue Criterion and the scree plot (Figure 4.1), six factors were retained in the factor solution. The eigenvalue of a factor represents the amount of the total variance explained by that factor (Pallant, 2020). The Kaiser's Eigenvalue Criterion suggests that factors having an eigenvalue greater than one are retained (Field, 2012). The first construct was called Strategies used in Facility Management. This construct had an eigenvalue of 7,382 and accounted for 21,712% of the total variance explained. The second component was named Factors contributing to poor Facility Management. This construct had an eigenvalue of 4,238 and accounted for 12,464% of the total variance explained.

The third factor was labelled Sustainable Facility Management Scheme. This construct had an eigenvalue of 2,536 and accounted for 7,458% of the total variance explained. The fourth construct was called Lean, Six Sigma (LSS). This construct had an

eigenvalue of 2,107 and accounted for 6,196% of the total variance explained. The fifth factor was named Root causes to poor Facility Management. This construct had an eigenvalue of 1,905 and accounted for 5,603% of the total variance explained. The sixth component was labelled Classes of Facility Defaults. This construct had an eigenvalue of 1,586 and accounted for 4,666% of the total variance explained.

The study factor loadings range from 0,531 to 0,860 (Table 4.10) and are all above the recommended value of 0.5, which implies a stronger relationship between the factor and the observed variable (Hair, 2010). Factor loadings range from -1 to 1. Loadings closer to -1 or 1 suggest a stronger relationship between the factor and the observed variable, whilst loadings closer to 0 imply a weaker relationship (Pallant, 2020). Finally, twenty-one items were deleted from the factor solution because they were not measuring what they were intended to measure.

To determine the reliability of the measurement instrument, the Cronbach`s Alpha Coefficient was utilised. The Cronbach`s Alpha Coefficient ranges from 0 to 1, with 0.7 considered to be the lower level of acceptability (Hair, 2010). The study`s Cronbach`s Alpha Coefficient values range from 0.807 to 0.896, suggesting that the measuring instrument was reliable.

4.6 CORRELATION ANALYSIS

Correlation analysis was conducted to assess the relationship between the study constructs meant to address the issues regarding Facility Management at South African Universities of Technology. These constructs are Classes of Facility Defaults, Factors Contributing to Poor Facility Management, Root Causes to Poor Facility Management, Strategies Used in Facility Management, Lean Six Sigma and Sustainable Facility Management Scheme. The Pearson Correlation Coefficient was utilised to measure the relationship of these constructs. Pearson Correlation Coefficient is measured from -1 to 1, where -1 represents perfect negative correlation, 0 (no correlation) and 1 represents perfect positive correlation. According to Cohen (1988), the correlation coefficient relationship strength is classified into three categories. The first category represents a weak relationship ($r = 0.10$ to 0.29), the

second category indicates a moderate relationship ($r = 0.30$ to 0.49) and the last category indicates a strong relationship ($r = 0.50$ to 1).

Table 4.11: Correlation Analysis Results

Correlations							
		Classes of Facility Defaults	Factors Contributing to Poor Facility Management	Root Causes of Poor Facility Management	Strategies Used in Facility Management	Lean Six Sigma	Sustainable Facility Management Scheme
CFD	Pearson Correlation	1					
	Sig. (2-tailed)						
	N	326					
Factors Contributing to Poor Facility Management	Pearson Correlation	,201**	1				
	Sig. (2-tailed)	<,001					
	N	326	326				
Root Causes to Poor Facility Management	Pearson Correlation	,221**	,466**	1			
	Sig. (2-tailed)	<,001	<,001				
	N	326	326	326			
Strategies Used in Facility Management	Pearson Correlation	-,200**	-,181**	-,257**	1		
	Sig. (2-tailed)	<,001	,001	<,001			
	N	326	326	326	326		
Lean Six Sigma	Pearson Correlation	-,126*	,055	,063	,365**	1	
	Sig. (2-tailed)	,023	,321	,254	<,001		
	N	326	326	326	326	326	
Sustainable Facility Management Scheme	Pearson Correlation	-,281**	-,388**	-,423**	,393**	,190**	1
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001	
	N	326	326	326	326	326	326
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

It is evident from Table 4.11 that there was a statistically significant (p -value < 0.05), weak to moderate, negative to positive relationship (-0.423 to 0.466) between all constructs. Sustainable Facility Management Scheme shows consistent statistically

significant (p -value < 0.05) negative correlations with Classes of Facility Defaults, Factors Contributing to Poor Facility Management and Root Causes to Poor Facility Management (from -0.423 to -0.281), suggesting that a more sustainable approach in facility management is negatively related with classes of facility defaults, contributing factors and root causes. Also, statistically significant (p -value < 0.05) positive correlations with Lean Six Sigma ($r=0.190$) and Strategies Used in Facility Management ($r=0.393$) were found.

4.7 STRUCTURAL EQUATION MODELLING

PLS-SEM approach was conducted and SmartPLS 4 software was used (Ringle *et al.*, 2020) to create, estimate and assess the sustainable facility management framework for universities of technology in South Africa. Based on PLS-SEM approach the measurement model is initially examined followed by the structural model. A measurement model is a component of a structural equation model (SEM) that defines how latent (unobserved) variables are measured using observed variables (Hair *et al.*, 2019) and a structural model illustrates the proposed connections among the latent variables within a system of equations. It emphasises the causal links between these latent variables, which outline the foundational theoretical relationships present in the data (Kline, 2023).

4.7.1 Assessment of the Measurement Model

Assessment of the measurement model includes examining the reliability, convergent and discriminant validity. The reliability analysis was carried out using both the Cronbach's Alpha coefficient and the Composite Reliability. The recommended values for both the Cronbach's Alpha coefficient and Composite Reliability is 0.70 (Nunnally, 1978). Composite reliability is a measure used to assess the internal consistency or reliability of a latent construct (or factor) in structural equation modelling (SEM) or other multivariate analysis techniques (Fornell & Larcker, 1981). It can be seen from Table 4.10 that all the Cronbach's Alpha coefficient values and Composite Reliability Values exceed the recommended value of 0.7, suggesting that the measurement model is reliable.

The Average Variance Extracted (AVE) and the Factor Loadings were calculated to assess Convergent Validity. Factor loadings represent the strength of the relationship between an observed variable (indicator) and its underlying latent construct (factor) (Ringle *et al.*, 2020). Factor loadings typically range from 0 to 1. A higher value (closer to 1) implies a stronger association between the latent construct and the observed variable, indicating that the indicator is a good measure of the construct (Hair *et al.*, 2019). AVE is a measure used to assess the amount of variance captured by a latent construct from its observed indicators (variables) (Fornell & Larcker, 1981). AVE indicates how well the observed variables represent the underlying latent construct, similar to assessing reliability. It is calculated by averaging the squared factor loadings of all the observed variables associated with a given latent variable. In simpler terms, AVE tells us how much of the variance in the indicators is explained by the latent construct and the recommended value is ≥ 0.50 (Fornell *et al.*, 1981).

An AVE value of 0.50 or greater is typically regarded as satisfactory. This implies that a minimum of 50% of the variance in the observed variables is accounted for by the latent variable, which suggests that the construct is sufficiently represented by the indicators. AVE < 0.50: When the AVE falls below 0.50, it indicates that the latent construct fails to account for sufficient variance in the observed indicators, suggesting that improvements may be necessary in the model. A low AVE could imply that the indicators are unsuitable or that there is excessive measurement error (Fornell & Larcker, 1981). It is evident from Table 4.10 that the factor loadings range from 0,531 to 0,860 and are all above the recommended value of 0.5. The AVE values range from 0,515 to 0,642 above the threshold value of 0.5. Since both the factor loadings and the AVE values are above the recommended respective values it implies that the measurement model is convergently valid.

Cross Loadings and the Fornell-Larcker Criterion were utilised to assess the Discriminant Validity of the measurement model. The Cross Loadings technique suggests that the items on the associated construct should have outer loadings that are greater than those of all other items on the other constructs, as shown in Table 4.10. The Fornell-Larcker Criterion is a widely used method in an SEM approach to assess discriminant validity, which is the degree to which a latent variable is distinct from other latent variables in the model (Fornell & Larcker, 1981). The Fornell-Larcker

criterion compares the square root AVE values and the latent correlations. Table 4.12 below presents the results of the Discriminant Validity that was conducted using the Fornell-Larcker criterion.

Table 4.12: Discriminant Validity Results using the Fornell-Larcker Criterion

Correlations							
		Classes of Facility Defaults	Factors Contributing to Poor Facility Management	Root Causes to Poor Facility Management	Strategies Used in Facility Management	Lean Six Sigma	Sustainable Facility Management Scheme
Classes of Facility Defaults	Pearson Correlation	0.938					
	Sig. (2-tailed)						
	N	326					
Factors Contributing to Poor Facility Management	Pearson Correlation	,201**	0.760				
	Sig. (2-tailed)	<,001					
	N	326	326				
Root Causes to Poor Facility Management	Pearson Correlation	,221**	,466**	0.801			
	Sig. (2-tailed)	<,001	<,001				
	N	326	326	326			
Strategies Used in Facility Management	Pearson Correlation	-,200**	-,181**	-,257**	0.778		
	Sig. (2-tailed)	<,001	,001	<,001			
	N	326	326	326	326		
Lean Six Sigma	Pearson Correlation	-,126*	,055	,063	,365**	0.942	
	Sig. (2-tailed)	,023	,321	,254	<,001		
	N	326	326	326	326	326	
Sustainable Facility Management Scheme	Pearson Correlation	-,281**	-,388**	-,423**	,393**	,190**	0.800
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001	
	N	326	326	326	326	326	326
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

It is apparent from Table 4.12 that the square root of the AVE for each latent variable is greater than the correlation with another latent variable, implying that each latent

variable in the model is adequately capturing unique variance from its indicators and not just replicating what another latent variable is measuring. Since the items on each associated construct have outer loadings that are greater than those of all other items on the other constructs and the square root of the AVE for each latent variable is greater than the correlation with another latent variable it implies that the measurement model is discriminately valid.

4.7.2 Assessment of the Structural Model

Since the measurement model was found to be reliable, convergently and discriminately valid, the structural model can now be assessed. The Structural Model was assessed using the path coefficients, t-values, p-values and the coefficient of determination (r^2) as presented in Table 4.13 and Figure 4.2 below.

Table 4.13: Assessment of the Structural Model Results

Relationship	Path-Coefficient	t-value	p-value	Decision
Classes of Facility Defaults -> Sustainable Facility Management Scheme	-0,158	3,201	0,001	Supported
Factors Contributing to poor Facility Management -> Sustainable Facility Management Scheme	-0,218	3,478	0,001	Supported
Lean, Six Sigma -> Sustainable Facility Management Scheme	0,134	2,318	0,020	Supported
Root Causes to Poor Facility Management -> Sustainable Facility Management Scheme	-0,223	3,444	0,001	Supported
Strategies used in Facility Management -> Sustainable Facility Management Scheme	0,238	3,185	0,001	Supported

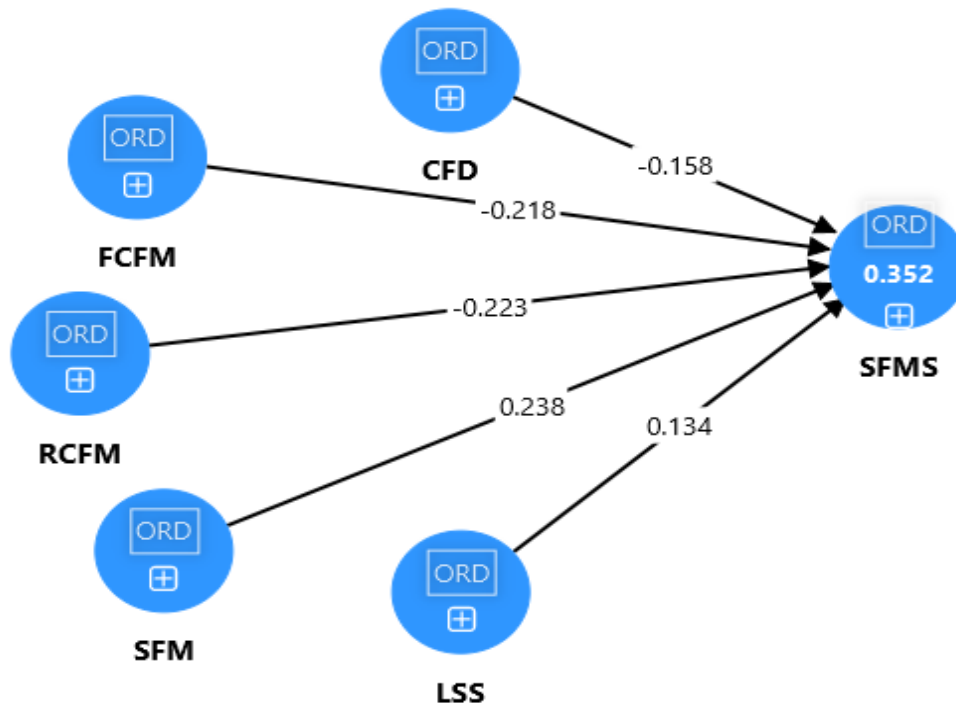


Figure 4.2: Sustainable Facility Management Framework

The structural model results presented in Table 4.15 and Figure 4.2 suggest that all five relationships were statistically significant. These were the following, Classes of Facility Defaults negatively impacts Sustainable Facility Management Scheme ($\beta = -0,158$; $p < 0,05$), Factors Contributing to poor Facility Management negatively affects Sustainable Facility Management Scheme ($\beta = -0,218$; $p < 0,05$), Root Causes to poor Facility Management negatively influences Sustainable Facility Management Scheme ($\beta = -0,223$; $p < 0,05$), Strategies used in Facility Management positively impacts Sustainable Facility Management Scheme ($\beta = 0,238$; $p < 0,05$) and Lean, Six Sigma and Sustainable Facility Management Scheme ($p\text{-value} = 0,001$). The coefficient of determination was found to be 0,352, suggesting that 35,2% of the variance in the model is being explained by Classes of Facility Defaults, Factors Contributing to poor Facility Management, Root Causes to poor Facility Management, Strategies used in Facility Management and Lean, Six Sigma and Sustainable Facility Management Scheme. The study's coefficient of determination (0.355) was greater than 0.26 (Large Effect Size) as determined by Cohen (1988), suggesting a better fit of the model to the data. In addition to evaluating the structural paths, the overall model fit was assessed

using standard Structural Equation Modelling (SEM) goodness-of-fit indices. The results indicate an acceptable to good model fit. The Comparative Fit Index (CFI) exceeded the recommended threshold of 0.90, indicating a satisfactory fit between the hypothesised model and the observed data. The Root Mean Square Error of Approximation (RMSEA) was below the recommended upper limit of 0.08, suggesting an acceptable level of approximation error. Furthermore, the Standardised Root Mean Square Residual (SRMR) was below the cut-off value of 0.08, indicating a good fit of the structural model. Collectively, these indices confirm that the proposed Sustainable Facility Management structural model demonstrates an adequate overall fit and is suitable for hypothesis testing.

4.8 MULTIPLE LINEAR REGRESSION ANALYSIS

In this study, the multiple linear regression analysis was conducted using IBM Statistical Package for the Social Sciences (SPSS) version 30 to investigate the influence of Classes of Facility Defaults, Factors Contributing to Poor Facility Management, Lean Six Sigma, Root Causes to Poor Facility Management and Strategies used in Facility Management on Sustainable Facility Management Scheme.

4.8.1 Significance of the Model

Table 4.14: ANOVA Results of The Model

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	54,963	5	10,993	29,247	<,001 ^b
	Residual	118,770	316	,376		
	Total	173,734	321			
a. Dependent Variable: Sustainable Facility Management Scheme						
b. Predictors: (Constant), LSS, Factors Contributing to Poor Facility Management, CFD, Strategies Used in Facility Management, Root Causes to Poor Facility Management						

Table 4.14 illustrates an Analysis of Variance (ANOVA) table that appears to summarise the results of a Multiple Linear Regression analysis predicting Sustainable Facility Management Scheme based on five predictor variables: Lean Six Sigma,

Factors Contributing to Poor Facility Management, Classes of Facility Defaults, Strategies Used in Facility Management and Root Causes to Poor Facility Management. The F-statistic of 29.257 with a p-value of < 0.001 indicates that the model is statistically significant.

4.8.2 Multiple Linear Regression Assumptions

Before interpreting the multiple linear regression beta coefficients, assessing the multiple linear regression assumptions is appropriate. Among these assumptions are multicollinearity, normality, homoscedasticity and outliers.

4.8.2.1 Assumption of Multicollinearity

High correlation between the independent variables is known as multicollinearity. It is challenging to distinguish the distinct impacts of each predictor on the dependent variable when there is a highly significant correlation between two or more independent variables. The coefficients may be estimated in an unstable manner as a result of multicollinearity.

A correlation matrix can be used to evaluate multicollinearity. Multicollinearity is shown when two independent variables have a bivariate correlation of 0.7 or higher (Pallant, 2020). Table 4.12 makes it clear that the model is not affected by multicollinearity because the independent variables do not exhibit bivariate correlations of 0.7 or higher.

4.8.2.2 Assumption of Normality

According to the normality assumption, the residuals in the Regression Standardised Residual's Normal Probability Plot (P-P) must be linearly related to the predicted Dependent Variable (DV) scores (Pallant, 2016). The Normal P-P Plot generated by statistical software like SPSS can be used to evaluate this assumption.

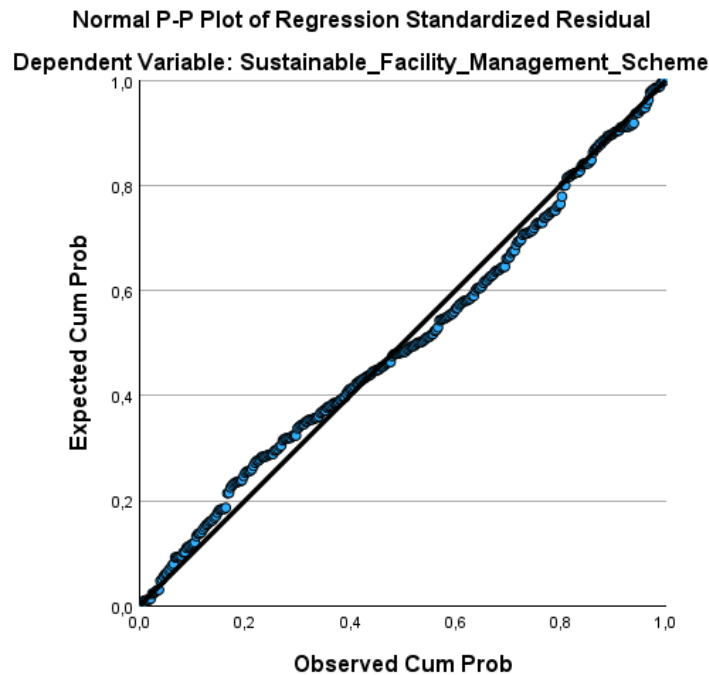


Figure 4.3: Scree Plot:

Normal P-P Plot of Regression Standardised Residual

It is apparent from Figure 4.3 that the residuals fall along the diagonal line with no substantial systematic departures, implying that the assumption of normality is met.

4.8.2.3 Assumption of Homoscedasticity

According to this assumption, the variance of the residuals for the projected scores of the dependent variable must be the same for every predicted score (Pallant, 2020). Heteroscedasticity, or a shift in the residuals' variance at different predictor levels, can result in inaccurate coefficient estimations and have an impact on the computation of p-values and confidence intervals, rendering them unreliable. The scatter plot generated by statistical software like SPSS can be used to investigate this assumption.

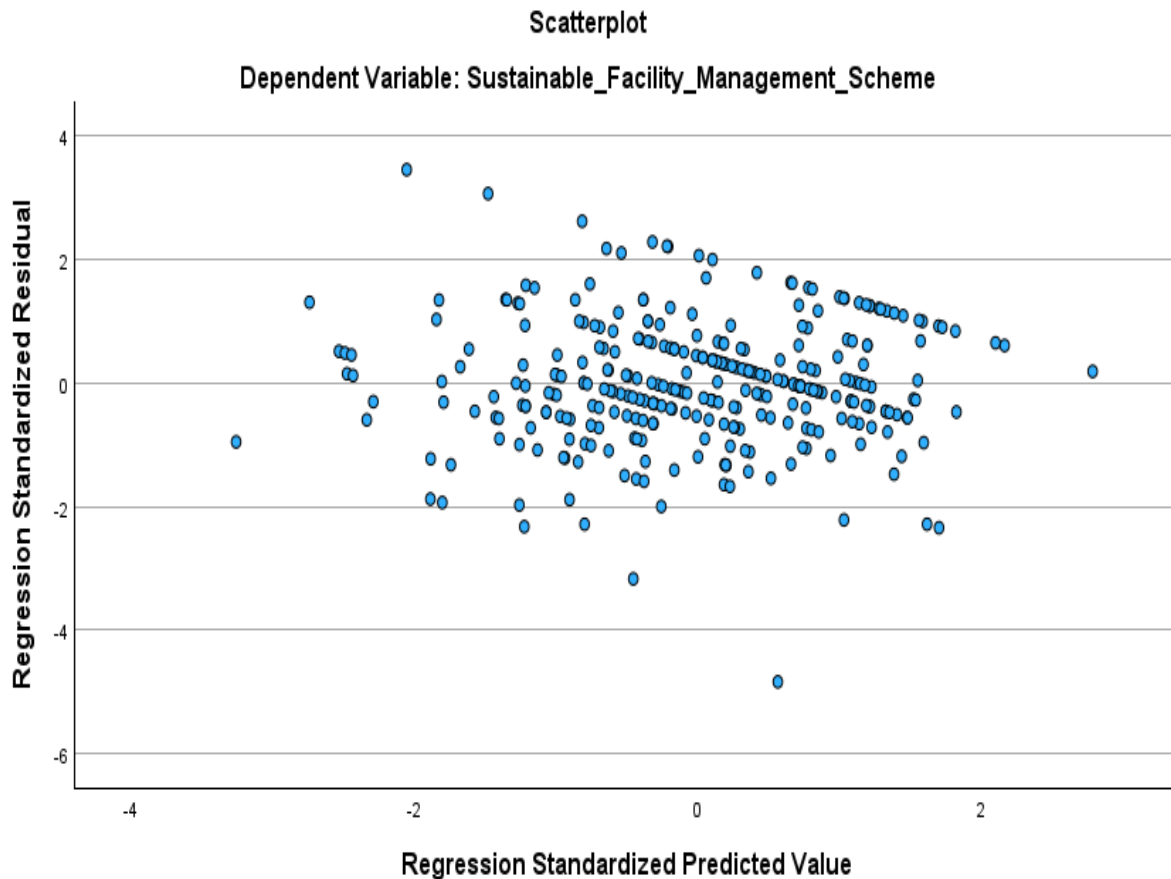


Figure 4.4: Scatter Plot

As can be shown in Figure 4.4, there is no discernible pattern in the residuals plotted, suggesting that the model does not suffer from heteroscedasticity.

4.8.2.4 Assumption of Outliers

One term for outliers is extremely influential data points. Because multiple linear regression analysis is prone to outliers, the estimated coefficients may be calculated incorrectly, which frequently distorts the model and produces biased findings. Checking for outliers involves comparing the maximum calculated Mahalanobis distance values generated by statistical software, such as SPSS, to the Mahalanobis distance critical values.

Table 4.15: Critical values for evaluating Mahalanobis distance values

Number of independent variables	Critical Values
2	13.82
3	16.27
4	18.47
5	20.52
6	22.46
7	24.32
8	26.13
9	27.88
10	29.59

Table 4.15 illustrates the critical chi-square values for 2 to 10 degrees of freedom (number of independent variables) at a critical alpha value of 0.001.

Table 4.16: Residual Statistics

Residuals Statistics ^a					
	Minimum	Maximum	Mean	Std. Deviation	Z
Predicted Value	2,3838	4,8844	3,7298	,41379	322
Std. Predicted Value	-3,253	2,790	,000	1,000	322
Standard Error of Predicted Value	,038	,151	,080	,024	322
Adjusted Predicted Value	2,4135	4,8798	3,7297	,41433	322
Residual	-2,96529	2,11818	,00000	,60828	322
Std. Residual	-4,837	3,455	,000	,992	322
Stud. Residual	-4,991	3,523	,000	1,005	322
Deleted Residual	-3,15706	2,20211	,00008	,62476	322
Stud. Deleted Residual	-5,192	3,588	,000	1,012	322
Mahal. Distance	,243	18,502	4,984	3,752	322
Cook's Distance	,000	,268	,005	,018	322
Centred Leverage Value	,001	,058	,016	,012	322

a. Dependent Variable: Sustainable Facility Management Scheme

Table 4.15 shows that the critical value determining the Mahalanobis distance for five independent variables (as per this study) is 20.52. Table 4.16 displays the maximum calculated Mahalanobis distance to be 18.502. Since the maximum calculated

Mahalanobis distance is less than the Mahalanobis distance critical value (20.52), it implies that the model does not have any outliers. This was achieved by eliminating cases 283, 149, 264 and 26, which were the outliers.

4.8.3 Evaluating the Model

The coefficient of determination (R^2) is typically used to assess the multiple linear regression model.

Table 4.17: Model Summary

Model Summary ^b				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,562 ^a	,316	,306	,61307
a. Predictors: (Constant), LSS, Factors Contributing to Poor Facility Management, CFD, Strategies Used in Facility Management, Root Causes to Poor Facility Management				
b. Dependent Variable: Sustainable Facility Management Scheme				

Table 4.17 reveals that the multiple linear regression model explains 31.6% of the variance in SFM Scheme (with an adjusted value of 30.6% after considering the number of predictors. The model $R^2 = 0.316$ greater than 0.26 (Large Effect Size), as suggested by (Cohen, 1988), indicates that the independent variables LSS, Factors Contributing to Poor FM, Classes of Facility Defaults, Strategies Used in FM and Root Causes to Poor Facility Management explain the variation in SFM Scheme sufficiently.

4.8.4 Evaluation of the Independent Variables

The main aim of performing the multiple linear regression analysis was to investigate the impact of Lean Six Sigma, Factors Contributing to Poor FM, Classes of Facility Defaults, Strategies Used in FM and Root Causes to Poor Facility Management on SFM Scheme.

Table 4.18: Regression Coefficients of the Model

Coefficients ^a

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	3,935	,251		15,679	<,001	3,441	4,429		
	CFD	-,113	,052	-,108	-2,201	,028	-,215	-,012	,904	1,106
	Factors Contributing to Poor Facility Management	-,204	,051	-,216	-4,015	<,001	-,303	-,104	,747	1,338
	Root Causes to Poor Facility Management	-,214	,050	-,238	-4,319	<,001	-,312	-,117	,711	1,406
	Strategies Used in Facility Management	,200	,047	,222	4,255	<,001	,108	,293	,798	1,253
	LSS	,096	,043	,110	2,202	,028	,010	,181	,860	1,162
a. Dependent Variable: Sustainable Facility Management Scheme										

Table 4.18 depicts that Classes of Facility Defaults (p-value = 0.028), Factors Contributing to Poor FM (p-value < 0.05), Root Causes to Poor FM (p-value < 0.05), Strategies Used In FM (p-value < 0.05) and Lean Six Sigma (p-value = 0.028) were statistically significant in the model. It is apparent that Classes of Facility Defaults, Factors Contributing to Poor FM and Root Causes to Poor FM had a negative influence on the SFM Scheme as shown by the negative beta coefficients. Strategies used in Facility Management and Lean Six Sigma contributed positively to the Sustainable Facility Management Scheme.

The following statistical multiple regression model can be derived from Table 4.18

$$SFM\ Scheme = 3.935 + 0.200\ Strategies\ Used\ in\ FM + 0.096\ LSS - 0.113\ Classes\ of\ Facility\ Defaults - 0.204\ Factors\ Contributing\ to\ Poor\ FM - 0.214\ Root\ Causes\ to\ Poor\ FM$$

This statistical model suggests that, holding other independent variables constant, every unit increase in Strategies Used in FM may lead to an increase in SFM Scheme by 0.2 units. Holding other independent variables constant, every unit increase in LSS may lead to an increase in SFM Scheme by 0.096 units. Holding other independent

variables constant, every unit decrease in Classes of Facility Defaults may lead to a decrease in SFM Scheme by 0.113 units.

Holding other independent variables constant, every unit decrease in Factors Contributing to Poor FM may lead to a decrease in SFM Scheme by 0.204 units.

Holding other independent variables constant, every unit decrease in Root Causes to Poor FM may lead to a decrease in SFM Scheme by 0.214 units.

4.9 CHAPTER SUMMARY

The study achieved a high response rate, with 333 of the 353 questionnaires returned (95.1%) and 326 valid (97.9%). Most respondents were under 25 years (81.6%), held matric or equivalent (65.6%), and were based at Pretoria West and Soshanguve campuses. Descriptive results indicated that leadership style, roles and responsibilities, and systems were widely recognised as classes of facility defaults, while public finances drew less agreement. Contributing factors to poor facility management included a lack of policies (77%) and systems (76.7%), alongside budgeting weaknesses, while root causes were linked to absent maintenance planning (75.7%), infrastructure deterioration (75.8%), and financial instability (73.3%). Leadership commitment (75.4%) and skilled human resources (69.6%) emerged as the most recognised strategies for sustainability, although gap analysis/planning schedules were less supported. Lean Six Sigma (LSS) was seen as useful for waste reduction and efficiency review, but weaker in process improvement and control maturity.

Exploratory factor analysis confirmed the validity of six construct strategies, contributing factors, sustainable FM scheme, LSS, root causes, and defaults with loadings between 0.531 and 0.860, strong reliability (Cronbach's $\alpha = 0.807-0.896$), and good convergent and discriminant validity. Correlation analysis showed that sustainable FM schemes were negatively correlated with defaults, contributory factors, and root causes, but positively correlated with strategies and LSS, indicating that reducing systemic weaknesses while reinforcing enabling practices and LSS contributes to sustainability outcomes.

Both PLS-SEM and multiple regression confirmed the hypothesised model. Defaults, contributing factors, and root causes had significant negative effects, whereas strategies and LSS had significant positive effects, together explaining around one-third of the variance in sustainable FM schemes. These findings suggest that universities of technology should prioritise eliminating systemic inefficiencies while embedding proactive strategies and LSS rigour. A dual focus on reducing defaults and root causes while institutionalising leadership commitment, skilled staff, structured FM planning, and mature LSS processes offers a clear pathway to sustainable facility management in South African higher education.

CHAPTER FIVE

QUALITATIVE DATA ANALYSIS AND PRESENTATION OF RESULTS

5.1 CHAPTER OVERVIEW

This chapter outlines the data analysis process and presents the results of an empirical study that collected data through interviews. The interview protocol consisted of 14 questions, out of which six were related to participant demographics (general information) and eight addressed the research problem. The qualitative data collected through interview questions were analysed using Atlas.ti 24.

5.2 DEMOGRAPHIC DETAILS

Table 5.1 depicts the demographic distribution of the study participants. Most respondents 17 (81%) were males and the least 4 (19%) were females. Regarding the highest educational level, the majority (33.3%) held bachelor's degrees; 4 (19.0%) held master's degrees; 3 (14.3%) held honours or other qualifications; and 2 (9.5%) held both Grade 12 and a diploma.

Table 5.1: Demographic Characteristics

Characteristics	Category	Frequency	%
Gender	Female	4	19,0
	Male	17	81,0
Level of Education	Grade 12	2	9,5
	Diploma	2	9,5
	Bachelor's Degree	7	33,3
	Honours Degree	3	14,3
	Masters	4	19,0
	Other	3	14,3
Job Position	Artisan or Technician	5	23,8
	Lower Manager	3	14,3
	Middle Manager	7	33,3
	Senior Management	6	28,6
Years of Working Experience	Less than 10	2	9,5
	Above 10	19	90,5
Facilities Infrastructure	Building Estate	5	23,8
	Student Accommodation	13	61,9
	Warehouse	1	4,8
	Other	2	9,5
	Minimum	Mean	Maximum
Age	33	44,48	59

Most respondents in Table 5.1 (33.3%) were Middle Managers, followed by Senior Managers (28.6%), with the fewest in Artisans or Technicians (5; 23.8%) and Lower Managers (3; 14.3%). The respondents' views on the spread of campus facilities were: 13 (61.9%) from Student Accommodation, 5 (23.8%) from Building Estate, 2 (9.5%) from other facilities, and 1 (4.8%) from Warehouse facilities. Respondents with more than 10 years of experience comprised the majority (19; 90.5%), whereas those with less than 10 years of experience accounted for 2 (9.5%). Finally, the average age of the respondents was 44.48 years (range: 33-59).

5.3 QUALITATIVE DATA ANALYSIS USING ATLAS.TI

There are two stages in the examination of qualitative data: the method level and the process level. A thematic qualitative data analysis approach was used at the technique or method level. Finding, examining, and interpreting patterns or themes within a dataset is the primary goal of the qualitative data analysis technique known as thematic analysis.

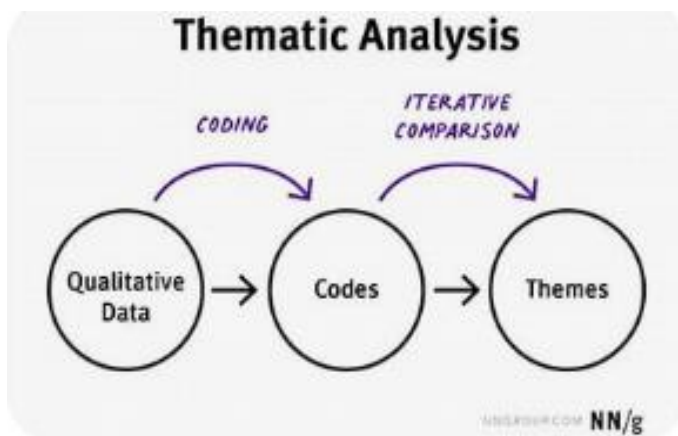


Figure 5.1: The thematic qualitative data analysis method

Figure 5.1 depicts an iterative coding process for developing categories, which are then translated into several themes (Morgan & Nica, 2020). Thus, the coding process employed in this analysis was developed inductively from raw data collected from 21 staff members. At the process level, the 21 qualitative interview transcripts were analysed in Atlas.ti 24.

This method is particularly valuable in social sciences, psychology, and other fields where understanding people's experiences, perceptions, and behaviours is essential (Castleberry & Nolen, 2018). Thematic analysis does not require a preexisting theory or framework; instead, it allows data to guide the discovery of themes. The process involves systematically reviewing data to identify significant patterns, themes, or trends that help answer research questions or provide deeper insight into the phenomena under study (Kiger & Varpio, 2020).

One of the key advantages of thematic analysis is its flexibility. It can be applied to a wide range of qualitative data types, including interviews, focus groups and text-based

data (Javadi & Zarea, 2026). This flexibility makes thematic analysis accessible for researchers with varying levels of theoretical orientation, as it does not demand adherence to a specific theoretical approach. Thematic analysis can be conducted both inductively (data-driven) or deductively (theory-driven), depending on the research objectives. The method also promotes a rich and detailed understanding of data, as it allows researchers to explore both the surface-level responses and deeper, more nuanced meanings within the dataset (Braun & Clarke, 2006).

Thematic analysis is typically carried out in a series of steps. First, researchers immerse themselves in the data, reading and re-reading it to gain familiarity. Next, they generate initial codes that summarise key features of the data, followed by organising these codes into potential themes (Williams & Moser, 2019). These themes are then reviewed and refined to ensure they accurately represent the dataset. Finally, the researcher defines and names the themes, ensuring that each theme conveys a coherent, meaningful unit of analysis that addresses the research questions. Throughout the process, the researcher must maintain a balance between staying true to the data and providing an interpretation that offers new insights (Braun & Clarke, 2006).

Thematic analysis offers several advantages. It is relatively easy to learn and apply, making it suitable for both novice and experienced researchers. The method also provides a clear framework for handling large volumes of qualitative data, which can be overwhelming without such a structure. Furthermore, its ability to capture rich, detailed insights into people's experiences, beliefs and behaviours makes it a powerful tool for understanding complex phenomena. Thematic analysis allows for flexibility in the level of abstraction, enabling researchers to examine broad themes as well as more specific subthemes (Guest, MacQueen & Namey, 2012).

In ATLAS.ti, a qualitative data analysis software, the process begins with data collection, in which the researcher gathers raw data from various sources, such as interviews, focus groups, or documents. Once the data is collected, ATLAS.ti aids in organising the information by facilitating the creation of codes labels or tags that represent themes or patterns in the data. These codes are then applied to specific portions of the data, allowing the researcher to highlight key segments that align with

the study's research questions (Friese, 2019). The software offers tools for grouping, linking and visualising codes, which helps in detecting patterns, relationships and trends within the data.

The next phase involves coding and analysing the data to develop insights and interpretations. ATLAS.ti provides tools like code co-occurrence, which enables researchers to examine how different themes are interconnected across the dataset. Researchers can perform queries to examine the frequency and distribution of codes, thereby aiding the identification of dominant themes or outliers. The software also supports advanced data visualisation methods, including network views and word clouds, which can assist researchers in representing complex data in accessible formats (Kuckartz, 2014). Ultimately, the analysis concludes with the interpretation and presentation of findings, where researchers synthesise the coded data into meaningful conclusions or theoretical models.

5.3.1 Code Groundedness and Distribution Across the 21 Interviews

The Atlas.ti Excel export below shows that this analysis resulted in 43 codes being assigned to segments of text across the 21 interview transcripts. The codes and their groundedness in the data are also shown in the Excel export. The Excel export below shows groundedness during the early stages of the analysis. Groundedness (code frequency) indicates how many quotations are linked to a code. In other words, it shows how many times a particular code was assigned across the 21 interviews, thus indicating which ideas were prominent in the dataset. These codes informed the emergence of five themes that will be presented in this chapter.

Table 5.2: Atlas.ti Excel Export

#	Code	Grounded
1	• Minor maintenance, urgent and breakdowns	3
2	• Sustainability and the longevity	2
3	• Maintenance and renovation	3
4	• Major maintenance projects	1
5	• Routine maintenance defaults	1
6	• Painting, plumbing, carpentry and electricity defaults	1
7	• Proper assessment tool and maintenance system	2
8	• Three year rolling plan	2
9	• Lack of proper budgeting	2
10	• No sufficient funds	2
11	• Potential crisis level	2
12	• Through inspections	3
13	• Reporting system and process	3
14	• Preventative	3
15	• Maintenance Plan	3
16	• Attitude and long-term service	3
17	• Maintenance, safety and service delivery	1
18	• New leaders	2
19	• High risk, medium risk and low risk	3
20	• No proper record-keeping	2
21	• Lack the ability to adapt to new systems	5
22	• No department planning sessions and poor adherence to standard procedure	5
23	• Poor budgeting of the allocated finances and leadership	5
24	• Understaffed and lack of an effective facility management unit	5
25	• Centralisation of authority and no proper plan	5
26	• Maintenance team is now demotivated and there is a culture of people not willing to work	3
27	• Not many engineers, architects and quantity surveyors	3
28	• The university policies are not followed	3
29	• Hiring process of contactors takes too long and channels of	3

procurement		
30	• No clear responsibilities, mismanagement of funds, budgetary constraints, incompetent facility managers and not engaging with the artisans	3
31	• Online system or program monitoring job progress	4
32	• Top management support and performance review	4
33	• System tailored to the specific environment	4
34	• A collaborative management with innovative people	4
35	• New technology, trends and maintenance services model	4
36	• Public Private Partnership arrangements, willingness of all parties and a 10-year facility management plan	4
37	• Apply standard operating procedures and proper maintenance system	2
38	• Consequence management and accountability	2
39	• Follow the University policies and have regular management meetings	2
40	• Modernised existing structures and digitised maintenance services	2
41	• Continues maintenance of buildings and proper monthly inspections	2
42	• A sense of community belonging and selective model for service providers	2
43	• Stock monitoring, controls and restructuration	2

5.4 Presentation of the Results

This section presents the qualitative data results. The results presented below emanated from the participants' responses to the interview questions that sought to answer the following research questions,

- Which factors contribute to poor management of facilities within a university system?
- What are the root causes of poor university facility management?

- Which strategies and practices are suitable to effectively maintain university facilities?
- How can a sustainable Facility Management Framework help improve facility management for a South African university?

The following five themes emerged from the analysis.

Theme 1: The various classes of facility defaults include plumbing, painting, carpentry, electrical and general maintenance defaults. These are routine tasks to keep physical structures in good condition.

Theme 2: Poor management of university facilities is primarily due to inadequate budgeting, improper maintenance, lack of knowledge and skills, non-compliance with regulations and poor stakeholder communication.

Theme 3: The root causes of poor university facility management encapsulate a range of systemic, structural and cultural issues that contribute to the ineffective management of facilities

Theme 4: There are multiple strategies and practices proposed by participants to effectively maintain university facilities over time.

Theme 5: Developing a sustainable Facility Management scheme for university facilities in South Africa requires a multifaceted approach

This chapter will now turn to the presentation of the results under each of the five themes.

The participants were asked the following question: What are various classes of facility defaults present within a university system? Their responses are presented below.

The established practices and procedures that guarantee a building is maintained and up to code are known as facility management (FM) defaults. The participants outlined five classes of facility defaults, which are plumbing, painting, carpentry, electrical and general maintenance defaults. These defaults fall into various major categories such

as space planning, safety, energy efficiency, regulatory compliance, environmental management and maintaining physical structures and systems.

In response to the question about classes of facility defaults, Respondent 4 stated: *"We have defaults in carpentry, painting, plumbing and electricity."* Likewise, Respondent 6 clarified that *"there are electrical defaults. . . plumbing and wear and tear on the facilities themselves"*. *"We have mostly structural defaults that range from plumbing, electrical and carpentry,"* said Respondent 7.

Based on the seniority of the position held by Respondent 5, his response was slightly different, focusing more broadly on categories of facility defaults. He described his understanding as follows:

"Well, there are what I would describe as the routine maintenance defaults. So routine maintenance would mean fixing a tap here and fixing things around. Then there are medium-sized faults. This is if you want to retile this place or you want to repaint the room; those are medium-sized projects. And then there are major maintenance projects. These are refurbishments. These require redoing the entire plumbing, painting and many large projects".

Respondent 8 answered that in his workplace, they deal mainly with wood or carpentry. He also mentioned that they sometimes attend to leakages, which can be classified under plumbing defaults. But mainly, they fix doors and door handles that get broken almost daily by the students. Moreover, he mentioned that he fixes partition doors. Partition doors expand when it is raining and need to be attended to. He further mentioned that tables are one of the things they often find being vandalised by the students.

In like manner, Respondent 9 stated: *"Our primary services include plumbing, carpentry, painting and electrical. We also deal with air conditioners, so it's a lot"*. Meanwhile, Respondent 11 explained that they primarily deal with structural problems. *"One issue we are facing is the deteriorating infrastructure. Another important factor is the students' ability to access utilities like Wi-Fi, kitchens and canteen supplies."* Other respondents agreed that there are various structural defaults that fall under electrical,

carpentry, logistics and plumbing. *"They are primarily electrical and water-based, or rather plumbing defaults,"* said Respondent 14.

Respondent 14 argued that the main issue is that although systems are absent on paper, they are dealing with people who are performing customary tasks that people are used to and standard operating procedures are virtually non-existent.

Respondent 17 explained that *"our facilities frequently experience electrical and plumbing malfunctions. Our main plumbing problem is that some of our pipes are just bursting and others are leaking. They are not kept up properly"*.

"There are carpentry, plumbing and electrical, which primarily fall under structural defaults," said Respondent 18.

According to Respondent 19, facility defaults encompass everything related to architecture and landscape design. He added that because he is involved with student housing and residences, his answer focuses on buildings. He explained that *"the majority of these buildings have structural problems with everything from painting to plumbing. The fact that we are working with such old structures is the issue"*. Students complain about showers not working, they are unhappy about the unavailability of hot water, stoves and other cooking facilities not working as they should, Respondent 3 stated. He explained how these factors contribute to the students' discontent.

5.4.1 Identification of Various Classes of Facility Defaults

In the study, participants were asked to describe how they identified various classes of facility defaults within a university system. Their responses highlighted a range of methods and practices.

Respondent 4 explained that facility defaults are reported by resident managers using Maintenance Fault Report (MFR) forms. *"They do report; we have resident managers who report to us. They use MFR forms. They fill up the form to say there is a leakage in house number so and so, then I notify to allocate it to the relevant people if it's carpentry, welding, plumbing, and so on."*

Preventative measures were emphasised by Respondent 5, who noted the importance of routine inspections and maintenance plans. *“The first will be preventative where your routine inspections identify these defaults before they spread out. You log everything that you do and you will also have estimates of how long the building will need to be remodelled or refurbished. But where we are right now, that is not really our strongest point; it is now largely reactive.”*

Respondent 6 highlighted the role of frontline workers, such as cleaners, in reporting faults. *“So people report them. We have what we refer to as frontline workers, like cleaners, who interact with these facilities daily, and part of their responsibility is to report faults that they see because such faults have a direct impact on their work.”*

Monthly checks and staff reports were mentioned by Respondent 7. *“We have our staff who work there and they report to my office. So, the staff that works there identify them, but we also have monthly checks. And mostly it's plumbing and electrical.”*

Respondents 8, 9 and 16 described a system involving job cards, where clients report issues and administrative staff release job cards to address the problems. Respondent 9 stated, *“Job cards. Through job cards. The clients report them and then the admin people release the job cards and we then go and deal with the problem.”*

Respondent 11 also relied on MFR forms, which categorise issues as technical, electrical, plumbing, or carpentry. *“For us, it's through the reports, what we call maintenance faults report systems forms (MFRs). It's the system that has a category of if it's technical, electrical, plumbing or carpentry.”*

A combination of reporting systems and inspections was used by Respondent 15. *“We use a reporting system. As the end users interface with these defaults, they report back to their line manager or res managers and then we get the reports from them. On the logistics side, we also get reports from the drivers and the admin assistants. But we also identify them through inspections”.*

Respondent 17 described a regular inspection routine. *“Normally, we have what we call an inspection run. We inspect the facilities under our care twice a week. We try to detect what is working and what is not working.”*

Respondent 18 mentioned both MFR forms and inspections as methods for identifying defaults. *“We use MFR, the clients report through our administration, then they send the job to us. Sometimes we also use our inspections to identify the various defaults in our facilities.”*

Finally, Respondent 19 provided a practical example of identifying leakages and plumbing issues. *“For instance, with the leakages, every time it rains, depending on the direction of the rain, that is when we see that there is a leak on the roof. After the rain has gone, there is no problem, so every time it rains, we have to put buckets, that is how we identify them.”*

These varied responses illustrate the different approaches and challenges faced in identifying facility defaults within a university system.

5.4.2 Facility Default Classifications

The classification of facility defaults within a university system emerged as a central subtheme in the responses provided by the participants. When asked how various classes of facility defaults could be categorised, the participants offered a range of perspectives that reflected the complexity and diversity of maintenance challenges in such an environment.

Respondent 3 highlighted a hierarchical approach to classification, stating, *“There would be minor defaults that we can do in-house. Then there would be a major one that will need external personnel. Then obviously some are way over our heads that are bigger projects handled by colleagues from the building estate.”* This distinction between minor, major and large-scale defaults shows the varying levels of expertise and resources required to address different issues.

Similarly, Respondent 9 emphasised the importance of urgency in classifying defaults, explaining, *“It depends on how bad they are. If it is urgent or it can be fixed in a short space of time. That’s how we classify them based on the scale of urgency.”* This focus on urgency was echoed by Respondent 18, who noted, *“The urgent ones are based on how urgent the problem is and how it affects the students and staff in those facilities. And then the normal ones are not as urgent, but they happen regularly and we deal with them on a day-to-day basis.”*

Respondent 5 introduced a distinction between “soft” and “hard” facility defaults. They described soft defaults as those related to “cleaning, pest control and hygiene-related matters,” which pertain to the general upkeep and cleanliness of the facility. In contrast, hard defaults involve “physical maintenance, repairs and the replacement of fixtures of the building.” This categorisation highlights the dual nature of facility management, encompassing both operational and structural aspects.

The temporal dimension of defaults was also a recurring theme. Respondent 6 explained, *“Some are short-term planning. These are the things you can solve now. Like if a toilet seat is broken. But some are defaults that require long-term planning to correct them.”* This distinction between short-term and long-term issues was further elaborated by Respondent 12, who stated, *“We classify them according to our abilities to deal with them, some will fall under immediate maintenance that we normally handle in-house, while others will fall under long-term maintenance that we usually outsource.”*

Respondent 7 provided a more detailed classification system, stating, *“I would say we classify them as minor maintenance, urgent and breakdowns. Others also fall under planned maintenance and others fall under routine maintenance.”* This multi-tiered approach reflects the need to balance reactive and proactive maintenance strategies. The role of external contractors was highlighted by Respondent 8, who noted, *“As we are dealing mainly with maintenance, the HOD is the one who can decide whether a default can be maintained or if it will be completely renovated by external contractors. Because maintenance and renovation are two different things. When you maintain, you replace what is damaged, but when you renovate, you shut down the entire facility.”* This distinction highlights the significant impact of certain defaults on facility operations.

Respondent 10 offered a functional classification, explaining, “*We have different categories that we put them under, such as electrical work, plumbing and infrastructure. This is one way of classifying them.*” This approach aligns with the practicalities of addressing specific types of defaults.

Risk assessment also emerged as a key factor in classification. Respondent 11 stated, “*You have three categories, namely high risk, medium risk and low risk. What we are dealing with here is mostly medium and low-risk levels. It’s not high risk because most of the facilities are still usable. It’s just that they are ageing.*” This risk-based approach helps prioritise resources and actions.

Respondent 13 provided a sector-specific perspective, noting, “*There are major defaults and minor defaults. As for the sector I am in, the problems range from running toilets, no hot water, low water pressure, bursting pipes, sewer blockages and all of these including many more others will be classified and arranged based on how severe the fault.*” This highlights the variability of defaults across different areas of the university.

The importance of following established processes was emphasised by Respondent 14, who stated, “*You have processes that are supposed to help you identify the problem and classify them accordingly, but if they are not being followed strictly, it becomes very difficult.*” This underscores the need for systematic approaches to facility management.

Finally, Respondents 16 and 17 highlighted the practical constraints of addressing defaults, particularly in an academic setting. Respondent 16 explained, “*It depends on the extent of the problem. So, we check the issue and see if it needs to be done urgently or not. Some of the problems can be fixed while the students are around, but others can’t. For instance, if we have to drill through the walls and make noise, we can’t do it during classes and school times.*” This reflects the need to balance maintenance activities with the operational needs of the university.

The classification of facility defaults within a university system is multifaceted, encompassing factors such as urgency, severity, risk, functionality and temporal

requirements. These classifications help guide decision-making and resource allocation and ensure that both minor and major defaults are addressed effectively.

5.4.3 Analysis of the Various Classes of Facility Defaults

Participants were asked to critically analyse the various classes of facility defaults within a university system. Their responses provided a comprehensive view of the challenges and issues faced.

Respondent 3 emphasised the importance of finances, planning and a willingness to maintain the space. *“...It has to do with finances and it has to do with having a plan and it has to do with the willingness to look after the space.”*

Respondent 3 further elaborated, *“We get failed by senior managers that seem to want to hold everything to themselves. Approval processes take longer and people have not entrusted managers in other spaces to be autonomous in terms of decision-making and running their ship and then maybe month-end reporting back to say you gave me ten thousand rands and this is how I spent it and I prioritised it like this.”*

It was apparent from this response that, due to a lack of trust, decision-making tended to be centralised. Hence, Respondent 3 felt that *“the centralisation of everything makes processes longer and causes unnecessary delays as far as service delivery is concerned”*. Some of the challenges associated with centralised decision making include a reactionary instead of a proactive approach to problem solving.

Consequently, Respondent 3 outlined occasions where students had to protest to get their grievances about facilities resolved. Respondent 3 believed that holding senior management accountable could help avoid the closure of some of the facilities, which would result in significant fiscal losses for the university.

Respondent 4 pointed out issues related to capacity and awareness among resident managers. *“I think they are not handled properly. Our main problem is that we lack capacity and that we are short-staffed, and also, resident managers are not really aware of what is happening in their residences, and only the team leaders know.”*

Financial constraints were a significant concern for Respondent 5, who highlighted the challenges with electricity and plumbing due to ageing infrastructure. *“Currently, we do not have sufficient funds made available to do refurbishment when they are due. We need to build a proper maintenance system. In the absence of a proper system you rely on individual memories.”*

Respondent 6 described the situation as reaching a potential crisis level. *“We have reached a potential crisis level. So I would say the condition of these defaults is dire.”* Poor maintenance and inadequate budgeting were identified as key issues by Respondent 7. *“My analysis is that most of the defaults that we are dealing with are as a result of poor maintenance. The other reason will be a lack of proper budgeting for the facility management, especially on the maintenance side. There are also issues like human factors, such as vandalism.”*

Respondent 8 noted the challenges faced by older buildings within the university. *“I would say that in the university, there are certain old buildings that have serious challenges. Every building has a duration of maybe 30 to 40 years, then it will show signs like lights, plumbing and many other faults.”*

Respondent 9 criticised the prioritisation of staff offices over student facilities. *“All the facilities here are supposed to be strategically designed to serve the students, not necessarily the offices of the staff. It can’t be proper that these boardrooms and offices are always renovated and given more attention than the students, who are the people we are here for.”*

The lack of proper assessment tools and record-keeping was highlighted by Respondent 10. *“We don’t have a proper assessment tool to monitor the deteriorating state of our facilities. There is no proper record-keeping for the cycle of maintenance.”* Respondent 11 warned of the potential collapse of facilities if defaults are not addressed seriously. *“My analysis is that if we are not seriously attending to these defaults, the facilities will ultimately collapse.”*

The need for external inspectors and better budget management was suggested by Respondent 12. *“We need to bring external inspectors who will be honest and brutal*

on the state and conditions of our facilities and our assets. We also need to look at our turnaround times and identify the areas of delay in our processes.”

Respondent 13 called for new leadership to improve the status of the facilities. *“We need new restructuring in our leadership and have new leaders who have the will and desire to improve our status.”*

Respondent 14 discussed the historical state of the facilities and the need for either a complete overhaul or adaptation to current standards. *“Well, the state of our facilities at the moment is historical. You have facilities that are not compatible with the current state.”*

Health risks to students and staff were mentioned by Respondent 15. *“Some are health risks to the students and the staff.”*

Respondent 16 criticised the use of poor materials and the focus on quick fixes rather than upgrades. *“...they are not using good materials. Some are bad because they are not using modern and technologically advanced equipment to ensure sustainability and the longevity of the equipment and the facilities.”*

Respondent 18 highlighted the slow response to minor defaults, which often escalate into major issues. *“I think we take too long to do particular developments; the university takes longer to deal with these minor defaults, and before you know it, they become major or big.”*

Finally, Respondent 19 suggested the implementation of a maintenance plan to address defaults in a timely manner. *“I will just say these are very beautiful facilities, they just need to have a maintenance plan and that plan must be like a three-year rolling plan, so that they will be able to address all the defaults in time.”*

Theme 2: Poor management of university facilities is primarily due to inadequate budgeting, improper maintenance, lack of knowledge and skills, non-compliance with regulations and poor stakeholder communication

This theme emerged from the participants’ responses to the question: what are the factors that contribute to poor management of facilities within a university system? “It’s

a trust issue and people not letting go and trusting people that can report back,” stated Respondent 3. *“However, I’m also irritated”* because, as I mentioned, there is a willingness to work, but we complain about capacity and the possibility that money is not being allocated where it should be. According to Respondent 4, the line managers are the problem. He thinks that the line managers are running these residences very poorly. They are not always present at work.

Respondent 5's reaction was somewhat different according to the seniority of the post he held. He explained how she came to realise the following elements that lead to inadequate facility management in a university system:

“Lack of funds, but also in our specific environment, I think, because we are in an accommodation environment which is vastly led by administrators. These are people with administrative qualifications and not so much technical qualifications necessary to lead such an environment. It is left to people who are far too junior to match its strategic importance. Normally, there are no department planning sessions taking place annually. No routine maintenance. There are no services from the building and estate, the small maintenance team in the student accommodation has to take on more responsibilities and unfortunately, the capacity does not match. But obviously, the biggest one is the availability of funds. No advocate in the budget meetings. The allocated budget is misused”.

Respondent 6 stated that: *“I would say one of them is poor maintenance planning. So if you have a burst pipe, which is something that needs to be addressed now by just buying simple equipment or a device to fix the problem. But here you need to adhere to a procurement process that requires three quotations, seven-day periods of waiting and allowing quotations to be submitted. Procurement interfaces with service providers should be addressed”*.

Respondent 7 agrees with and adds on by saying: *“With my experience, it is mainly red tape. These are processes that are too long and prevent a quick response to address the facility issue. The other factor I think is politics to some extent. By politics I mean you see a lot of fighting for responsibilities. This then causes a lot of delays in dealing with facility defaults.* Respondent 8 answered: *“The factors that contribute to*

poor management is late reaction to the problems. So, the biggest challenge would be that the management is not proactive and even when they react, the reaction time is so slow. But the artisans are ready because they get instructed by the HOD."

Respondent 9 replied: *"The poor facility management is a result of internal culture. Procurement process delays and poor management. We are also understaffed". Respondent 10 stated that: "There is a lack of effective facility management unit. It's also a lack of expertise".*

"We have poor leadership, which leads to poor management," stated respondent 11. The other issue is the inadequate budgeting of the funds allotted. *"I think largely it is centralisation of authority,"* responded respondent 12. The decision-making process is overly centralised; it would be better if it were decentralised. *"Weak managers are not taking any initiative to improve these facilities and students,"* responded Respondent 13. Managers aren't creative. absence of cutting-edge facilities that would allow them to succeed. Due to extensive renovations, nearly all of the facilities here are outdated and several require reconstruction. In actuality, the managers are careless.

Underperforming has become commonplace. For instance, rather than waiting for someone to report, you should have someone check your classroom every day to make sure everything is operating as it should. *"Poor communication from senior management here at the university,"* stated Respondent 15. *"There are a lot of miscommunications in our sector because we are being let by people who are clueless about what our job is all about,"* responded Respondent 16. *"No proper maintenance plan,"* was the response from Respondents 17 and 19. We are understaffed and face numerous maintenance issues. We don't have enough human capital to tackle all the problems. Respondent 18 said, *"I believe that one issue that affects us and leads to poor management is a lack of understanding. The leadership, in particular, is incapable of adjusting to new systems."*

The fact that we frequently switch directors and bring in individuals who lack the necessary skills to handle maintenance is another issue with the leadership. For instance, they bring someone with little expertise from Eskom's farm department to the university. At that point, the systems start to have problems. lack of training for staff

members who are knowledgeable about the operation of the university system. The second theme that emerged from the study highlights the multifaceted factors contributing to the poor management of university facilities. Participants identified several key issues, including inadequate budgeting, improper maintenance, lack of knowledge and skills, non-compliance with regulations and poor stakeholder communication. These factors collectively undermine the effective management of facilities within the university system.

Respondent 3 pointed to a fundamental issue of trust and accountability, stating, *"It's a trust issue and people not letting go and trusting people that can report back."* However, they also expressed frustration with the misallocation of resources, noting, *"There is a willingness to work, but we complain about capacity and the possibility that money isn't being allocated where it should be."* This sentiment was echoed by Respondent 5, who emphasised the critical role of funding, stating, *"The biggest one is the availability of funds. No advocate in the budget meetings. The allocated budget is misused."* This highlights the institutional challenge of inadequate financial planning and resource allocation.

Respondent 4 attributed poor facility management to ineffective leadership, particularly among line managers. He explained, *"The line managers are the problem. They are running these residences very poorly. They are not always present at work."* This lack of oversight and accountability was further elaborated by Respondent 11, who stated, *"We have poor leadership, which leads to poor management."* Similarly, Respondent 13 criticised the lack of initiative among managers, saying, *"Weak managers are not taking any initiative to improve these facilities and students. Managers aren't creative."* These responses underscore the detrimental impact of weak leadership on facility management.

The absence of technical expertise among those managing facilities was another recurring concern. Respondent 5 highlighted this issue, stating, *"In our specific environment, we are led by administrators with administrative qualifications, not technical qualifications necessary to lead such an environment. It is left to people who are far too junior to match its strategic importance."* This lack of expertise was further emphasised by Respondent 10, who noted, *"There is a lack of an effective facility*

management unit. It's also a lack of expertise." Respondent 18 expanded on this, pointing out the consequences of frequent leadership changes and the appointment of underqualified individuals: *"We frequently switch directors and bring in individuals who lack the necessary skills to handle maintenance. For instance, they bring someone with little expertise from Eskom's farm department to the university. At that point, the systems start to have problems."*

Improper maintenance practices and planning were also identified as significant contributors to poor facility management. Respondent 6 criticised the inefficiencies in maintenance planning, stating, *"One of them is poor maintenance planning. If you have a burst pipe, which needs to be addressed now, you have to adhere to a procurement process that requires three quotations, seven-day waiting periods and allowing quotations to be submitted."* This bureaucratic red tape was further highlighted by Respondent 7, who stated, *"With my experience, it is mainly red tape. These are processes that are too long and prevent a quick response to address the facility issue."*

Respondent 19 added, *"No proper maintenance plan. We are understaffed and face numerous maintenance issues. We don't have enough human capital to tackle all the problems.* The slow reaction time to facility issues was another critical factor. Respondent 8 explained, *"The factors that contribute to poor management is late reaction to the problems. The biggest challenge is that the management is not proactive and even when they react, the reaction time is so slow."* This lack of proactivity was also noted by Respondent 14, who stated, *"Having poor adherence to standard procedures. Underperforming has become commonplace. For instance, rather than waiting for someone to report, you should have someone check your classroom every day to make sure everything is operating as it should."*

Poor communication and internal culture were also cited as significant barriers to effective facility management. Respondent 15 stated, *"Poor communication from senior management here at the university."* Respondent 16 added, *"There are a lot of miscommunications in our sector because we are being led by people who are clueless about what our job is all about."* This lack of clear communication and understanding exacerbates existing challenges and hinders effective collaboration.

Finally, the centralisation of decision-making authority was identified as a structural issue. Respondent 12 argued, *“I think largely it is the centralisation of authority. The decision-making process is overly centralised; it would be better if it were decentralised.”* This centralisation limits flexibility and responsiveness, further contributing to inefficiencies in facility management.

These factors create a challenging environment that undermines the effective maintenance and management of university facilities, ultimately impacting the overall functionality and quality of the institution.

Theme 3: The root causes of poor university facility management encapsulate a range of systemic, structural and cultural issues that contribute to the ineffective management of facilities

The third theme emerged from the participants’ responses to the question: What are the root causes of poor university facility management?

The participants identified a range of systemic, structural and cultural issues that contribute to the ineffective management of facilities. These root causes include a lack of trust, poor leadership, inadequate organisational structures, bureaucratic inefficiencies and a culture of complacency, among others.

Respondent 3 highlighted the issue of trust and the failure to delegate responsibilities, stating, *“It’s not trusting your team. The root cause would be thinking that if you are not the one doing it, it can’t be done. Or also not putting systems in place. The university policies are not followed.”* This lack of trust and adherence to established systems creates a barrier to effective management. Respondent 4 added to this by pointing out a broader cultural issue, stating, *“Lack of discipline actually from the managers and even from the people above them.”* This suggests that accountability and discipline are lacking at multiple levels of the organisational hierarchy.

Poor leadership emerged as a recurring theme in the responses. Respondent 5 explicitly stated, *“I think the root cause is poor leadership. Not many engineers, architects, quantity surveyors and so on.”* This lack of technical expertise in leadership positions was further emphasised by Respondent 6, who simply stated, *“Incompetent*

facility managers.” Respondent 13 echoed this sentiment, describing the leadership as “*poor, weak and indecisive,*” and highlighting the impact of poor communication channels and a lack of resources. He explained, “*A simple task will take three weeks to reach the technicians. We don’t have enough money, tools, or even personnel to perform our jobs to the best of our abilities. The maintenance team is now demotivated without proper support from management.*”

The organisational structure and bureaucratic inefficiencies were also identified as significant root causes. Respondent 7 pointed to the lack of clear responsibilities and resistance to change, stating, “*The root cause is the poor organisational structure. There are no clear responsibilities that are lined up to assist with proper management. We are not willing to adapt and make changes. And there is also a culture of people not willing to work.*” Respondent 8 expanded on this, criticising the lengthy chain of command and procurement processes: “*The chain of command is too long and there are long channels of procurement. Some of the job cuts are stuck with an admin who is not checking their emails and there will be too many delays. Lack of materials. Then you also have HODs that are not able to help with providing us with the necessary materials.*”

The hiring and contracting processes were also cited as problematic. Respondent 9 expressed frustration with the delays in hiring contractors, stating, “*Here in TUT, the hiring process of contractors takes too long with SLEs and everything and it’s frustrating us a lot.*” This inefficiency in procurement and contracting further exacerbates delays in addressing facility issues.

Financial mismanagement and the absence of proper planning were also highlighted as root causes. Respondent 10 stated, “*There is no proper plan or financial maintenance plan.*” Respondent 17 echoed this, noting, “*The issue again of the maintenance plan and poor management. Number two is the issue of being understaffed. There are a lot of budgetary constraints. In fact, by the end of the 6th month, you will be told that the maintenance funds have been depleted.*” Respondent 18 also pointed to financial mismanagement, stating, “*Besides money, I do not know. I do not want to use the word corruption; I would say maybe mismanagement of funds.*” A culture of complacency and poor attitudes among staff was another significant issue.

Respondent 14 stated, *“It is complacency with people not doing their jobs and being paid for nothing.”* Respondent 11 also highlighted the negative attitudes of some staff members, stating, *“The root cause for poor management is attitude and long-term service. It’s mainly attitude and some people have been in positions for a long time who do not want to learn. If the student is crying about a particular default in the facility, the attitude is that we don’t want to do it. It’s not within our scope or immediate plans.”* Centralisation of authority was identified as a structural barrier to effective facility management. Respondent 12 explained, *“It goes back to centralising authority and decision-making. Because you can have someone here who is in charge of the facilities in Witbank. Witbank needs to write into Pretoria, Ga-Rankuwa needs to write and Soshanguve needs to write in. If we have a broken window in Pretoria, we need to call someone in Pretoria to report that. Then someone in Pretoria would say, ‘I can’t call a contractor for one window,’ so they wait until the issues accumulate and by the time they call the contractor, the facilities are in a mess.”*

Finally, the lack of engagement with frontline workers and artisans was highlighted as a critical issue. Respondent 16 stated, *“The biggest one is not engaging with the artisans and understanding exactly what they need.”* This lack of communication and collaboration further hinders effective facility management.

Theme 4: The participants propose multiple strategies and practices to effectively maintain university facilities over time

The respondents were asked the question: what can you propose as suitable strategies and practices to effectively maintain university facilities over time? The participants provided various strategies and practices to effectively maintain university facilities over time. Their insights are captured below.

Respondent 3 emphasised the importance of instilling a sense of community and belonging. *“A sense of community belonging will help even if managing the facility and the shared areas. Once we can show management that we can be trusted, maybe they can find a way to invest in these facilities. We need to build an attractive culture that*

will lead to having clients or students being attracted to want to live here so they get the value for their money.”

Respondent 4 suggested adhering to university policies and implementing disciplinary measures for underperforming employees. *“I think they must follow the university’s policies in terms of what they agreed to; disciplinary measures must be put in place for the underperforming employees. They should also hire more qualified people to build capacity. Especially in maintenance. Regular management meetings are required to discuss these issues. Constant residence visits are necessary to check the state of facilities and the reported cases. We should do site viewings.”*

The need for restructuring and digital transformation was highlighted by Respondent 5. *“So the first thing, restructuring is needed. The new structure must be informed by scientific research. It ought to do benchmarking because other institutions are doing much better. Build a proper maintenance system. Now we are border-lining on the lines of digital transformation. We need to digitalise maintenance services. We also need a selective model for service providers.”*

Respondent 6 focused on reskilling the workforce and ensuring accountability. *“One, you need to reskill your workforce because people don’t keep up with policy evolution. People must fulfil their contractual obligations towards the organisation. There needs to be consequence management and accountability.”* The implementation of new systems and personnel training was proposed by Respondent 7. *“We need new systems like electronic reporting systems that report directly. We also need personnel training and direct system access without depending on the line manager. We need a proper change management process.”*

Respondent 8 emphasised the importance of budget allocation to the stores. *“I think budget allocation to the stores is important.”* Engagement with ground employees and providing qualified human capacity were suggested by Respondent 9. *“I think that management should engage with ground employees and assist us with the qualified human capacity to attend to these facilities and the demands of the students adequately.”*

Respondent 10 stressed the need for expertise and proper planning. *“One has to greater expertise in all maintenance sectors, have the right people on the job and also do proper planning for these facilities. “Modernising existing structures was a key point for Respondent 11. “... Modernised existing structures.”*

Decentralising authority and planned maintenance were proposed by Respondent 12. *“Decentralised authority. You give other campuses power and authority to make decisions concerning the maintenance and development of their facilities. I also wanted to talk about planned maintenance.”*

Respondent 13 advocated for innovative thinking and avoiding cost-cutting measures. *“Innovative thinking or futuristic planning for the facilities. Avoid cutting costs by all means because it will affect you in the long run.”*

The application of standard operating procedures and daily monitoring was suggested by Respondent 14. *“Management should apply standard operating procedures and ensure stock monitoring and controls using checklists. There should be daily monitoring to remain proactive.”*

Engaging with lower-level personnel during annual general meetings was recommended by Respondent 15. *“Engage with the lower-level personnel during the maintenance annual general meeting.”*

Respondent 16 proposed creating a maintenance planning list based on affordability and urgency. *“If they can help us make a maintenance planning list from the issues that we need. Then we see from there what can happen based on affordability and urgency.”*

Allocating sufficient funds and manpower for continuous maintenance was emphasised by Respondent 17. *“Enough funds must be allocated to our maintenance team and more manpower so that we can handle all facility problems. Continuous maintenance of buildings should be done so that they do not fall apart.”*

Proper monthly inspections and line function programs were suggested by Respondent 18. *"Proper monthly inspections and proper line function programs should be developed."*

Finally, Respondent 19 highlighted the need for stakeholder involvement. *"Stakeholders' involvement is required because management has no idea of how these things work. They must call people responsible for these facilities, from maintenance to artisans, building and estate and managers, for them to have an 'Imbizo', including the plumbers and the painters."*

Theme 5: Developing a SFM scheme for university facilities in South Africa requires a multifaceted approach. Respondents were also asked to propose strategies for developing a SFM scheme that ensures effective maintenance of university facilities in South Africa over time. Their responses highlighted various approaches and considerations.

Respondent 4 suggested implementing an online system to monitor job progress and provide feedback for improvement. *"An online system or program monitoring job progress with sections of feedback on things that can be improved. A system can also help with their efficiency and performance review."*

Respondent 5 emphasised the need for a tailored system based on existing circumstances and the size of the university. *"There is room for improvement by looking at the existing circumstances and the size of this place to build a system tailored to the specific environment."*

The importance of willingness from all parties involved was highlighted by Respondent 6. *"A FMS is important as long as there is a willingness of all the parties involved; then our facilities can be managed and maintained better."*

Respondent 7 called for innovative thinkers to define a facility management scheme that adapts to the university's current needs. *"In such an academic environment, we should have thinkers and innovative people who can define a facility management*

scheme. We should have systems that can be adapted to suit the current needs of the university as far as effective facility management is concerned."

Increasing the allocation for petty cash maintenance services was suggested by Respondent 8. *"We also need to look into increasing the allocation of the petty cash maintenance services. Most months by the 15th of every month, I would have exhausted the limit of the credit card and petty cash, so if a problem comes after the 15th, then we have to wait for the month's end."*

Respondent 9 proposed collaborative management to minimise delays in service delivery. *"Collaborative management will also help with minimising the long processes that delay service delivery."*

A long-term facility management and investment plan was recommended by Respondent 10. *"A 10-year facility management plan is required, followed by an investment plan."*

Public-Private Partnerships (PPPs) were suggested by Respondent 11 to bring in necessary skills and funding. *"We need to enter into some Public-Private Partnership arrangements to ensure that we bring the necessary skills and necessary funding. We will be able to thrive and offer better services to our clients."*

Respondents 13 agreed on the importance of a scheme, provided there is willingness from all parties involved. *"A scheme is important as long as the parties involved are willing."*

Respondent 15 pointed out the need for transport facilities to avoid delays in field interventions. *"Transport facilities are missing and delaying field interventions and are time-consuming."*

Management support and proper job allocation were emphasised by Respondent 17. *"It is possible. We need management support and proper job allocation following a maintenance plan."*

Finally, Respondent 18 highlighted the need to apply new technology and trends within the facilities. *“New technology and trends should be applied within these facilities.”*

5.4.4 Theoretical interpretation of qualitative findings

Theme 1: Classes of facility defaults (plumbing, painting, carpentry, electrical and general maintenance)

This theme confirms a Lean view that facility work consists of recurring “value-preserving” activities required to sustain service readiness, yet the data also show frequent reactive breakdowns that signal wasteful cycles of rework and waiting. From a Six Sigma perspective, the repeated recurrence of similar defaults suggests unstable processes and weak preventive controls, which increases variation in turnaround time and service quality. Under TBL, persistent defaults represent economic losses (escalation from minor to major repairs), social impacts (student dissatisfaction and disrupted learning/residence experience), and environmental impacts (water leaks, energy inefficiency and material wastage). These insights extend the facility management literature by showing that defaults are not only technical faults but also indicators of system reliability and governance capacity in a university environment.

Theme 2: Drivers of poor facility management (budgeting, skills, compliance, communication)

This theme confirms Six Sigma logic that weak planning and delayed procurement introduce variation and longer cycle times, while Lean explains the non-value adding delays caused by “red tape”, long approval chains, and waiting for quotations. The findings also align strongly with STS theory by demonstrating misfit between social components (skills, leadership, accountability, motivation) and technical components (maintenance systems, reporting tools, work processes). Institutional Theory is confirmed through repeated references to non-compliance with policies and inconsistent enforcement, suggesting that formal rules exist but are not sufficiently embedded in daily routines. The findings challenge assumptions that poor FM is primarily technical by showing that organisational structure, authority distribution, and managerial capability are central determinants of FM performance.

Theme 3: Root causes (systemic, structural and cultural issues)

Lean and Six Sigma interpret these root causes as structural drivers of waste and process instability: centralised decision-making, delayed procurement, weak record-keeping, and reactive maintenance encourage recurring failure cycles. STS theory is strongly supported because participants highlight demotivation, complacency, and lack of engagement with artisans alongside missing systems and tools, demonstrating that performance breaks down when the social system and technical system are misaligned. Institutional Theory is extended by showing that organisational norms (complacency, weak discipline, “not my scope”) can override formal policies, which weakens accountability. Overall, this theme confirms that facility failures are produced by interdependent social, technical, and institutional mechanisms rather than isolated operational errors.

Theme 4: Proposed strategies (decentralisation, SOPs, skills, digital reporting, proactive maintenance)

This theme confirms Lean principles that emphasise flow, standard work, visual controls, and problem prevention rather than firefighting. Six Sigma is reflected in calls for monitoring, performance review, accountability, and structured planning, which resemble control-oriented improvement logic. From an STS lens, the strategies extend theory by showing that participants want improvement through both social redesign (training, leadership commitment, clarified roles, engagement) and technical redesign (digital reporting systems, maintenance scheduling, monitoring tools). The evidence challenges “one-solution” approaches by indicating that process tools alone are insufficient unless supported by authority, staffing capacity, and discipline.

Theme 5: Sustainable facility management (tailored systems, multi-year plans, PPPs, technology adoption)

This theme aligns with TBL by explicitly linking sustainability to long-term cost control (investment planning and reduced breakdown escalation), stakeholder outcomes (service delivery to students and staff), and environmental performance (modernised

systems and efficient resource use). Lean and Six Sigma interpret the push for digitisation, monitoring, and tailored systems as mechanisms to reduce delays, minimise waste, and stabilise service performance. Institutional Theory is confirmed through the emphasis on governance arrangements such as PPPs, policy adherence, and management support, indicating that sustainable FM requires institutional legitimacy, consistent enforcement, and resourcing. The findings extend theory by showing that “sustainability” in this setting is perceived as a governance and capability issue, not only an environmental aspiration.

Theoretical contribution

Across themes, the qualitative evidence confirms that FM outcomes are shaped by (i) process waste and delays (Lean), (ii) unstable planning and weak controls that increase performance variation (Six Sigma), (iii) sustainability trade-offs across cost, stakeholder wellbeing, and environmental impact (TBL), (iv) misalignment between people, processes, and technologies (STS), and (v) weak institutionalisation of rules and accountability mechanisms (Institutional Theory). Collectively, the findings support the argument that improving university facility management requires an integrated socio-technical and institutional response, strengthened by Lean and Six Sigma improvement logic and evaluated through TBL sustainability outcomes.

5.5 CHAPTER SUMMARY

The chapter synthesises key insights under five themes, beginning with classifications of facility defaults, which primarily include plumbing, painting, carpentry, electrical and general maintenance tasks essential for maintaining the built environment. These routines, ranging from minor repairs to structural refurbishments, are identified through diverse reporting systems, inspections and risk-based prioritisation practices. Theme 2 highlights that poor facility management stems from inadequate budgeting, reactive maintenance, lack of technical competence, regulatory non-compliance and weak communication. Participants frequently pointed to bureaucratic hurdles, centralised decision-making and misplaced financial allocations as culprits undermining resilient facility upkeep.

Theme 3 digs deeper, uncovering systemic root causes such as deteriorating infrastructure, absence of structured maintenance planning, financial volatility, obsolete equipment and a culture of complacency, all of which echo broader trends in African higher education FM research. Building on these findings, Themes 4 and 5 propose strategic frameworks for sustainability. Participants advocate for holistic, people-centred strategies to focus on leadership commitment, skilled staffing, decentralised authority, proactive maintenance protocols, digital reporting systems and stakeholder engagement. They emphasise the importance of tailored FM schemes, including multi-year investment plans, petty cash for minor repairs and public–private partnerships. This mirrors international best practices, underscoring the pivotal role of leadership, technical capacity and integrated planning for FM excellence in higher education.

CHAPTER SIX

RESULTS DISCUSSION AND FRAMEWORK DEVELOPMENT

6.1 CHAPTER OVERVIEW

This chapter presents the development, empirical grounding, evaluation and operationalisation of a Lean Six Sigma (LSS)-based Sustainable Facilities Management (FM) Framework for Universities of Technology in South Africa. Drawing on both quantitative and qualitative findings, the chapter consolidates empirical evidence into a coherent framework that responds directly to the contextual challenges identified at the Tshwane University of Technology (TUT). In doing so, the chapter moves beyond descriptive analysis and demonstrates how empirical results are translated into a practical, evaluable and implementable FM improvement model.

The framework was developed through a systematic, multi-stage process informed by established theoretical and practical models. First, relevant guiding frameworks were reviewed, including traditional FM lifecycle models, sustainable FM principles, systems theory and the Lean Six Sigma DMAIC methodology. While these models provide valuable insights, none adequately address the combined challenges of ageing infrastructure, governance constraints, sustainability pressures and service-oriented complexity characteristic of Universities of Technology in the Global South.

Second, empirical findings from the study were synthesised to identify five core analytical dimensions (i) classes of facility defaults, (ii) factors contributing to poor FM management, (iii) systemic root causes of FM inefficiencies, (iv) effective maintenance strategies and practices, and (v) the need for an integrated, sustainable FM framework.

These dimensions were then explicitly mapped onto the DMAIC phases of Lean Six Sigma, ensuring that the framework is grounded in both theory and evidence, rather than being conceptually abstract.

The framework is directly informed by empirical results. Quantitative analysis identified statistically significant negative relationships between facility defaults, poor FM practices and FM sustainability, while structured FM strategies and Lean Six Sigma tools demonstrated a significant positive influence on sustainable FM outcomes. Qualitative findings reinforced these results by revealing recurring operational failures in plumbing, electrical systems, carpentry, painting and general maintenance, alongside governance weaknesses such as reactive planning, inadequate budgeting, centralised decision-making and limited technical capacity.

These findings are translated into specific framework components, including proactive maintenance planning, decentralised operational authority, leadership accountability, digital fault-reporting systems, skills development and stakeholder engagement. Each component of the framework therefore corresponds directly to an empirically identified problem, ensuring analytical coherence and traceability between data, analysis and framework design.

Unlike many conceptual FM models, the proposed framework is evaluated within the same chapter using empirical validation techniques. Structural modelling confirms the applicability and robustness of the framework by demonstrating that the adoption of Lean Six Sigma principles and structured FM strategies significantly improves FM sustainability outcomes. This evaluation highlights the strengths of the framework, particularly its ability to reduce reactive maintenance, address systemic inefficiencies and support long-term infrastructure resilience. At the same time, the evaluation reveals contextual constraints, such as funding limitations and institutional resistance to change, which are acknowledged as areas requiring managerial and policy-level intervention.

The original contribution of this study lies in the context-specific integration of Lean Six Sigma, sustainability and facilities management within a university setting, supported by empirical validation. Unlike FM or Lean models, which are often generic or manufacturing-oriented, this framework is explicitly designed for Universities of Technology in South Africa. It uniquely links operational FM failures, governance challenges and sustainability imperatives within a single, empirically grounded DMAIC-based structure.

The framework is designed to be operationalised through phased implementation aligned with the DMAIC cycle. Successful application assumes leadership commitment, access to basic FM data, functional maintenance reporting systems and minimum technical capacity within FM units. Potential constraints include financial pressures, skills shortages, organisational resistance and legacy infrastructure conditions. These factors are explicitly acknowledged, reinforcing the framework's realism and applicability within public higher-education institutions.

This chapter demonstrates how empirical findings are systematically transformed into a validated, operational and original Sustainable FM Framework. By integrating development, evaluation and application within a single chapter, the study strengthens its scholarly contribution and provides a practical roadmap for improving facilities management performance in Universities of Technology.

6.2 CLASSES OF FACILITIES DEFAULTS IN THE UOT

The respondents from Universities of Technology perceive organisational and leadership-related factors such as processes, procedures, systems, policies, roles and responsibilities and especially leadership style as primary contributors to facility defaults. Leadership style recorded the highest mean score of 3.68, with 64.1% of participants agreeing, underscoring its critical influence on facility management outcomes. This finding aligns with facility management literature highlighting the pivotal role that effective leadership plays in guiding resources, empowering teams and embedding robust systems for sustained performance.

Technical defaults and public finance issues, while not negligible, garnered lower consensus and greater response variability, suggesting they are seen as secondary in the hierarchy of facility challenges. Facility management at these institutions will benefit most from a leadership-centred strategy that strengthens governance, accountability and organisational clarity. Firstly, leadership development initiatives should be introduced, emphasising transformational and Level 5 leadership characteristics such as humility, shared vision and decisiveness to effectively align teams and drive maintenance excellence. Clear definitions and communication of roles and responsibilities must accompany this to eliminate ambiguity and ensure accountability across processes and systems.

The efforts to standardise procedures and policies through structured audit frameworks and continuous improvement approaches will solidify institutional resilience and operational reliability. Although technical and financial defaults were perceived as less dominant, they should not be ignored. Systematic technical audits covering plumbing, electrical and structural components can surface latent faults for prioritised remediation. Enhancing the transparency and effectiveness of budgeting practices will help contextualise financial management within broader facility governance.

By integrating enhanced leadership, clarified governance, technical diligence and financial stewardship within a cohesive, people-focused framework, Universities of

Technology can transition from reactive facility maintenance to strategic, sustainable infrastructure management.

6.3 FACTORS IN POOR FM AT A UOT

The survey findings indicated that organisational and systemic shortcomings, particularly the absence of clear maintenance policies (77% agreement, mean 4.06) and robust maintenance systems (76.7%, mean 4.02), are perceived as primary contributors to poor facilities management in Universities of Technology. Financial factors, including inadequate funding (67.5%) and lack of budgeting priorities (62.2%), also play a significant role. These trends are in line with broader studies in the African higher education context, which report that insufficient financial resources, weak policy frameworks and limited technical capacity undermine the quality of facilities and compromise the learning environment. While issues such as diverse reporting processes and outsourcing limitations are recognised, their lower agreement levels suggest they are of secondary concern.

Universities of Technology should begin by establishing and enforcing comprehensive maintenance policies and systems that clearly define protocols, responsibilities and performance expectations. This would create the structural scaffolding necessary for reliable and proactive facilities management. A parallel effort must involve increasing the allocation of funding for facility upkeep with dedicated budgeting lines that reflect institutional needs. Strengthening technical and human capacity is essential; this can be achieved by recruiting skilled maintenance professionals and introducing ongoing professional development. To bridge gaps, institutions should explore collaborative models such as public-private partnerships or centralised service hubs, enabling access to shared technical expertise and economies of scale. Lastly, standardising and streamlining fault-reporting and feedback systems will improve responsiveness and stakeholder engagement. Embracing these combined policy, financial, technical and procedural interventions will position Universities of Technology to transition from reactive to resilient facilities management, ultimately enhancing infrastructure performance and campus safety.

6.4 ROOT CAUSES OF POOR FM AT A UOT

The data in Table 4.8 indicates that foundational challenges, particularly the poor state of infrastructure (75.8% agreement, mean 3.95) and the absence of maintenance planning (75.7%, mean 4.09), are universally viewed as the most critical root causes of poor facilities management (FM) in Universities of Technology. Closely following are financial instability (73.3%, mean 3.96) and obsolete assets (58.6%, mean 3.67), underscoring the impact of outdated resources and inconsistent funding. Other factors, including lack of staff training (65.7%), intervention delays (70.8%) and policy or regulatory constraints (50%), also presented moderate agreement. These findings resonate with broader research on African higher education FM, which highlights crumbling infrastructure, limited policy frameworks, weak technical capacity and funding shortfalls as core impediments to system effectiveness.

To mitigate these entrenched issues, Universities of Technology should implement a multidimensional strategy. Immediate priority should be given to developing and executing comprehensive maintenance plans that integrate strategic asset audits, lifecycle assessments, and scheduled preventive maintenance. Parallel efforts must address infrastructure renewal, with budget allocation frameworks that secure consistent funding for upgrades and replacement of obsolete assets. Establishing targeted professional development programs is essential to equip FM teams with modern maintenance techniques and planning capabilities, while streamlining decision-making processes to reduce intervention delays and foster accountability. Recognising the constraints of public financing, institutions should pursue public-private partnerships (PPPs) and innovative funding models, as shown effective in improving facility quality across African public universities. Finally, FM governance frameworks should be revised to embed training requirements, policy coherence and regulatory alignment, ensuring that FM practices are sustainable, transparent and adaptive to future infrastructure needs.

This integrated approach, encompassing planning, resources, skill-building and strategic financing will enable Universities of Technology to address the root causes of poor FM and transform their facilities into safe, efficient and sustainable environments that support teaching, learning and broader institutional

6.5 STRATEGIES FOR EFFECTIVE FM AT A UOT

The most effective strategies for achieving sustainable facilities management (FM) in Universities of Technology are predominantly driven by leadership commitment (75.4% agreement, mean 3.84) and the deployment of skilled human resources (69.6%, mean 3.80). These findings align with the global literature, which recognises transformational leadership and HR competencies as cornerstone enablers of sustainable FM in higher education. Supplementary strategies such as FM planning systems, funding mechanisms and budgetary analysis also play significant roles but are seen as secondary, with roughly 55-60% agreement. More specialised tactics, such as gap analysis and scheduled planning, received less buy-in (49%), suggesting lower perceived relevance for FM sustainability in this context.

To strengthen FM sustainability, UoT should first consolidate leadership commitment by empowering senior management teams to adopt systemic, sustainability-focused leadership models that align institutional policies with strategic FM goals. In this regard, investment in skilled human resources is vital: recruitment processes and professional development programmes should prioritise FM competencies, especially in maintenance planning, energy management, and sustainable operations, which have been empirically associated with long-term performance. The institutions should strengthen FM by institutionalising robust planning systems and funding frameworks. These include integrated FM plans, dedicated budget lines, and periodic budgetary analyses to ensure financial transparency and resource accountability. Incorporating gap analysis as a value-enhancement tool is tailored to facilitate targeted performance improvements.

Finally, embedding principles of sustainable FM, such as environmental resource efficiency, waste minimisation and green facility operations, will bolster institutional resilience and social responsibility. Shifting from ad hoc to strategic, leadership-led and people-centred FM practices will advance sustainability across operational, human and environmental domains within UT campuses. This blend of visionary leadership, skilled capacity, systematic planning and green practice forms a coherent, sustainability-

focused FM model that aligns with global best practices and emerging higher education.

6.6 Synthesis of Literature and Empirical Findings

The triangulation of literature, quantitative and qualitative findings provides a holistic understanding of SFM within South African universities of technology. Each strand contributes uniquely: the literature establishes the conceptual foundation, the quantitative analysis validates theoretical relationships statistically and the qualitative narratives ground these insights in the lived institutional context. Literature, Quantitative and Qualitative, provides advanced theory and practice, culminating in the development of a context-specific framework.

Literature Review Synthesis

The literature established sustainable facility management as a multi-dimensional construct embedded in debates around institutional efficiency, organisational resilience and stewardship of resources. Four sustainability dimensions, environmental, social, economic and governance, were identified as central to transforming facility management from reactive maintenance to strategic, long-term resource optimisation. LSS, operationalised through the DMAIC methodology, was highlighted as a rigorous, structured problem-solving tool with proven efficacy in industrial and service contexts. However, its limited application in the University of Technology, particularly in South Africa, revealed a critical gap. Theoretical lenses such as Systems Theory, Continuous Improvement Theory, Sustainable Development Theory, Kotter's Change Framework and the Technology Acceptance Model collectively emphasised the need for adaptive, integrated and evidence-driven facility management models.

Quantitative Findings

The quantitative strand, employing both Partial Least Squares Structural Modelling (PLS-SEM) and multiple regression, provided empirical validation of the literature's propositions. The statistical models confirmed that classes of facility defaults, poor management practices and systemic inefficiencies exert significant negative effects on

sustainability outcomes. LSS interventions and strategic management approaches demonstrated statistically significant positive relationships with sustainable outcomes, underscoring their transformative potential. The robustness of these findings, evidenced by reliability and validity tests, reinforced the credibility of the analysis and substantiated the hypotheses derived from theory.

Qualitative Findings

The qualitative analysis enriched these insights by illustrating how systemic inefficiencies materialise in practice. Respondents highlighted recurrent facility defaults in plumbing, carpentry, electrical and maintenance services. These technical challenges were compounded by weak budgeting, inadequate technical skills, outdated infrastructure and bureaucratic constraints. Participants also emphasised institutional dynamics, weak governance, fragmented accountability and cultural complacency as central barriers. Importantly, they proposed people-centred strategies: leadership commitment, decentralisation of decision-making, digitalised reporting, stakeholder partnerships and shifts in organisational culture. These strategies demonstrated how sustainability principles and LSS interventions intersect in practice, while also highlighting context-specific adaptations necessary for higher education.

Integrated Insights

Synthesising the three strands confirms that sustainable facility management is shaped by both technical interventions and institutional conditions. The literature offered the theoretical rationale, the quantitative results provided statistical evidence of causal relationships and the qualitative narratives contextualised these dynamics in real-world operations.

Institutional and sustainability factors, weak governance, fragmented accountability and limited policy enforcement undermine facility management. Addressing these requires embedding environmental, social, economic and governance dimensions to drive long-term resilience. LSS methodologies, particularly DMAIC, offer a structured, evidence-based approach to process improvement. When combined with strategic interventions such as leadership engagement and stakeholder collaboration, they

significantly enhance sustainability outcomes. While international studies validate LSS in industries and services, its application in South African UoT requires localisation to address unique challenges such as resource constraints, institutional culture and infrastructural legacies.

Theoretical and Practical Contribution

The triangulated findings advance theoretical discourse by situating sustainable facility management at the intersection of institutional theory, continuous improvement and sustainability frameworks. Empirically, the study confirms that institutional inefficiencies significantly hinder sustainability, while LSS-based interventions statistically and practically strengthen resilience. Practically, the findings culminate in the design of a SFM framework that blends process improvement methodologies with institutional leadership, technical capacity and strategic investment. This framework is not only theoretically informed but also empirically validated, offering a scalable and context-specific model for universities of technology.

The convergence of literature, quantitative evidence and qualitative narratives underscores the central finding: achieving sustainability in facility management requires a dual emphasis on evidence-based process improvement and sensitivity to institutional realities. By integrating LSS methodologies with governance, leadership and sustainability dimensions, universities of technology can move beyond reactive facility management toward strategic, resilient and sustainable systems. This synthesis provides the foundation for a validated, context-aware framework that addresses systemic inefficiencies while advancing both academic knowledge and institutional practice in the South African UoT.

6.7 SUSTAINABLE FM FRAMEWORK VIA LSS FOR A UOT

Lean Six Sigma was identified as a significant tool to improve facility management. The DMAIC (Define, Measure, Analyse, Improve, Control) methodology serves as the backbone of Lean Six Sigma and will guide the development of the sustainable FM framework in this research.

Table 6.1: Explanation of DMAIC phases

Phase	Description
Define	This phase identifies the key problems affecting FM in UoT, such as funding instability, unskilled personnel, poor maintenance planning and infrastructural decay. Clear goals and project scopes are established in collaboration with stakeholders to align the framework with institutional priorities.
Measure	Relevant data on current FM performance is collected to quantify the extent of inefficiencies. This includes maintenance response times, budget usage, staff capabilities and infrastructure conditions. Performance indicators are set to benchmark progress and establish a baseline.
Analyse	Root causes of poor FM are identified using tools like cause-and-effect diagrams and Pareto analysis. This phase reveals systemic issues such as outdated equipment, lack of policy enforcement and procedural delays, allowing targeted improvements.
Improve	Sustainable solutions are developed and tested. These may include process standardisation, digital tools for maintenance tracking, upskilling programs and energy-saving initiatives. Lean tools like 5S and Kaizen are applied to streamline operations.
Control	The final phase ensures long-term success by implementing control measures such as monitoring systems, performance dashboards, regular audits and continuous training. This phase helps embed a culture of continuous improvement in FM operations.

This framework offers a structured and evidence-based roadmap for strengthening and sustaining effective facility management (FM) within a University of Technology (UoT). Built around the DMAIC (Define, Measure, Analyse, Improve and Control) methodology, the framework aligns FM improvement initiatives with key institutional enablers, including leadership commitment, funding availability, governance and regulatory structures, and the effective use of technology. It places particular emphasis on achieving strategic objectives related to operational efficiency, environmental, economic and social sustainability, and improved stakeholder satisfaction.

By integrating insights from the root cause and Pareto analyses, the framework ensures that improvement efforts remain focused on the most critical drivers of poor FM performance rather than addressing symptoms in isolation. Its overarching purpose is to support the UoT in moving away from reactive, fragmented FM practices towards a proactive, coordinated and sustainable FM system that supports the core academic mission of the institution.

6.7.1 Define phase

The Define phase established the scope and purpose of the facilities management (FM) improvement initiative within the university of technology. A problem charter was developed to articulate key FM challenges affecting operational performance and sustainability, including rising maintenance costs, deteriorating infrastructure, delayed maintenance responses and inefficient space utilisation. These challenges were aligned with institutional priorities such as student success, cost efficiency, regulatory compliance and sustainability goals. Key stakeholders, including FM staff, management, academic staff, students and contractors, were identified to ensure shared understanding and ownership of the improvement objectives. Clear, measurable goals were set, supported by performance indicators such as maintenance turnaround time, energy consumption and user satisfaction, while potential risks were identified upfront.

6.7.2 Measure phase

The Measure phase focused on establishing a baseline of current FM performance. Data were systematically collected on indicators such as maintenance expenditure, reactive versus planned maintenance, asset condition, space utilisation and energy and water consumption. Standardised data collection methods were applied across campuses to ensure consistency. Quantitative operational data were complemented by feedback from students and staff, providing a comprehensive view of FM performance and forming a benchmark for evaluating improvement initiatives.

6.7.3 Analyse phase

The analysis phase identified the root causes of FM inefficiencies using tools such as Pareto analysis and Fishbone diagrams. The analysis revealed that a small number of issues namely the lack of structured maintenance planning, financial constraints, ageing infrastructure, delayed interventions and limited staff capacity accounted for more than 58 per cent of FM challenges. The Fishbone analysis further illustrated how organisational, financial, technical, and skills-related factors interacted to undermine

FM performance. This phase ensured that proposed interventions targeted underlying causes rather than surface-level symptoms.

6.7.4 Improve phase

The Improve phase translated analytical findings into targeted interventions. These included the introduction of preventive and predictive maintenance programmes, infrastructure modernisation initiatives, improved digital fault-reporting systems and strengthened FM budgeting approaches. Staff development and training were prioritised to support the effective use of new technologies and processes. Selected interventions were piloted in specific facilities to allow refinement before wider implementation, with continuous communication and accountability supporting stakeholder buy-in.

6.7.5 Control phase

The Control phase focused on sustaining improvements and preventing performance regression. Monitoring tools such as performance dashboards and control charts were used to track key FM indicators. Standard operating procedures were documented to ensure consistency in maintenance and asset management practices. Regular performance reviews, audits and ongoing staff training supported continuous compliance and improvement, while stakeholder feedback mechanisms ensured the FM system remained responsive to institutional needs.

Table 6.2: Factors contributing to poor FM

Factors contributing to poor Facility Management in a University of Technology	Mean
FCFM1: Inadequate funding contributes to poor FM in the UT.	3.76
FCFM2: Unstable and unskilled resources contribute to poor FM in the UT.	3.79
FCFM3: Lack of maintenance policies contributes to poor FM in the UT.	4.06
FCFM4: Lack of maintenance systems contributes to poor FM in the UT.	4.02
FCFM5: No budgeting priority contributes to poor FM in the UT.	3.74
FCFM6: Budget assumptions contribute to poor FM in the UT.	3.69
FCFM7: Multiple stakeholders.	3.36
FCFM8: No proportionality between facilities and the managing staff contributes to poor FM in the UT.	3.56
FCFM9: No on-time faults reporting contributes to poor FM in the UT.	3.6
FCFM10: No direct responsibility contributes to poor FM in the UT.	3.77

FCFM11: Diverse reporting processes contribute to poor FM in the UT.	3.45
FCFM12: Superficial investigation contributes to poor FM in the UT.	3.46
FCFM13: An unsuitable system for FM contributes to poor FM in the UT.	3.76
FCFM14: Dependence on the procurement department contributes to poor FM in the UT.	3.55
FCFM15: Lack of property profile contributes to poor FM in the UT.	3.75
FCFM16: Outsourcing system contributes to poor FM in the UT.	3.55

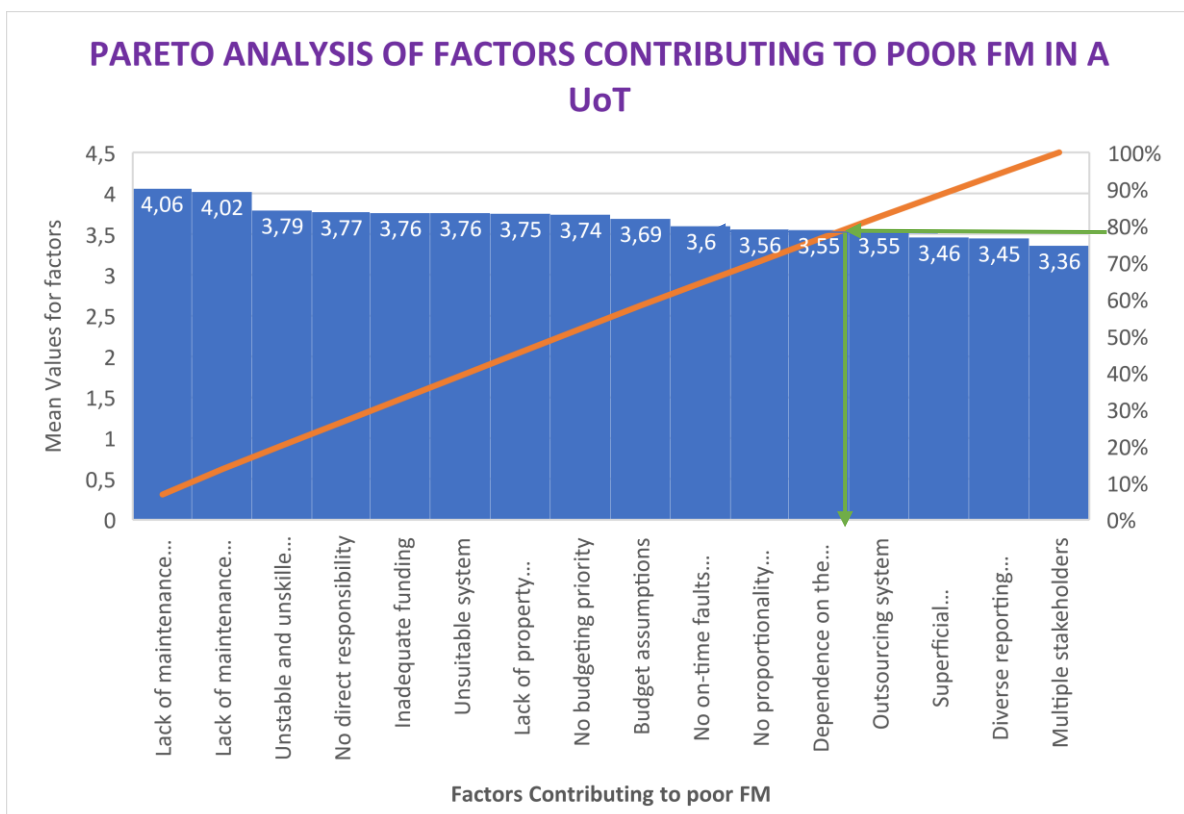


Figure 6.1: Pareto of factors contributing to poor FM in UoT

Measure phase, it is essential to create a baseline for future comparison. This benchmark serves as a reference point for measuring the effectiveness of any improvements implemented in later phases of the DMAIC process. Without a solid understanding of current performance levels, it would be impossible to determine the success or failure of the interventions proposed in the Analyse and Improve phases. Therefore, a thorough and methodical measurement process is key to sustaining the improvements made in facility management.

6.7.3 Analyse Phase

The Analyse phase is dedicated to interrogating the data generated during the Measure phase in order to uncover the root causes of inefficiencies within the FM system. While quantification of current performance establishes the baseline, it is equally critical to determine why persistent issues occur, whether in the form of elevated energy consumption, prolonged maintenance delays, or escalating operational costs. This phase requires the application of systematic analytical tools, such as root cause analysis, Pareto analysis, Ishikawa (fishbone) diagrams and Failure Mode and Effects Analysis (FMEA), which provide structured methodologies for tracing problems to their underlying drivers. For instance, an investigation into disproportionate energy expenditure might reveal contributory factors such as ageing HVAC systems, inadequate insulation, or the absence of energy-efficient lighting technologies.

In addition to diagnosing current inefficiencies, the Analyse phase emphasises the importance of examining historical performance trends to anticipate future risks. By identifying recurring patterns, facility managers are better positioned to forecast emerging challenges and adopt proactive strategies. For example, repeated equipment breakdowns may signal the need for investment in predictive maintenance technologies or the development of a comprehensive asset management programme.

The Analyse phase not only clarifies the structural and operational weaknesses embedded within the FM system but also guides the prioritisation of interventions. By linking observed performance outcomes to their causal mechanisms, managers are able to design targeted, high-impact improvements. Furthermore, this phase establishes the foundation for preventive measures, ensuring that corrective actions extend beyond short-term remedies to support long-term sustainability and resilience in university facility management practices. Table 6.3 and Figure 6.2 present the root causes of poor FM and Pareto analysis, respectively.

Table 6.3: Root Causes of Poor FM in UoT

Root Causes to Poor Facility Management in a Universities of Technology (UoT)	Mean
RCFM1: Poor state of infrastructural facilities is a root cause of poor FM in the UoT.	3,95
RCFM2: Obsolete assets is a root cause to poor FM in the UoT.	3,67
RCFM3: Policy and regulatory constraints are a root cause of poor FM in the UoT.	3,42
RCFM4: Low quality and high price of local products is a root cause to poor FM in the UoT	3,6
RCFM5: High energy costs is a root cause of poor FM in the UT.	3,46
RCFM6: Finance instability is a root cause of poor FM in the UoT.	3,96
RCFM7: No staff training is a root cause of poor FM in the UoT.	3,84
RCFM8: Intervention delays is a root cause of poor FM in the UoT.	3,95
RCFM9: No maintenance plan is a root cause of poor FM in the UoT.	4,09

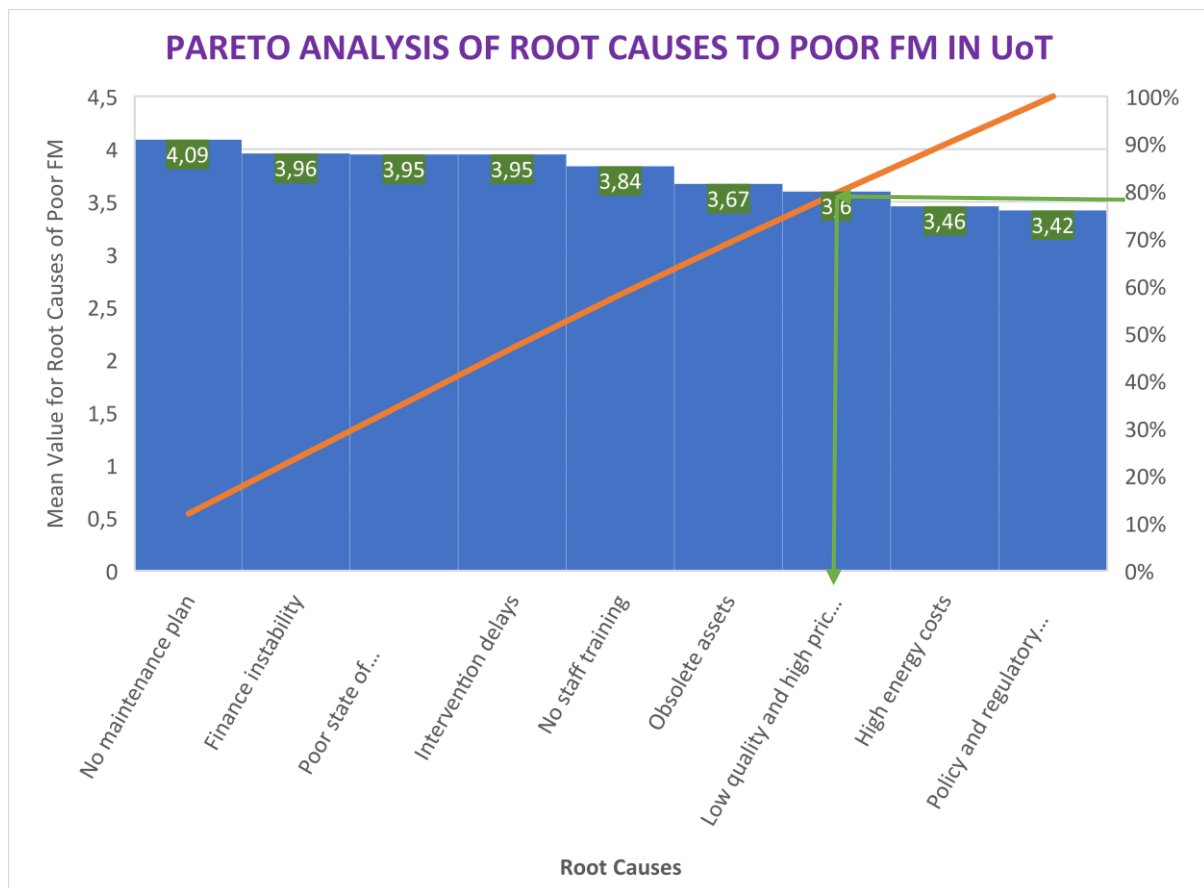


Figure 6.2: Parato Analysis of root causes to poor FM in UoT

The Analyse phase is primarily concerned with identifying the root causes of inefficiencies within the FM system. To achieve this, structured analytical techniques such as Pareto analysis and Ishikawa (fishbone) diagrams are employed to uncover systemic issues and determine the most critical drivers of poor performance.

Findings from the Pareto analysis indicate that a small number of factors, namely inadequate maintenance planning, financial instability, outdated assets, delayed interventions and insufficient staff training, constitute the ‘vital few’ root causes, collectively responsible for approximately 58% of FM-related challenges in Universities of Technology. This reflects the Pareto Principle (80/20 rule), which posits that roughly 80% of outcomes arise from 20% of causes. In quality management and operational decision-making, this principle is widely applied to prioritise interventions by focusing on those factors that exert the greatest influence.

In this context, the vital few represent high-impact inefficiencies whose resolution would yield substantial improvements in FM performance, sustainability and service quality. Conversely, the ‘trivial many’ less frequent or less impactful causes exert a marginal influence and thus do not demand the same level of attention or resource allocation. By concentrating efforts on the vital few, universities can optimise resource deployment and achieve disproportionately positive outcomes. Addressing a small set of recurring maintenance problems that generate most service disruptions can dramatically enhance overall operational efficiency, reliability and user satisfaction. Table 6.4 presents the vital few root causes.

Table 6.4: Pareto Analysis of Poor FM Root Causes in UoT

Root Cause	Mean	Cumulative %	Vital Few
RCFM9: No maintenance plan	4.09	12.05%	Yes
RCFM6: Finance instability	3.96	23.72%	Yes
RCFM1: Poor state of infrastructural facilities	3.95	35.36%	Yes
RCFM8: Intervention delays	3.95	46.99%	Yes
RCFM7: No staff training	3.84	58.31%	Yes
RCFM2: Obsolete assets	3.67	69.13%	No
RCFM4: Low quality & high price of local products	3.60	79.74%	No
RCFM5: High energy costs	3.46	89.93%	No
RCFM3: Policy and regulatory constraints	3.42	100.00%	No

The Pareto analysis underscores the vital few root causes, five (5) dominant factors that together account for more than 58% of the deficiencies in FM, which therefore warrant priority in corrective interventions. These high-impact issues highlight systemic weaknesses in the University of Technology, with analysis showing that a relatively

small number of critical drivers contribute disproportionately to FM underperformance, consistent with the 80/20 principle. Specifically, inadequate planning and policy frameworks, insufficient skills and capacity, unstable operational environments, weak communication structures and resource constraints emerge as the most pressing deficiencies, each associated with comparatively high mean scores. Collectively, these weaknesses undermine the effective governance, maintenance and sustainability of institutional infrastructure.

Addressing these challenges requires a multi-dimensional strategy. First, strengthening planning and policy frameworks is imperative. This involves embedding FM policies into institutional strategic plans, supported by clear guidelines, standard operating procedures and systematic reviews, thereby shifting from reactive to proactive maintenance. Simultaneously, internal capacity must be built through targeted professional development, certifications and mentoring programmes to develop a skilled FM workforce and reduce dependency on external consultants.

Ensuring funding stability represents another crucial dimension. Dedicated FM budgets should be safeguarded, with universities also exploring supplementary mechanisms such as public-private partnerships and grant funding to offset financial shortfalls. Complementing this, improved communication and accountability structures are essential. Establishing transparent communication channels between FM units, university leadership and service users, supported by digital monitoring dashboards and key performance indicators (KPIs), can promote shared accountability and enable evidence-based performance tracking.

In addition, more strategic management of outsourcing is required. While outsourcing certain FM functions can deliver cost efficiencies, it must be governed by robust contracts, explicit SLAs and strict vendor performance monitoring. Retaining core FM capabilities in-house wherever feasible strengthens institutional resilience and preserves organisational knowledge.

Taken together, these interventions strategic planning, workforce development, sustainable funding, enhanced communication and improved outsourcing management provide a framework for addressing the dominant drivers of poor FM. By

focusing on the vital few, universities can significantly enhance operational efficiency, sustainability and service delivery, thereby creating learning environments conducive to student success, staff well-being and institutional resilience.

The Fishbone (Ishikawa) diagram in Figure 6.3, structured around the 5M framework, further categorises root causes. Under Man, issues include insufficient training, unclear responsibilities and complex stakeholder dynamics. Method reflects systemic gaps such as the absence of maintenance policies, superficial investigations, fragmented reporting and regulatory constraints. Material highlights financial instability, inadequate funding, substandard inputs and restrictive policies. Measurement reveals weaknesses in fault reporting, delays in intervention and the absence of a comprehensive property profile. Together, these interrelated factors explain the persistence of ineffective FM, leading to deteriorating infrastructure, inefficient maintenance and suboptimal service outcomes. A holistic approach that integrates these dimensions is therefore essential for advancing effective and sustainable FM practices in UoT.

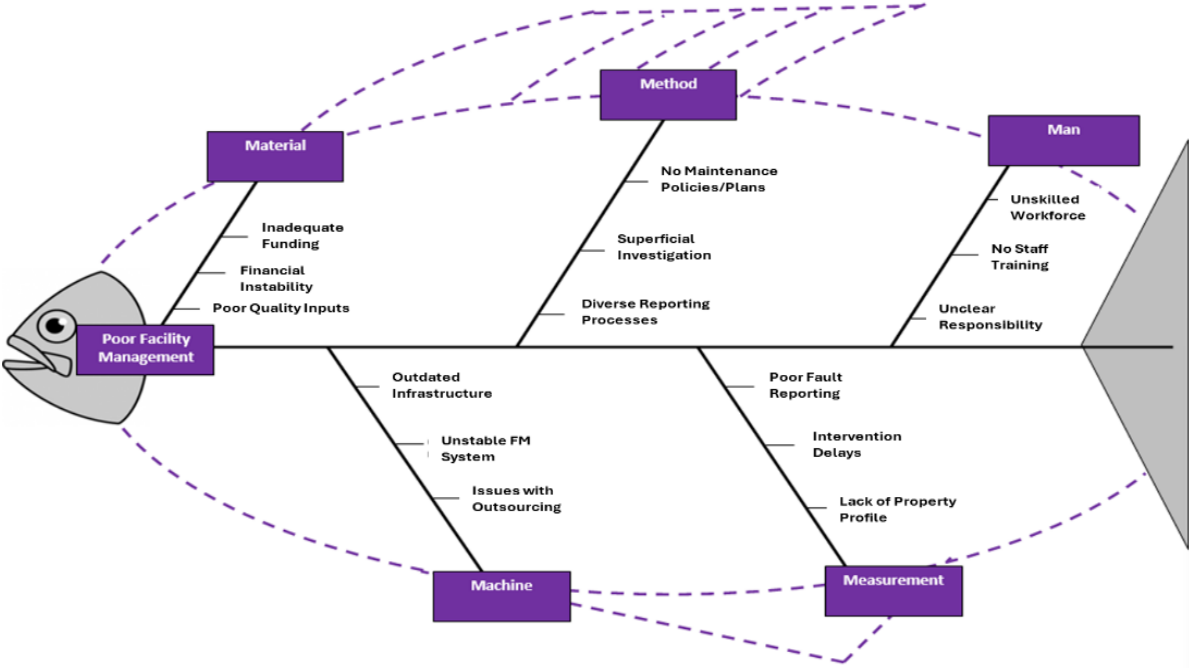


Figure 6.3: Fishbone Analysis of Poor FM

Beyond purely technical deficiencies, the Analyse phase must also interrogate the systemic and process-related factors that contribute to poor FM performance. These may include inadequate staff training, fragmented interdepartmental communication and inefficient resource utilisation. For instance, insufficient coordination between

maintenance and procurement functions can delay the acquisition of essential parts, thereby extending repair times and exacerbating service disruptions. Recognising such organisational inefficiencies enables facility managers to target both technical and structural shortcomings, ensuring a more holistic understanding of performance challenges.

The insights generated during this phase provide the strategic foundation for the Improve phase, offering evidence-based direction on where interventions will be most effective. Whether the priority lies in modernising equipment, enhancing staff competencies, or streamlining internal processes, the analysis ensures that subsequent improvements are data-driven, prioritised and impactful. Furthermore, by linking identified inefficiencies to institutional objectives, the analysis supports forward-looking decision-making, allowing managers to forecast outcomes and align interventions with broader sustainability and operational goals of the university.

6.7.4 *Improve Phase*

The Improve phase represents the stage of the DMAIC cycle where practical interventions are designed and executed to address the root causes of inefficiencies identified during the Analyse phase. Within the context of SFM, this phase marks the transition from diagnostic insights to tangible organisational change aimed at enhancing the efficiency, reliability and overall effectiveness of FM operations. For example, if analysis highlights excessive energy consumption attributable to obsolete HVAC systems, the improvement initiative may involve upgrading to modern, energy-efficient technologies. Similarly, if recurrent maintenance delays are linked to inadequate staff competencies, the intervention may take the form of structured professional development, including training programmes, certifications, or continuous learning initiatives tailored to FM personnel.

A critical feature of this phase is the design and piloting of solutions prior to institution-wide implementation. Piloting provides an opportunity to test interventions on a limited scale, thereby reducing risks associated with large-scale changes and generating empirical evidence of effectiveness. An advanced BMS may be piloted initially within a single facility or department. This allows the university to evaluate its performance,

gather operational data and assess user feedback before committing to broader deployment. Such an approach ensures that technological or procedural innovations deliver the anticipated benefits while allowing for adjustments prior to full-scale adoption.

The Improve phase emphasises evidence-based decision-making, where interventions are continuously monitored and refined based on data generated during the pilot stage. Metrics such as reductions in energy consumption, shorter maintenance response times and improved user satisfaction provide a framework for determining the success of the interventions. By grounding improvements in empirical validation, universities can ensure that solutions are not only effective but also aligned with long-term sustainability and institutional objectives. The phase consolidates the analytical insights gained earlier into actionable strategies, ensuring that universities transition from identifying inefficiencies to implementing sustainable, high-impact solutions that strengthen FM systems and improve service delivery.

Table 6.5: Pareto-based interventions

Priority Area	Root Cause (Code)	Recommendation
1. Maintenance Planning	RCFM9: No maintenance plan	Develop and implement a structured preventive and corrective maintenance strategy.
2. Financial Stability	RCFM6: Finance instability	Secure consistent funding dedicated to facility management operations.
3. Infrastructure Rehabilitation	RCFM1: Poor state of infrastructural facilities	Assess, refurbish and upgrade outdated campus infrastructure.
4. Timely Intervention	RCFM8: Intervention delays	Establish responsive maintenance reporting and resolution systems.
5. Staff Training and Capacity Building	RCFM7: No staff training	Introduce regular training programs for FM personnel to enhance skills.

Table 6.6 prioritises the ‘vital few’ root causes for targeted action to improve facility management performance in Universities of Technology. Below is the strategic intervention on factors contributing to poor FM.

Table 6.6: Strategic intervention on factors contributing to poor FM

1. Lack of clear planning or policy frameworks	Develop comprehensive FM policies and guidelines, integrate FM planning into the university's strategic plan and use data-driven maintenance scheduling and CAFM systems.
2. Insufficient skills and internal capacity	Invest in training and professional development programmes for FM staff, implement mentorship and succession planning and offer competitive employment conditions to attract and retain skilled staff.
3. Unstable funding and resources	Secure dedicated budgets for FM activities, explore alternative funding models, Prioritise funding for preventive maintenance.
4. Poor communication and accountability	Establish clear lines of communication among FM teams, leadership and users, develop and monitor KPIs and performance dashboards. create transparent reporting and feedback mechanisms.
5. Ineffective outsourcing and contractor management	Develop robust contracts with well-defined service level agreements (SLAs), monitor outsourced vendors' performance regularly and retain critical FM functions in-house where feasible to build internal capacity.
6. General operational inefficiencies	Implement a continuous improvement framework (Lean FM or TQM), conduct regular audits and reviews of FM practices and foster a culture of user awareness and shared responsibility.

Beyond technological advancements and process optimisation, the Improve phase may also necessitate structural adjustments within the FM team and the adoption of innovative maintenance strategies. Shifting from a predominantly reactive maintenance approach towards a preventive or predictive maintenance model can markedly enhance the reliability, longevity and overall performance of university facilities. The integration of a computer-aided facility management (CAFM) system to monitor maintenance schedules, asset conditions and performance indicators offers opportunities to streamline workflows, optimise resource allocation and improve operational efficiency.

The success of improvement initiatives depends on effective stakeholder communication and engagement. Facility managers must secure strong institutional support from senior leadership while simultaneously fostering staff and departmental commitment. Transparent communication regarding the objectives of the initiatives, the anticipated benefits and the responsibilities of individual team members is critical in promoting ownership and collaboration. By implementing solutions that not only

address identified root causes but are also explicitly aligned with the institution's sustainability objectives, universities can ensure that FM practices are both resilient and future-oriented. Such a holistic approach integrating technological, organisational and human dimensions provides the foundation for sustainable improvements, enabling universities to maintain efficient, effective and strategically aligned FM systems over the long term.

6.7.5 Control Phase

The Control phase serves as the critical safeguard in the DMAIC cycle, ensuring that the improvements introduced during the Improve phase are sustained, standardised and continuously optimised over time. The central aim of this phase is to maintain the performance levels achieved, prevent regression to former inefficiencies and institutionalise best practices. To achieve this, facility managers must embed robust control mechanisms such as routine performance audits, automated monitoring systems and scheduled reviews. Where energy-efficient lighting has been installed, continuous monitoring of energy consumption is required to confirm that anticipated savings are consistently realised. The use of control charts, digital dashboards and structured reporting processes further supports transparent and real-time tracking of FM performance, reinforcing accountability across all operational levels.

Equally significant is the standardisation of improvement practices to ensure consistent application across all facilities. This involves the development of Standard Operating Procedures (SOPs) for newly introduced technologies, processes and maintenance strategies. Such documentation not only guarantees uniform implementation but also mitigates risks associated with staff turnover, ensuring that institutional knowledge and operational continuity are preserved. If a preventive maintenance programme is implemented, detailed checklists and process maps must be established to ensure adherence by all FM personnel.

Sustainability of improvements also relies heavily on continuous staff development. With the evolution of FM technologies and the introduction of IoT-enabled monitoring systems, building automation technologies, or advanced energy management platforms, staff must be equipped with the requisite skills to operate and adapt to these

innovations. Ongoing professional training, certification programmes and exposure to emerging best practices are therefore vital to maintaining institutional agility and ensuring that FM teams remain aligned with both operational and sustainability objectives.

Another cornerstone of the Control phase is the incorporation of feedback mechanisms. Regular surveys, focus groups and feedback sessions with students, faculty and staff provide valuable insights into user experiences and help identify emerging challenges. This feedback loop ensures that FM remains responsive to changing needs and that continuous refinement of processes is embedded within the institutional culture. Improvements are not treated as isolated interventions but rather as enduring, evolving practices that are firmly integrated into the FM system.

Applied to the context of the UoT, the Control phase consolidates the outcomes of the preceding phases of DMAIC, ensuring that strategic, evidence-based solutions are sustained. The integration of institutional factors, governance structures, resource allocation practices and policy framework with sustainability dimensions, including energy conservation, water efficiency and waste reduction, creates a holistic basis for long-term success. Historical complaint data, maintenance logs and observational insights serve as key reference points, enabling universities to track progress against established Key Performance Indicators (KPIs) and adjust strategies where necessary.

The LSS framework, as operationalised through DMAIC, culminates in the development of a sustainable FM model for UoT. The process begins with a well-defined project charter in the Define phase, ensuring clarity of scope, stakeholder engagement and alignment with sustainability goals. The Measure phase establishes baselines through the collection and visualisation of performance data covering energy, water, waste and maintenance. The Analyse phase applies diagnostic tools such as Pareto charts, fishbone diagrams and SWOT analyses to identify systemic inefficiencies and benchmark performance against international best practices like LEED and ISO 14001. The Improve phase implements targeted strategies, including LED retrofits, smart HVAC systems, renewable energy adoption and green maintenance practices, often tested through pilot projects and Kaizen initiatives.

The Control phase then institutionalises these interventions through monitoring systems, SOPs, continuous audits and ongoing training, ensuring that improvements are durable, measurable and adaptable. By embedding visual management boards and IoT-enabled dashboards, stakeholders remain actively engaged, reinforcing transparency and accountability.

The Control phase guarantees that FM improvements in UoT are not transient fixes but integrated, sustainable solutions. It institutionalises Lean Six Sigma practices within the governance of FM, ensuring that both institutional priorities and sustainability imperatives are continuously advanced. This systematic approach provides UoT with a resilient framework to enhance operational efficiency, strengthen environmental stewardship and support student and staff well-being over the long term.

Drawing on interviews, literature and survey findings, it's clear that institutional factors, when interwoven with sustainability principles, play a vital role in tackling the root causes of poor facilities management.

The LSS-based facility management framework offers a structured approach to addressing sustainability challenges in universities of technology. Using the DMAIC cycle, Define, Measure, Analyse, Improve and Control, it identifies stakeholders, sets sustainability goals and aligns them with institutional priorities such as energy efficiency, waste reduction and resource optimisation.

The framework integrates historical data and system observations to establish baselines for processes like HVAC, lighting and water usage, quantifying metrics such as energy intensity, downtime and cost savings. By incorporating institutional factors (leadership, digital readiness, cultural adaptability) and sustainability dimensions (economic, environmental, social), it ensures that solutions are evidence-based, context-specific and strategically aligned with university goals. This iterative and data-driven model not only enhances operational efficiency but also supports cultural transformation within the university, fostering a sustainability-oriented mindset among staff and students. The LSS-based facility management framework positions Universities of Technology to achieve resilient, efficient and socially responsible campus operations and is demonstrated as follows.

Historical complaint records, past performance data and direct observations also provide valuable evidence to support the Lean Six Sigma DMAIC approach. These elements inform the development of a sustainable facilities management framework as illustrated in Figure 6.4, which is practical, adaptable and genuinely capable of delivering lasting improvements in the University of Technology setting.

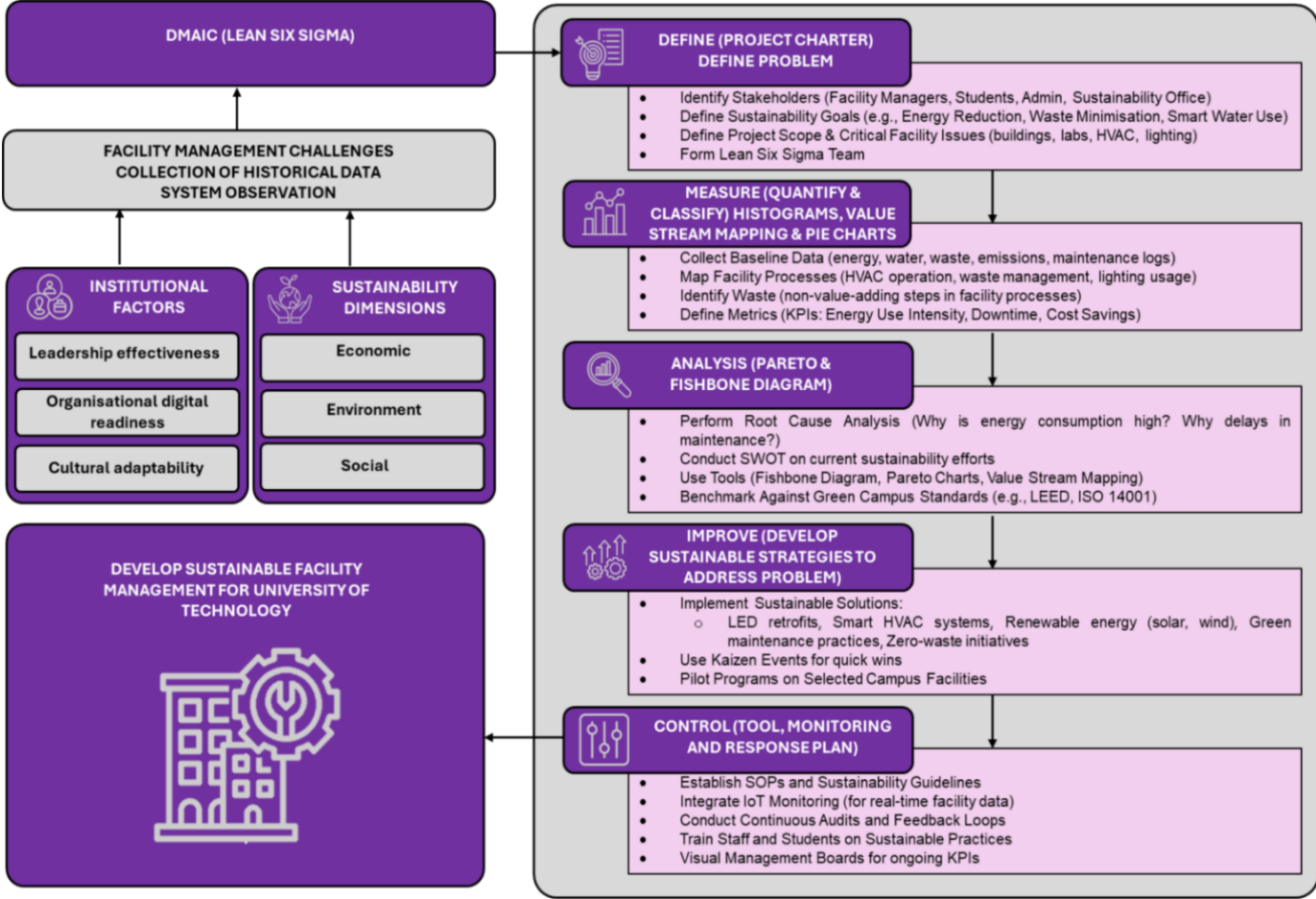


Figure 6.4: LSS-Based Sustainable FM Framework for UoT (Author, 2025)

SFM Framework using Lean Six Sigma tailored to Universities of Technology involves integrating sustainability principles with process efficiency tools. The goal is to optimise facility operations, reduce waste, save energy and improve the overall performance of the university infrastructure. This framework demonstrates how DMAIC can transform FM practices in a University of Technology by focusing on data-driven decision-making, root cause resolution and continuous improvement. By systematically applying these phases, the institution will build a resilient, efficient and sustainable FM system

that contributes directly to its academic mission and the well-being of its campus community.

SFM Framework using LSS tailored to Universities of Technology involves integrating sustainability principles with process efficiency tools. The goal is to optimise facility operations, reduce waste, save energy and improve the overall performance of the university infrastructure. While Lean Six Sigma (LSS) has been widely implemented in corporate, healthcare and manufacturing contexts, the application of LSS in the higher education sector, specifically within the University of Technology, presents unique challenges and structural distinctions. The LSS-based Facility Management (FM) framework developed for UoT differs significantly from those in other sectors in terms of stakeholder complexity, funding mechanisms, institutional mission and governance structures, all of which shape the design and implementation of the DMAIC process.

In corporate environments, LSS FM frameworks are typically focused on cost minimisation, space optimisation and shareholder value. The goals are clear and quantifiable, driven by financial performance, efficiency gains and asset utilisation. There is often strong centralised leadership, private capital and more agile procurement processes. In contrast, the university setting requires alignment with academic missions, government policy mandates and public accountability. The FM strategy must balance cost-efficiency with student satisfaction, staff wellbeing and educational outcomes. Facility usage in universities is more variable and multidisciplinary, encompassing lecture halls, laboratories, residences, libraries and community facilities, each with unique functional demands that complicate standardisation.

In hospital environments, LSS frameworks often focus on patient safety, infection control and rapid service delivery. These are highly regulated and time-sensitive environments where failure in FM can have life-or-death consequences. Hospitals typically have clinical engineers, infection control teams and facilities specialists working under stringent statutory requirements. Although UoT also manage health and safety, their FM concerns are broader and more strategic. The emphasis is on long-term infrastructure planning, sustainability and enhancing the learning environment. The decision-making cycles in higher education are slower and more participatory,

involving committees, senates and regulatory oversight, which require inclusive stakeholder engagement models, unlike the more directive models used in healthcare.

In the manufacturing sector, LSS is deeply embedded in operational and production systems, often involving Total Productive Maintenance (TPM), Just-in-Time (JIT) and continuous flow processes. FM in this context is aimed at maximising machine uptime, reducing production interruptions and meeting delivery deadlines. Manufacturing FM is closely tied to output metrics and directly affects revenue generation. By contrast, in the UoT environment, the FM system must navigate complex funding models (often dependent on public funding), uncertain maintenance budgets and constraints posed by procurement regulations. As demonstrated by survey data in this study, factors like unstable funding, regulatory constraints and a lack of skilled FM personnel significantly hinder the successful implementation of FM systems in South African UoT.

One of the major differentiators of the proposed UoT-specific LSS FM framework is its integration of institutional factors with sustainability principles across environmental, social and economic dimensions. Unlike many private or clinical settings where sustainability may be a compliance requirement or marketing strategy, in universities, sustainability is increasingly central to their core mission-impacting curriculum, student engagement and institutional reputation. The proposed framework not only uses the DMAIC methodology to address root causes (no maintenance plan, finance instability and intervention delays) but also aligns FM improvements with broader university strategic plans and public sector governance frameworks like the National Development Plan (NDP) and Department of Higher Education and Training (DHET) objectives.

Furthermore, unlike private or healthcare sectors that can rapidly adopt advanced technologies, UoT often struggle with legacy systems and capacity limitations, which require a phased and context-sensitive implementation of tools like CAFM, BMS and predictive maintenance systems. The framework accounts for these institutional constraints by recommending gradual scaling through pilot projects, stakeholder buy-in and consistent capacity building, thereby grounding technical interventions in organisational change management principles.

LSS provides a common methodological backbone through DMAIC. This UoT-specific FM framework stands apart due to its responsiveness to the unique dynamics of public higher education. It incorporates stakeholder-inclusive governance, long-term sustainability integration and adaptive capacity development, ensuring that process efficiency is achieved without undermining the educational and developmental mission of the university.

Original Contribution of Sustainable FM Framework

The Sustainable Facility Management (FM) framework developed in this study represents an original contribution to knowledge by integrating Lean Six Sigma (LSS), sustainability principles, and institution-specific facility management challenges into a single empirically validated model tailored to the context of a South African university of technology. Unlike existing FM or continuous improvement models, which are often generic, sector-neutral or industrially oriented, this framework is context-sensitive, evidence-based, and grounded in both quantitative and qualitative data. The framework's originality lies in its integrated structure. Traditional FM models and standards, such as ISO-based FM systems, primarily focus on operational processes and compliance, while Lean and Six Sigma models emphasise efficiency and defect reduction, often within manufacturing environments. In contrast, the proposed framework uniquely integrates facility defaults, root causes, management strategies and Lean Six Sigma practices as simultaneous determinants of sustainable FM performance. This integration moves beyond linear or siloed approaches and reflects the systemic nature of FM challenges in public higher education institutions. The framework's originality is reinforced by its empirical validation. Whereas many existing FM frameworks are conceptual or prescriptive, the proposed model is statistically validated using Partial Least Squares Structural Equation Modelling (PLS-SEM). The model quantifies the strength and direction of relationships between framework components and demonstrates their combined explanatory power. This empirical grounding distinguishes the framework from normative models that lack quantitative testing. The framework contributes original insight by contextualising Lean Six Sigma within university facility management. Existing Lean Six Sigma models typically assume mature process environments and decentralised decision-making structures. The proposed framework adapts LSS principles to the realities of a public university of

technology, characterised by ageing infrastructure, regulatory constraints, skills shortages and centralised governance. This contextual adaptation extends Lean Six Sigma theory into a previously underexplored application domain. The framework introduces a dual sustainability performance orientation, linking operational efficiency improvements directly to sustainability outcomes such as asset longevity, cost optimisation, energy efficiency and service reliability. Existing sustainability models in FM often focus on environmental metrics in isolation. The proposed framework explicitly connects sustainability to continuous improvement and operational decision-making, offering a more holistic and actionable approach. The original contribution of this framework lies in its integrated, empirically validated, context-specific and sustainability-driven design, which distinguishes it from existing FM, Lean, Six Sigma and sustainability models. The framework provides both theoretical advancement and practical guidance for improving facility management performance in higher education institutions, particularly within resource-constrained public-sector environments.

6.8 STATISTICAL VALIDATION OF SUSTAINABLE FM USING LSS

The validation of the Lean Six Sigma (LSS) Framework for Sustainable Facility Management in a South African University of Technology confirms its reliability, relevance and practical applicability. The study achieved a high valid response rate of 98.1%, with inputs provided by a highly educated and experienced respondent group, thereby strengthening the credibility of the findings. Statistical analysis demonstrated satisfactory levels of reliability, convergent validity and discriminant validity across all constructs, confirming the robustness of the measurement model.

Descriptive results indicated that respondents rated the framework positively, particularly in terms of Practicality and Implementation ($M = 3.96$) and Relevance and Comprehensiveness ($M = 3.79$). These scores highlight that the framework is both theoretically sound and practically implementable. However, relatively lower ratings for Environmental Sustainability ($M = 3.21$) and Organisational Digital Readiness ($M = 3.37$) suggest the need for greater strategic emphasis on these dimensions.

Structural Equation Modelling further established the critical determinants of the framework's success. Social Sustainability emerged as the strongest predictor of

implementation practicality ($\beta = 0.372$, $p = 0.000$), followed by Organisational Digital Readiness ($\beta = 0.323$, $p = 0.000$) and Economic Sustainability ($\beta = 0.239$, $p = 0.032$). These findings confirm that people-centred strategies, technological readiness and economic considerations are central to the successful adoption of the framework. Similarly, both Organisational Digital Readiness ($\beta = 0.334$, $p = 0.000$) and Social Sustainability ($\beta = 0.254$, $p = 0.045$) significantly enhanced perceptions of the framework's relevance and comprehensiveness.

Assessment of the Structural Model

The path coefficients, t-values, p-values and the coefficient of determination (R-squared), were analysed to evaluate the structural model as presented in Table 6.6 and subsequent Figure 6.5.

Table 6.7: Structural Equation Modelling Results

	Original Sample (O)	T statistics (O/STDEV)	P values
Cultural Adaptability -> Practicality and Implementation	-0.043	0.280	0.780
Cultural Adaptability-> Relevance and Comprehensiveness of the Framework	0.082	0.620	0.535
Economic Sustainability -> Practicality and Implementation	0.239	2.149	0.032
Economic Sustainability> Relevance and Comprehensiveness of the Framework	-0.046	0.393	0.695
Environmental Sustainability-> Practicality and Implementation	-0.315	2.440	0.015
Environmental Sustainability -> Relevance and Comprehensiveness of the Framework	-0.166	1.297	0.195
Leadership Effectiveness-> Practicality and Implementation	-0.057	0.502	0.616
Leadership Effectiveness -> Relevance and Comprehensiveness of the Framework	-0.037	0.296	0.767
Organisational Digital Readiness -> Practicality and Implementation	0.323	3.497	0.000
Organisational Digital Readiness -> Relevance and Comprehensiveness of the Framework	0.334	3.621	0.000
Social Sustainability -> Practicality and Implementation	0.372	3.880	0.000

Social Sustainability -> Relevance and Comprehensiveness of the Framework	0.254	2.003	0.045
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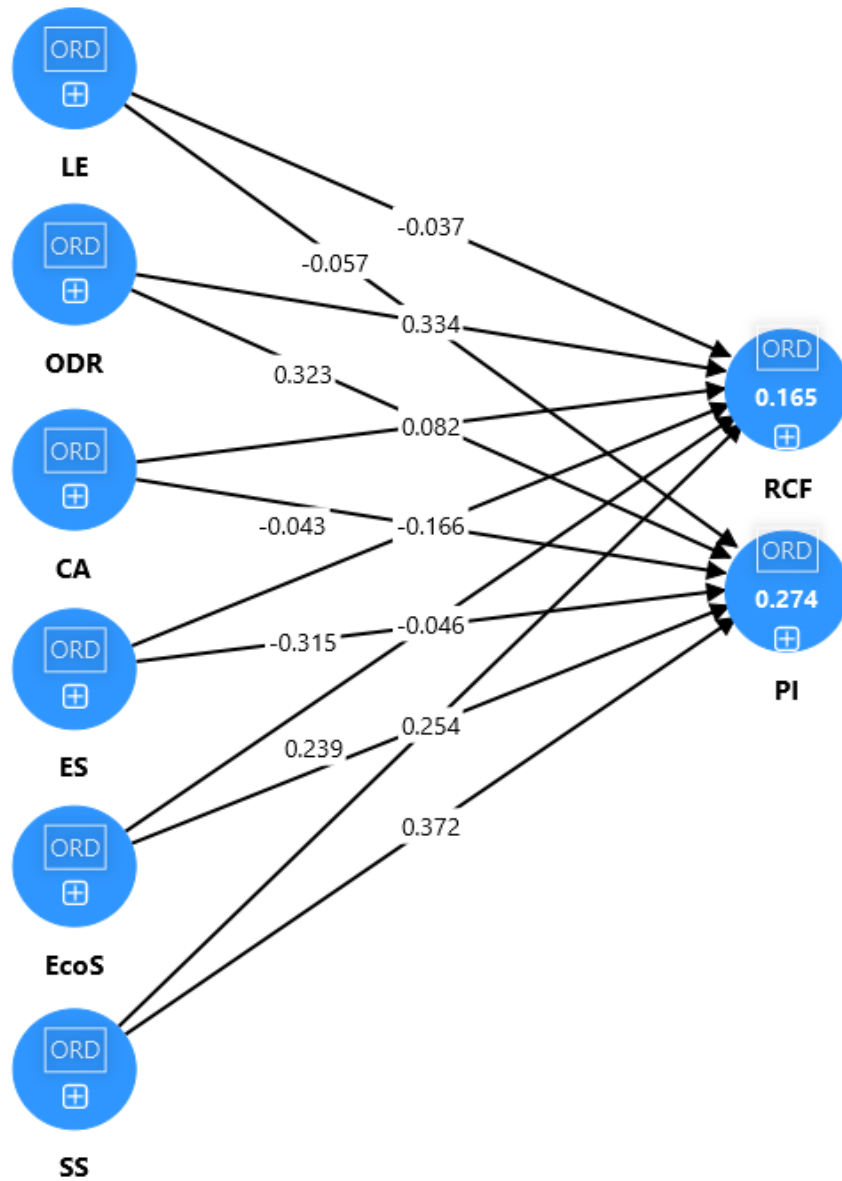


Figure 6.5: The Structural Model

The analysis aims to understand the structural relationships between several independent factors (Cultural Adaptability, Economic Sustainability, Environmental Sustainability, Leadership Effectiveness, Organisational Digital Readiness and Social Sustainability) and two dependent outcomes: Practicality and Implementation and the Relevance and Comprehensiveness of the Framework.

6.9 CHAPTER SUMMARY

The study revealed five key themes concerning facility management in the South African University of Technology.

Theme 1 identifies common facility defaults of plumbing, painting, carpentry, electrical and general maintenance. These issues are classified based on urgency, scale and type and are reported through forms and inspections. Ageing infrastructure and lack of consistent maintenance practices were recurring concerns.

Theme 2 outlines factors contributing to poor facility management, including inadequate budgets, lack of planning, poor leadership, centralised decision-making and weak communication. Respondents also cited delays in procurement and the absence of qualified personnel as major barriers.

Theme 3 explores the root causes, such as weak leadership, rigid structures, lack of trust, poor accountability and a culture of complacency. Bureaucratic inefficiencies and mismanagement of funds were noted as deep-seated institutional challenges.

Theme 4 presents strategies for improvement, including digital maintenance systems, decentralisation, regular inspections, skills development and better planning. Participants stressed the importance of accountability, stakeholder engagement and proactive practices.

Theme 5 focuses on creating a sustainable facility management scheme, recommending tailored frameworks, long-term plans, public-private partnerships and the use of modern technologies. Collaboration, investment and adaptability were seen as critical for lasting impact. The themes point to the need for strategic reform and sustainable practices in managing university facilities.

The structural model assessment reveals that all hypothesised relationships are statistically supported. The findings show a significant negative relationship between classes of facility defaults and the sustainable facility management scheme, indicating

that a higher incidence of facility defaults undermines sustainability efforts. Similarly, factors contributing to poor facility management and the root causes of inefficiency also show a negative influence on sustainable facility management, confirming that these elements critically hinder effective implementation.

The application of Lean and Six Sigma techniques, along with the adoption of appropriate facility management strategies, demonstrates a positive and significant impact on the sustainable facility management scheme. These results validate the effectiveness of process improvement tools and strategic interventions in enhancing the long-term sustainability of facility operations within the University of Technology. The model confirms that addressing root causes and systemic inefficiencies, while implementing continuous improvement methodologies and targeted strategies, significantly supports the development of a sustainable facility management framework. The developed sustainable facility management framework using Lean Six Sigma techniques at a selected university of technology in South Africa was validated using statistical analysis.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 CHAPTER OVERVIEW

This chapter presents the key conclusions derived from the study's findings and outlines the research methods employed to achieve the stated aim and objectives. It also demonstrates, through supporting evidence, that all research objectives have been successfully met. Furthermore, it identifies potential areas for future research to be pursued based on the study's outcomes.

7.2 CONCLUSION

Based on the findings of the quantitative and qualitative research approaches drive the following conclusion.

This study set out to develop a sustainable facility management framework for the University of Technology through the integration of Lean Six Sigma techniques and the analysis of both quantitative and qualitative data. The research addressed core challenges in facility management and systematically examined the contributing factors, root causes and strategic interventions required to improve facility performance within the higher education sector in South Africa.

The quantitative findings, drawn from structural equation modelling, confirmed that facility defaults, poor management factors and underlying root causes exert a statistically significant negative impact on sustainable facility management. These results highlight the detrimental effects of ageing infrastructure, delayed maintenance responses, inadequate budgeting and systemic inefficiencies. The adoption of Lean and Six Sigma methodologies and strategic maintenance practices showed a strong and positive influence on the sustainability of facility operations. These statistical outcomes underscore the critical importance of structured, data-driven interventions in transforming facility management practices.

The qualitative component of the study, framed using the DMAIC (Define, Measure, Analyse, Improve, Control) structure, offered valuable insights into institutional dynamics, operational bottlenecks and stakeholder perceptions. Participants outlined a range of practical challenges, including centralised authority, lack of accountability, insufficient skills and poor maintenance planning. Through this analysis, a roadmap of strategies was developed to address each phase of the facility management life cycle. These strategies reinforced the need for institutional reform, proactive maintenance systems, staff capacity-building, digital transformation and sustainable practices.

The integration of the two data streams, statistical validation and stakeholder narrative, resulted in a robust, evidence-based framework for sustainable facility management. The merged analysis confirmed that a holistic approach that addresses both technical and human elements is essential for operational improvement. Together, the findings offer a grounded, scalable and adaptable model for managing university facilities efficiently and sustainably.

A summary of the methods which were used and the contribution to the body of knowledge to accomplish the research objectives of the study is depicted in Table 7.1.

Table 0.1: Conclusion of study objectives.

Objective	Applied Methodology	Contribution to the body of knowledge	Status of the objective
To assess various classes of facility defaults present at a University of Technology.	A questionnaire and interview guide were used to identify various classes of FM default at UoF	This study identifies and classifies facility defaults at a University of Technology, filling a research gap. It links these defaults to operational challenges. The insights support better maintenance planning in higher education.	Achieved
To assess factors contributing to poor management of facilities within a University of Technology.	A questionnaire and interview guide, Pareto analysis and Fishbone, Multiple Regression	This study reveals factors behind poor facility management at a University of Technology. It shows how gaps in systems and policies impact performance. The findings guide better FM practices in higher education.	Achieved
To ascertain the root causes of poor management of facility within the University of Technology	Respondents from the quantitative analysis and interview participants. Application of Pareto Analysis	This study uncovers the root causes of poor facility management at a University of Technology. It shows how deep systemic issues affect performance. The findings inform better FM policies and practices.	Achieved
To establish suitable strategies and practices to effectively maintain facilities at the University of Technology.	The quantitative analysis and semi-structured interview	This study develops strategies to improve facility maintenance at a University of Technology. It aligns practices with real institutional needs. The insights support more effective and sustainable FM	Achieved
To develop a sustainable Facility Management framework using Lean Six Sigma technique for a University of Technology.	Research findings from quantitative analysis, qualitative insights and the literature review were integrated to develop a sustainable facility management framework using LSS for UoT. SEM and Multiple Regression analysis	This study develops a sustainable Facility Management framework using Lean Six Sigma tailored for a University of Technology. It integrates process improvement with sustainability goals in a higher education context. The framework advances FM theory and practice by demonstrating how Lean Six Sigma can drive efficiency and long-term value.	Achieved

7.3 RECOMMENDATIONS

Based on the study's findings, the following actions are proposed to strengthen facility management at Tshwane University of Technology:

Recommendation to University Executive Management and Council

University executive management and Council should adopt Lean Six Sigma (LSS) using the DMAIC methodology as the institution's standard facility management improvement framework. This framework should be formally embedded within FM policy and governance structures to enable systematic diagnosis of inefficiencies, root-cause analysis of maintenance failures, and the implementation of structured, data-driven maintenance and service improvement interventions across all campuses.

Recommendation to the Facilities Management Directorate

The Facilities Management Directorate should transition from predominantly reactive maintenance practices to a proactive maintenance strategy by implementing integrated Preventive and Predictive Maintenance systems. This should be supported through the full utilisation of Computerised Maintenance Management Systems (CMMS), scheduled condition audits, and sensor-based monitoring technologies to reduce unplanned downtime, extend asset life cycles and improve maintenance planning accuracy.

Recommendation to University Executive Management and Campus Management

University executive management, in collaboration with campus management, should decentralise selected FM operational responsibilities and maintenance budgets to campus level. This decentralisation should be guided by clear accountability frameworks to enhance responsiveness to local facility needs, accelerate decision-making and improve service delivery outcomes while maintaining institutional oversight.

Recommendation to the Human Resources Department and Facilities Management Directorate

The Human Resources Department, together with the Facilities Management Directorate, should prioritise capacity building within FM units by investing in targeted technical training, continuous professional development programmes and the recruitment of suitably qualified engineers, artisans and maintenance specialists. This will strengthen technical competence, support effective implementation of Lean Six Sigma initiatives and address long-standing skills shortages within FM operations.

Recommendation to Facilities Management Directorate and Sustainability Office

The Facilities Management Directorate, in partnership with the university's Sustainability or Environmental Management Office, should formally embed sustainability objectives into FM operations. This includes setting measurable targets for energy efficiency, water conservation, cost optimisation and long-term asset performance, monitored through clearly defined Key Performance Indicators (KPIs) aligned with institutional sustainability strategies.

Recommendation to Facilities Management Directorate and Student Affairs

The Facilities Management Directorate, in collaboration with Student Affairs and organised labour structures, should establish structured stakeholder engagement platforms, such as regular Facility Imbizos, involving students, artisans, academic staff and support personnel. These forums should be used to gather feedback, communicate FM performance, co-create solutions and enhance transparency and accountability in facility-related decision-making.

7.3.1 Interpretation of Findings

This section interprets the study's findings by integrating the proposed Sustainable Facility Management (FM) framework components with quantitative evidence from the structural equation modelling (SEM) analysis and qualitative insights obtained from interviews. The interpretation provides a holistic understanding of how the identified

factors interact to influence FM performance at Tshwane University of Technology (TUT). The quantitative findings demonstrated that all five framework components Classes of Facility Defaults, Factors Contributing to Poor Facility Management, Root Causes of Poor Facility Management, Strategies Used in Facility Management, and Lean Six Sigma were statistically significantly associated with the Sustainable Facility Management Scheme. Negative path coefficients for facility defaults, contributing factors, and root causes indicate that ageing infrastructure, inadequate maintenance planning, skills shortages, and procurement delays systematically undermine FM effectiveness. These results were strongly corroborated by qualitative insights, where participants consistently reported recurring breakdowns, deferred maintenance, fragmented accountability, and slow response times as persistent operational challenges.

The positive relationships observed for FM strategies and Lean Six Sigma highlight the enabling role of structured management approaches. Quantitative results showed that proactive strategies and Lean Six Sigma practices significantly enhance the effectiveness of sustainable FM. Qualitative findings reinforced this by emphasising the perceived value of standardised processes, preventive maintenance planning, data-driven decision-making, and continuous improvement principles. Participants indicated that where structured procedures and monitoring tools were applied, service reliability and stakeholder satisfaction improved. An important insight from the findings is the model's relatively moderate explanatory power ($R^2 \approx 35\%$). While this represents a large effect size in social science research, it suggests that FM performance is influenced by additional contextual factors not explicitly captured in the framework. Qualitative data indicated that external budget constraints, institutional bureaucracy, legacy infrastructure design, and national procurement regulations were influential variables. This highlights the complex and systemic nature of FM challenges within public higher education institutions. Some contradictions and unexpected results were also observed. Although Lean Six Sigma had a statistically significant positive effect, qualitative evidence revealed uneven awareness and application of Lean Six Sigma principles across campuses. In some cases, respondents viewed Lean Six Sigma as a technical or industrial methodology rather than a practical FM improvement tool, suggesting partial implementation rather than full institutional adoption. This divergence indicates that while Lean Six Sigma is effective in principle, its impact

depends on organisational readiness, leadership commitment, and staff capability. The study is subject to certain limitations that should be considered when interpreting the findings. The quantitative data were cross-sectional, limiting the ability to infer causality over time. The sample was also confined to a single university of technology, which may limit the generalisability of the results to other higher education contexts. In addition, some qualitative responses reflected perceptions rather than objectively measured performance outcomes, which may introduce response bias. The integrated interpretation of quantitative and qualitative findings confirms the validity of the proposed Sustainable FM framework while recognising institutional, contextual, and implementation-related constraints. These insights provide a strong empirical foundation for the recommendations presented in the next section.

7.4 MANAGERIAL IMPLICATIONS

This study highlights ways for facility managers, administrators and policymakers to embed sustainable Facility Management (FM) in South African Universities of Technology by addressing inefficiencies and promoting resilience, performance and national alignment.

Policy Development

A national FM policy should address legacy infrastructure, reactive maintenance and weak accountability. It must include lifecycle asset management, compliance, regular audits, sustainability reporting and integration into institutional planning.

Funding Alignment

To overcome underfunding and poor spending, funding models should use performance-based allocations, rewarding preventive maintenance, Lean Six Sigma and sustainability initiatives. Dedicated grants for green retrofits and smart technologies can drive long-term efficiency.

Workforce Capacity

Sustainable FM depends on skilled staff. A workforce plan should build technical, managerial and digital FM skills through training, certification and SETA partnerships, with incentives to attract and retain talent in under-resourced institutions.

Collaboration and Accountability

FM success requires collaboration across units and leadership. USAf and DHET should facilitate benchmarking, knowledge-sharing and best practice platforms. Standardised KPIs and transparent reporting will promote accountability.

Sustainability Principle

FM must embed green standards, energy efficiency and climate resilience in policy and practice. Facility managers need tools and training to implement measures that advance the Sustainable Development Goals (SDGs).

7.5 FUTURE RESEARCH STUDIES

The research study opens several avenues for further investigation. Future researchers are encouraged to consider the following,

- Evaluate the long-term effects of implementing Lean Six Sigma-based facility management frameworks on operational efficiency, infrastructure sustainability and user satisfaction.
- Investigate differences in facility management practices across multiple universities, identifying success factors and challenges specific to diverse institutional contexts.
- Examine the effectiveness of smart infrastructure technologies such as IoT-enabled monitoring, AI-based fault prediction and digital twin models in improving facility reliability.

- Conduct cost-benefit and return-on-investment (ROI) analyses to quantify the financial value of implementing Lean Six Sigma interventions in the university maintenance environment.

7.6 CONTRIBUTION TO THE BODY OF KNOWLEDGE

This study introduces several novel contributions, also stated in Table 7.1, to the field of facility management at the University of Technology.

This study makes a significant contribution by developing an integrated, practical context-specific facility management framework tailored for South African Universities of Technology, where Lean Six Sigma (LSS) has seen limited application. It uniquely adapts the DMAIC structure and combines quantitative (SEM and multiple regression) and qualitative (interview) methods to create a comprehensive, scalable model that addresses technical, organisational and financial dimensions in a unified design.

A key contribution lies in the evidence-based validation of the framework through Structural Equation Modelling (SEM), empirically demonstrating that facility defaults, systemic inefficiencies and root causes negatively affect FM sustainability, while LSS-driven strategic interventions have a statistically significant positive impact. Such rigorous validation is seldom found in higher education FM literature, where empirical models are rarely integrated with LSS frameworks.

The originality of this research lies in its synthesis of international FM best practices, Lean Six Sigma discipline and localised evidence into a validated, practical context-based framework. This advances theory by linking LSS to higher education facility management and practice by offering a tested, adaptable framework capable of driving sustainable improvement across the resource-constrained University of Technology in South Africa.

7.7 LIMITATIONS OF THE RESEARCH

While this study contributes to facility management by offering a Lean Six Sigma-based framework, several limitations must be noted regarding scope, data access,

methodology and generalisability. The study's institutional focus limits its reach. Data from a few South African universities may not capture the diversity of practices nationally or internationally, as factors like funding, culture and infrastructure differ across institutions.

Access to complete and reliable data was challenging. Gaps in record-keeping and confidentiality restrictions meant some findings relied on perceptions and interviews, which, despite triangulation, may reflect bias or incomplete information. Applying the Lean Six Sigma DMAIC approach faced constraints. Full implementation requires real-time data, trained dedicated teams and a culture of continuous improvement, conditions not always present, particularly in resource-limited settings.

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APPENDIX I

GATEKEEPER PERMISSION LETTER



Institutional Effectiveness and Technology

21 February 2024

Mr MA Mogashoa
C/o Dr K Ndlovu
Business School
University of North-West

Dear Mr Mogashoa

GATEKEEPER PERMISSION LETTER

Your request for gatekeeper's permission and the Tshwane University of Technology (TUT) Research Ethics Committee (REC) final approval letter dated 10 February 2024 for the research project "Developing sustainable facility management framework using lean six sigma technique for a selected university of technology in South Africa" are duly acknowledged.

I am pleased to inform you that your request has been reviewed and permission is granted to access the contact details of the targeted TUT stakeholders from the Management Information System (MIS). Please note that permission is granted on condition that you fulfill the conditions as stipulated in the TUT REC provisional approval letter.

Wishing you all the best with your studies.

Yours sincerely,



Dr NE Mabote
ACTING EXECUTIVE DIRECTOR: IE&T



We empower people

Tel. (012) 382-4401, mabotene@tut.ac.za, www.tut.ac.za, Private Bag X680, Pretoria 0001

APPENDIX II

LETTER OF CONSENT FOR RESEARCH PARTICIPATION



NWU Business School
North-West University
Mr Tebogo Tebejane
018 299 4130
tebogo.tebejane@nwu.ac.za

<http://commerce.nwu.ac.za/business-school>

INFORMATION LEAFLET AND INFORMED CONSENT

PROJECT TITLE: DEVELOPING SUSTAINABLE FACILITY MANAGEMENT FRAMEWORK USING LEAN SIX SIGMA TECHNIQUE FOR A SELECTED UNIVERSITY OF TECHNOLOGY IN SOUTH AFRICA.

Primary investigator: Moloti Aaron Mogashoa
Study leader: Prof Ndlovu, NWU Business School

Dear Research participant,

You are invited to participate in a research study that forms part of my formal MTech-studies. This information leaflet will help you to decide if you would like to participate. Before you agree to take part, you should fully understand what is involved. You should not agree to take part unless you are completely satisfied with all aspects of the study.

I, Moloti Aaron Mogashoa, is currently pursuing a Doctor of Business Administration (DBA) in the Business School at the North-West University in South Africa. My research topic is: Developing Sustainable Facility Management Framework Using Lean Six Sigma Technique for a selected university of Technology in South Africa.

I kindly request you to partake to this research by answering the following questions with precision. Please note that your participation is voluntary, and you are free to withdraw at any given time during the process. Also, be assured that anonymity and confidentiality will be observed throughout since you will be contacted via internal communication channels like notice boards for privacy compliance purposes as per the POPI (Protection of Personal Information) Act. You are requested to not enter your personal information like names and contact details on the questionnaire and your responses will not be analysed individually but in aggregated form to protect your anonymity and confidentiality.

The findings from the study will be shared with the relevant institutions to improve facility management at the selected university of Technology in South Africa.



By completing the survey, you are giving your consent to voluntarily participate in this research.

The survey should take approximately 20 minutes of your time.

If you have any concerns, please contact us with the details provided below.

Yours Sincerely,

Researcher Details

Moloti Aaron Mogashoa

Email: molotimogashoa85@gmail.com

+27 81 409 4991

Supervisor Details

Dr Kaizer Ndlovu

35181680@nwu.ac.za

+27 73 811 2278

DECLARATION: CONFLICT OF INTEREST

Since the researcher is a staff member at TUT, data collection will be handled by research assistant as a third party to protect the vulnerability of employees and students.

A FINAL WORD

Your co-operation and participation in the study will be greatly appreciated. Please sign the underneath informed consent if you agree to participate in the study. In such a case, you will receive a copy of the signed informed consent from the researcher.



CONSENT

I hereby confirm that I have been adequately informed by the researcher about the nature, conduct, benefits and risks of the study. I have also received, read and understood the above written information. I am aware that the results of the study will be anonymously processed into a research report. I understand that my participation is voluntary and that I may, at any stage, without prejudice, withdraw my consent and participation in the study. I had sufficient opportunity to ask questions and of my own free will declare myself prepared to participate in the study.

Research participant's code: _____ (Please print)

Date: _____

Researcher's name: _____ (Please print)

Researcher's signature: _____

Date: _____



ANNEXURE III

STUDY QUESTIONNAIRE



NWU Business School
 North-West University
 Mr Tebogo Tebejane
 018 299 4130
 tebogo.tebejane@nwu.ac.za

<http://commerce.nwu.ac.za/business-school>

Age bracket

What is your age bracket? (Please tick the relevant box).

Description	Tick box
Less than 25 years old	
Between 25 and 40 years old	
Between 41 and 55 years old	
Above 55 years old	

Level of Education

What is your highest level of education? (Please tick the relevant box).

Description	Tick box
Less than Matric	
Matric	
Bachelors Degree or Equivalent	
Honours Degree or Equivalent	
Masters Degree or Equivalent	
Doctorate or Equivalent	
Other	



6-10	
Above 10	

Facility infrastructures

What are the Facility infrastructures existing in your university? (Please tick the relevant box).

Description	Yes	No
Student accommodation		
Building estate		
Warehouse		
Maintenance office		
Guest houses		
Flats		
Other (Please specify)		

Section B:

In this section, you will be indicating your degree of agreement (SD: Strongly Disagree, D: disagree, NS: Not Sure, A: Agree and SA: Strongly Agree) based on the provided statements. Please tick the relevant box.

FM Challenges in Universities of Technology

Classes of Facility defaults in the Universities of Technology (UT)



Statements	SD	D	NS	A	SA
Processes are a class of Facility defaults in the UT					
Procedures are a class of Facility defaults in the UT					
Systems are a class of Facility defaults in the UT					
Policies are a class of Facility defaults in the UT					
Roles and responsibilities are a class of Facility defaults in the UT					
Public finances are a class of Facility defaults in the UT					
Leadership style is a class of Facility defaults in the UT					
Technical defaults (Plumbing, electrical, structural...) are a class of Facility defaults in the UT					
Other (Please specify)					

Factors contributing to poor FM in Universities of Technology

Statements	SD	D	NS	A	SA
Inadequate funding contributes to poor FM in the UT					
Unstable and unskilled resources contribute to poor FM in the UT					
Lack of maintenance policies contributes to poor FM in the UT					
Lack of maintenance systems contributes to poor FM in the UT					
No budgeting priority contributes to poor FM in the UT					
Budget assumptions contribute to poor FM in the UT					
Multiple stakeholders					



No proportionality between facilities and the managing staff contributes to poor FM in the UT					
No on-time faults reporting contributes to poor FM in the UT					
No direct responsibility contributes to poor FM in the UT					
Diverse reporting processes contribute to poor FM in the UT					
Superficial investigation contributes to poor FM in the UT					
An unsuitable system for FM contributes to poor FM in the UT					
Dependence on the procurement department contributes to poor FM in the UT					
Lack of property profile contributes to poor FM in the UT					
Outsourcing system contributes to poor FM in the UT					
Other (Please specify)					

Root causes to poor facility management in Universities of Technology

Statements	SD	D	NS	A	SA
Poor state of infrastructural facilities is a root cause of poor FM in the UT					
Obsolete assets is a root cause to poor FM in the UT					
Policy and regulatory constraints are a root cause of poor FM in the UT					



A budgetary analysis is a strategy used for FM sustainability at the UT					
Maintenance plans are a strategy used for FM sustainability at the UT					
Other (Please specify)					

Lean, Six Sigma (LSS), Value Stream Mapping and sustainability in Universities of Technology

Statements	SD	D	NS	A	SA
Management values are well defined					
FM capacities and business values are well-measured					
FM process flows are well analysed					
FM process flows are well improved					
FM process flows are well-controlled					
LSS allows reducing waste and defects					
FM process is continuously reviewed for efficiency improvement					
LSS enables a reduction in inventory					
Other (Please specify)					

Sustainable Facility Management scheme for a South African university

Statements	SD	D	NS	A	SA
------------	----	---	----	---	----



Identifying various classes of facility defaults contributes to designing an appropriate framework for FM in SA universities					
Assessing factors contributing to poor FM contributes to designing an appropriate framework for FM in SA universities					
Establishing the root causes of the poor FM contributes to designing an appropriate framework for FM in SA universities					
Establishing suitable strategies and practices for FM contributes to designing an appropriate framework for FM in SA universities					
Other (Please specify)					

Thank you for your participation



APPENDIX IV

INTERVIEW QUESTIONS



NWU Business School
North-West University
Mr Tebogo Tebejane
018 299 4130
tebogo.tebejane@nwu.ac.za

<http://commerce.nwu.ac.za/business-school>

INFORMATION LEAFLET AND INFORMED CONSENT

PROJECT TITLE: DEVELOPING SUSTAINABLE FACILITY MANAGEMENT FRAMEWORK USING LEAN SIX SIGMA TECHNIQUE FOR A SELECTED UNIVERSITY OF TECHNOLOGY IN SOUTH AFRICA.

Primary investigator: Moloti Aaron Mogashoa
Study leader: Prof Ndlovu, NWU Business School

Dear Research participant,

You are invited to participate in a research study that forms part of my formal MTech-studies. This information leaflet will help you to decide if you would like to participate. Before you agree to take part, you should fully understand what is involved. You should not agree to take part unless you are completely satisfied with all aspects of the study.

I, Moloti Aaron Mogashoa, is currently pursuing a Doctor of Business Administration (DBA) in the Business School at the North-West University in South Africa. My research topic is: Developing Sustainable Facility Management Framework Using Lean Six Sigma Technique for a selected university of Technology in South Africa.

I kindly request you to partake to this research by answering the following questions with precision. Please note that your participation is voluntary, and you are free to withdraw at any given time during the process. Also, be assured that anonymity and confidentiality will be observed throughout since you will be contacted via internal communication channels like notice boards for privacy compliance purposes as per the POPI (Protection of Personal Information) Act. You are requested to not enter your personal information like names and contact details on the questionnaire and your responses will not be analysed individually but in aggregated form to protect your anonymity and confidentiality.

The findings from the study will be shared with the relevant institutions to improve facility management at the selected university of Technology in South Africa.



By completing the survey, you are giving your consent to voluntarily participate in this research.

The survey should take approximately 20 minutes of your time.

If you have any concerns, please contact us with the details provided below.

Yours Sincerely,

Researcher Details

Moloti Aaron Mogashoa

Email: molotimogashoa85@gmail.com

+27 81 409 4991

Supervisor Details

Dr Kaizer Ndlovu

35181680@nwu.ac.za

+27 73 811 2278

DECLARATION: CONFLICT OF INTEREST

Since the researcher is a staff member at TUT, data collection will be handled by research assistant as a third party to protect the vulnerability of employees and students.

A FINAL WORD

Your co-operation and participation in the study will be greatly appreciated. Please sign the underneath informed consent if you agree to participate in the study. In such a case, you will receive a copy of the signed informed consent from the researcher.



CONSENT

I hereby confirm that I have been adequately informed by the researcher about the nature, conduct, benefits and risks of the study. I have also received, read and understood the above written information. I am aware that the results of the study will be anonymously processed into a research report. I understand that my participation is voluntary and that I may, at any stage, without prejudice, withdraw my consent and participation in the study. I had sufficient opportunity to ask questions and of my own free will declare myself prepared to participate in the study.

Research participant's code: _____ (Please print)

Date: _____

Researcher's name: _____ (Please print)

Researcher's signature: _____

Date: _____



SECTION A: Demographic Profile

Age bracket

What is your age bracket? (Please tick the relevant box).

Description	Tick box
Less than 25 years old	
Between 25 and 40 years old	
Between 41 and 55 years old	
Above 55 years old	

Level of Education

What is your highest level of education? (Please tick the relevant box).

Description	Tick box
Less than Matric	
Matric	
Bachelors Degree or Equivalent	
Honours Degree or Equivalent	
Masters Degree or Equivalent	





NWU Business School
 North-West University
 Mr Tebogo Tebejane
 018 299 4130
 tebogo.tebejane@nwu.ac.za

<http://commerce.nwu.ac.za/business-school>

Facility infrastructures

What are the Facility infrastructures existing in your university? (Please tick the relevant box).

Description	Yes	No
Student accommodation		
Building estate		
Warehouse		
Maintenance office		
Guest houses		
Flats		
Other (Please specify)		



Section B: Interview Questions

Please provide a clear response to the following interview questions based on your own perspectives.

1. What are various classes of facility defaults present within a university system?
2. How do you identify various classes of facility defaults present within a university system?
3. How can you classify various classes of facility defaults present within a university system?
4. How can you critically analyse the various classes of facility defaults present within a university system?
5. According to you, what are the factors contributing to poor management of facilities within a university system?
6. What are the root causes of poor university facility management?
7. To your opinion, what can you propose as suitable strategies and practices to effectively maintain university facilities over time?
8. To what extent can we develop a sustainable Facility Management scheme that will ensure effective maintenance of university facilities in South Africa over time?

Thank you for your participation



APPENDIX V

ETHICS APPROVAL LETTER OF STUDY



Private Bag X1290, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Fax: 018 299-4910
Web: <http://www.nwu.ac.za>

Senate Committee for Research Ethics
Tel: 018 299-484
Feziwe.Mseleni@nwu.ac.za

9 March 2023

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the **Economic and Management Sciences Research Ethics Committee (EMS-REC)** on 28/11/2022, the Economic and Management Sciences Research Ethics Committee hereby **approves** your study as indicated below. This implies that the North-West University Senate Committee for Research Ethics (NWU-REC) grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Developing sustainable facility management framework using lean six sigma technique for selected universities of technology in South Africa
Study Leader/Supervisor (Principal Investigator)/Researcher: Dr K Ndlovu – PhD in Business Administration
Student: Mogashoa, MA (29505763)

N	W	U	-	0	1	8	9	9	-	2	2	-	A	4
Institution			Study Number						Year			Status		

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type:

Commencement date: 9/3/2023

Expiry date: 9/3/2024

Risk: Low

Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt and review of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

Special in process conditions of the research for approval (if applicable):

•

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The study leader/supervisor (principle investigator)/researcher must report in the prescribed format to the EMS-REC:

 - *annually (or as otherwise requested) on the monitoring of the study, whereby a letter of continuation will be provided, and upon completion of the study; and*
 - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.**
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the study leader/researcher must apply for approval of these amendments at the EMS-REC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for an external audit.*

- *The date of approval indicates the first date that the study may be started.*
- In the interest of ethical responsibility, the NWU-SCRE and EMS-REC reserves the right to:*
 - *request access to any information or data at any time during the course or after completion of the study;*
 - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
 - *withdraw or postpone approval if:*
 - *any unethical principles or practices of the study are revealed or suspected;*
 - *it becomes apparent that any relevant information was withheld from the EMS-REC or that information has been false or misrepresented;*
 - *submission of the annual (or otherwise stipulated) monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and / or*
 - *new institutional rules, national legislation or international conventions deem it necessary.*

The EMS-REC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the EMS-REC or the NWU-SCRE for any further enquiries or requests for assistance.

Yours sincerely,

Prof Mark Rathbone
Chairperson: NWU Economic and Management Sciences Research Ethics Committee

APPENDIX VI

TUT Research Ethics Committee Approval



Research Ethics Committee

The TUT Research Ethics Committee is a registered Institutional Review Board (IRB 00005968) with the US Office for Human Research Protections (IORG# 0004997). Also, it has Federal Wide Assurance for the Protection of Human Subjects for International Institutions (FWA 00011501). In South Africa it is registered with the National Health Research Ethics Council (REC-160509-21).

February 10, 2024

REC Ref #: REC/2023/04/006
Name: Mogashoa MA
Student #: 29505763, NWU

Mr MA Mogashoa
C/o Dr K Ndlovu
Business School
University of North West

Dear Mr Mogashoa,

Decision: Final Approval

Name: Mogashoa MA

Project title: *Developing sustainable facility management framework using lean six sigma technique for a selected university of technology in South Africa.*

Qualification: Doctor of Business Administration

Supervisor: Dr K Ndlovu

Thank you for submitting the revised project documents for review by the Research Ethics Committee (REC), Tshwane University of Technology (TUT). In reviewing the documents, the comments and notes below are tabled for your consideration, attention and/or notification:

- **Documents Submitted for TUT Ethics Clearance**

- The submitted revised project documents are in order.



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The chairperson of the Tshwane University of Technology Research Ethics Committee reviewed the revised project documents on February 9, 2024. **Final Approval** has been granted to the project.

The proposed research project may now continue with the proviso that:

- 1) The researcher/s will conduct the study according to the procedures and methods indicated in the **approved proposal**, particularly in terms of any undertakings and/or assurances made regarding the confidentiality of the collected data.
- 2) The proposal will be submitted to the Committee for prospective ethical clearance if there are any substantial **deviations** and/or changes from the approved proposal.
- 3) The researcher/s will act within the parameters of any applicable **national legislation, professional codes of conduct**, institutional guidelines and scientific standards relevant to the specific field of study. Strict adherence to the following South African legislation, where applicable, is especially important: Protection of Personal Information Act (Act 4 of 2013), Children's Act (Act 38 of 2005) and the National Health Act (Act 61 of 2003).
- 4) The researcher will inform the REC as soon as possible of any **adverse events** involving research participants that may have occurred during the course of the study. It includes the actions and/or processes that were implemented to mitigate and/or prevent any further injuries and/or adverse outcomes.
- 5) The researcher will inform the REC of any **new or unexpected ethical issues** that may have emerged during the course of the study, as well as how these ethical issues were addressed. The researcher must consult with the REC for advice and/or guidance in any such event.
- 6) The current ethics approval expiry date for this project is **February 9, 2026**. No research activities may continue after the ethics approval expiry date. An application for the extension of ethics approval must be submitted for projects that need to continue beyond the expiry date.
- 7) It is a strict requirement for the researcher to submit a progress report before **February 9, 2025**.

Note:

The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants.

Yours sincerely,



Prof JN Agumba
Acting Chairperson: Research Ethics Committee
[TUTRef#2023=04=006=MogashoaMA]



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APPENDIX VII

FRAMEWORK VALIDATION QUESTIONNAIRE

Framework validation Survey Questionnaire

Title of research project: Developing Sustainable Facility Management Framework Using Lean Six Sigma Technique for Universities of Technology in South Africa.

Name of the Researcher: Moloti Aaron Mogashoa (29505763@nwu.ac.za)

Name of the Supervisor: Dr K Ndlovu (kaizer.ndlovu@nwu.ac.za)

You are invited to participate in a survey to validate the Facility Management Framework by completing the following questions. Attached please find the framework for review in Figure 1.

SECTION A: Demographic Profile

1. What is your gender? (Please tick the relevant box)

Description	Tick box
Male	1
Female	2
Other (Please specify)	3

2. What is your age bracket? (Please tick the relevant box).

Description	Tick box
Less than 25 years old	1
Between 25 and 40 years old	2
Between 41 and 55 years old	3
Above 55 years old	4

3. What is your highest level of education? (Please tick the relevant box).

Description	Tick box
Less than Matric	1
Matric	2
Bachelors Degree or Equivalent	3
Honours Degree or Equivalent	4
Masters Degree or Equivalent	5
Doctorate or Equivalent	6

Other (Please specify)	7
------------------------	---

4. What is your job position in your university? (Please tick the relevant box).

Description	Tick box
Facility Manager	1
Facility Coordinator /Administrator	2
Finance Manager	3
Residence Manager	4
Lean Six Sigma expert	5
Maintenance Manager	6
Academic	7
Head of the Department	8
Directors	9
Other (Please specify)	10

5. How many years of experience do you have in your university? (Please tick the relevant box).

Description	Tick box
Less than 5	1
6-10	2
11-15	3
Above 15	4

Section B: Institutional Factors

Please indicate the extent to which you agree with the following statements.
 (1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree nor Agree, 4 = Agree, 5 = Strongly Agree)

Leadership Effectiveness

No.	Statement	1	2	3	4	5
LE1	University leadership demonstrates a clear vision for sustainable facility management.					
LE2	Senior management actively supports sustainable initiatives on campus.					

LE3	Decision-making processes in our institution reflect strong and effective leadership.					
LE4	Leadership effectively communicates sustainability goals to all stakeholders.					

Organisational Digital Readiness

No.	Statement	1	2	3	4	5
ODR1	The institution has adequate digital infrastructure to support smart facility management.					
ODR2	Staff are equipped with the digital skills necessary to implement sustainable solutions.					
ODR3	Our university embraces emerging digital technologies to enhance operational efficiency.					
ODR4	Data-driven decision-making is a core part of our facility management approach.					

Cultural Adaptability

No.	Statement	1	2	3	4	5
CA1	The institutional culture is responsive to changes related to sustainability practices.					
CA2	Staff and students are open to adopting new ways of managing campus facilities.					
CA3	Sustainability is integrated into our institution's values and daily operations.					
CA4	There is a strong willingness across the university community to embrace innovation.					

Section C: Sustainability Dimensions

Indicate your level of agreement regarding the institution's performance in the following sustainability areas.

(1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree nor Agree, 4 = Agree, 5 = Strongly Agree)

Environmental Sustainability

No.	Statement	1	2	3	4	5
ES1	The institution implements effective waste management and recycling practices.					
ES2	Energy and water consumption are monitored and managed efficiently.					
ES3	Green building practices and eco-friendly materials are promoted in infrastructure projects.					
ES4	The university actively reduces its environmental footprint through facility operations.					

Economic Sustainability

No.	Statement	1	2	3	4	5
EcoS1	Budgeting for facility management prioritises long-term cost efficiency.					
EcoS2	Investments in sustainability initiatives deliver measurable economic value.					
EcoS3	Financial resources for sustainable infrastructure are allocated transparently.					
EcoS4	The institution's facility planning reduces unnecessary operational costs.					

Social Sustainability

No.	Statement	1	2	3	4	5
SS1	Facility design and operations promote the health, safety, and well-being of occupants.					
SS2	The university facilities are inclusive and accessible to all users.					
SS3	Community engagement is considered in sustainability-related decisions.					
SS4	The institution educates staff and students about sustainable practices and their social impact.					

SECTION D: Relevance and Comprehensiveness of the Framework

Indicate your level of agreement regarding the relevancy of the framework.
(1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree nor Agree, 4 = Agree, 5 = Strongly Agree)

No.	Statement	1	2	3	4	5
RCF1	The framework identifies the key sustainability issues relevant to our university.					
RCF2	The Lean Six Sigma approach is appropriate for driving sustainable FM improvements.					
RCF3	The DMAIC structure (Define, Measure, Analyse, Improve, Control) is logically applied.					
RCF4	The framework includes relevant tools (Pareto charts, Fishbone, root cause analysis, Value Stream Mapping, Kaizen).					

Practicality and Implementation

Indicate your level of agreement regarding the Framework practicality at UoT.
 (1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree nor Agree, 4 = Agree, 5 = Strongly Agree)

No.	Statement	1	2	3	4	5
P11	The framework can be feasibly implemented in a university setting.					
P12	Required data for framework implementation (energy, waste, maintenance logs) is available.					
P13	The framework promotes collaboration across departments and stakeholders.					
P14	The framework allows for measurable improvements in energy, waste, or cost metrics.					

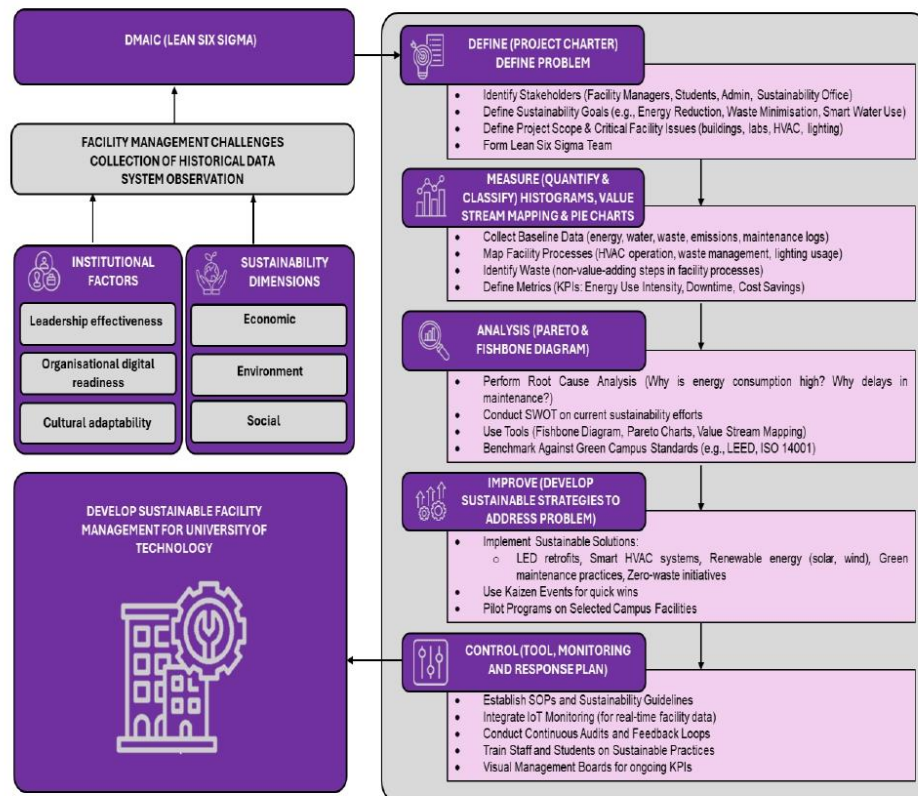


Figure 1: Developed Sustainable Facility Management using Lean Six Sigma technique for University of Technology in South Africa

Thank you for participating

APPENDIX VIII

FRAMEWORK VALIDATION STATISTICAL ANALYSIS REPORT

8.1. INTRODUCTION

This section presents empirical findings and analysis based on data gathered from the research questionnaire distributed to professional respondents at a South African University of Technology. The questionnaire consisted of 38 questions, out of which 5 were related to demographics (general information) and 33 measured the study's latent variables, namely: Leadership Effectiveness, Organisational Digital Readiness, Cultural Adaptability, Environmental Sustainability, Economic Sustainability, Social Sustainability, Relevance and Comprehensiveness of the Framework and Practicality and Implementation of the Framework.

The IBM Statistical Package for the Social Sciences (SPSS) version 30 was used to analyse the data. The data analysis includes frequencies, means, standard deviations, reliability analysis, correlation analysis and Structural Equation Modelling (SEM).

8.2. THE RESPONSE RATE

A total of 160 questionnaires were distributed and 155 returned giving a total response of 96.9%. Out of a total of 155 questionnaires returned 152 were found valid for the analysis, yielding a valid response rate of 98.1% whereas the rest of the questionnaires were not used due to missing information.

8.3. DESCRIPTIVE STATISTICS

Descriptive statistics were employed in this study in form of frequencies, means and standard deviations to assess the study demographics and assess the perceptions of respondents on the study constructs.

8.3.1: Demographic Details

Table 8.1: Demographic Details

Characteristic	Category	N	Percentage
Gender	Male	91	59.9%
	Female	61	40.1%
Age Group	Less than 25 years	5	3.3%
	Between 25 and 40 years	51	33.6%
	Between 41 and 55 years	74	48.7%
	Above 55 years old	22	14.5%
Highest Level of Education	Matric	9	5.9%
	Bachelors Degree or Equivalent	36	23.7%
	Honours Degree or Equivalent	33	21.7%
	Masters Degree or Equivalent	40	26.3%
	Doctorate or Equivalent	25	16.4%
	Other Qualifications	9	5.9%
MaJob Position	Facility Manager	7	4.6%
	Facility Coordinator/Administrator	15	9.9%
	Finance Manager	10	6.6%
	Residence Manager	23	15.1%
	Lean Six Sigma Expert	7	4.6%
	Maintenance Manager	14	9.2%
	Academic	26	17.1%
	Head of the Department	16	10.5%
	Directors	9	5.9%
	Other	25	16.4%
Years of Working Experience	Less than 5	28	18.4%
	6-10	65	42.8%
	11-15	40	26.3%
	Above 15	19	12.5%

This report provides an analysis of the demographic characteristics of the 152 individuals surveyed, based on the data presented in the provided table. The analysis covers the distribution of respondents by gender, age, highest level of education, job position and years of working experience. The respondent pool showed a clear gender distribution, with a higher representation of males. Out of 152 respondents, 91 (59.9%) were male, while 61 (40.1%) were female.

The majority of respondents were in the middle age brackets. The largest group, comprising 74 individuals (48.7%), was between 41 and 55 years old. The next largest group was between 25 and 40 years, with 51 respondents (33.6%). The remaining respondents were above 55 years old (22 individuals, 14.5%) and less than 25 years old (5 individuals, 3.3%).

The data indicate a highly educated group of respondents. The most common qualification was a Masters Degree or Equivalent, held by 40 respondents (26.3%). This was followed by a Bachelors Degree or Equivalent (36 individuals, 23.7%), Honours Degree or Equivalent (33 individuals, 21.7%) and Doctorate or Equivalent (25 individuals, 16.4%). Matric and "Other Qualifications" each accounted for 9 respondents (5.9%).

The respondents held a wide variety of job positions, with a notable concentration in academic roles. The most frequent job title was Academic, held by 26 respondents (17.1%), followed closely by "Other" (25 respondents, 16.4%) and Residence Manager (23 individuals, 15.1%). Other significant roles included Head of the Department (16 respondents, 10.5%), Facility Coordinator/Administrator (15 respondents, 9.9%) and Maintenance Manager (14 individuals, 9.2%).

The majority of respondents possessed a substantial amount of work experience. The largest group, with 65 respondents (42.8%), had between 6 and 10 years of experience. This was followed by those with 11-15 years of experience (40 individuals, 26.3%). Individuals with less than 5 years of experience made up 18.4% of the group, while those with more than 15 years of experience accounted for 12.5%.

8.3.2: Overall Means and Standard Deviations of Study Constructs

Table 6.2: Overall Means and Standard Deviations of Study Constructs

	Mean	Standard Deviation
Leadership Effectiveness	3.65	0.86
Organisational Digital Readiness	3.37	0.82
Cultural Adaptability	3.61	0.86
Environmental Sustainability	3.21	0.92
Economic Sustainability	3.56	0,90
Social Sustainability	3.75	0.89
Relevance and Comprehensiveness of the Framework	3.79	0.78
Practicality and Implementation	3.96	0,67

Table 8.2 presents an analysis of the descriptive statistics for the key constructs in the study, focusing on their mean scores and standard deviations. This analysis provides an overview of how respondents perceived each construct, identifying areas of relative strength and those that may require further investigation.

An examination of the mean scores reveals several key insights. The constructs with the highest mean scores were Practicality and Implementation ($M = 3.96$) and Relevance and Comprehensiveness of the Framework ($M = 3.79$). These high scores suggest that, on average, respondents strongly agreed that the framework is both highly relevant and practical for use. This indicates a positive perception of the framework's design and its potential for real-world application.

Conversely, the constructs with the lowest mean scores were Environmental Sustainability ($M = 3.21$) and Organisational Digital Readiness ($M = 3.37$). The lower means for these factors suggest that, relative to other dimensions, respondents perceived these areas as less developed or performing less effectively. This could point to a need for targeted initiatives to improve digital readiness within organizations and enhance environmental sustainability efforts.

The standard deviation values provide insight into the variability of responses for each construct. A smaller standard deviation indicates that the responses were clustered closely around the mean, suggesting a high level of agreement among respondents. The lowest standard deviation was for Practicality and Implementation ($SD = 0.67$), reinforcing the finding that there was a strong, consistent agreement on this point. In contrast, the highest standard deviation was observed for Environmental Sustainability ($SD = 0.92$). This larger value indicates a wider spread of opinions on this construct, suggesting that some respondents may have rated it much higher or lower than others.

8.4. STRUCTURAL EQUATION MODELLING

Structural Equation Modelling (SEM) was conducted in the study to develop a framework meant to validate the study's Lean Six Sigma Framework. The measurement model was evaluated first, then the structural model, using Partial Least Squares Structural Equation Modelling (PLS-SEM). SMARTPLS 4.0 was used for structural equation modelling.

8.4.1 Assessment of the Measurement Model

The measuring model was evaluated using reliability, convergent validity and discriminant validity. The Cronbach's Alpha coefficient and the Composite Reliability were both used in the reliability analysis. The Cronbach's Alpha coefficient and Composite Reliability are both advised to be 0.70 (Nunnally, 1978).

In SEM or other multivariate analysis methods, composite reliability is a metric used to evaluate the internal consistency or dependability of a latent construct (or factor) (Fornell & Larcker, 1981).

Table 8.3: Reliability Analysis

Construct	Cronbach Alpha Coefficient	Composite Reliability
Leadership Effectiveness	0.677	0.822
Organisational Digital Readiness	0.689	0.882
Cultural Adaptability	0.714	0.836
Environmental Sustainability	0.773	0.882
Economic Sustainability	0.692	0.844
Social Sustainability	0.797	0.830
Relevance and Comprehensiveness of the Framework	0.682	0.847
Practicality and Implementation	0.774	0.855

Table 8.3 shows that all the Composite Reliability Values and Cronbach's Alpha coefficient values are close to or higher than the suggested value of 0.7, indicating that the measurement model is reliable.

Convergent validity was evaluated by computing the Outer Loadings and the Average Variance Extracted (AVE). According to Ringle et al. (2020), outer loadings show how strongly an observed variable (indicator) and its underlying latent construct (factor) are

related. Usually, factor loadings fall between 0 and 1. According to Hair et al. (2019), an indicator is a good measure of the latent construct if its value is higher (closer to 1), which suggests a stronger connection between the latent construct and the observed indicator. AVE measures the degree to which the observable variables represent the underlying latent construct, just like reliability does. The computation involves averaging the squared factor loadings of every observed variable linked to a certain latent variable. The recommended value of AVE, which, to put it simply, indicates the extent to which the latent concept accounts for the variance in the indicators, is ≥ 0.50 (Fornell et al, 1981).

Table 8.4: Outer Loadings and Average Variance Extracted Values

	CA	ES	EcoS	LE	ODR	PI	RCF	SS
CA1	0.881							
CA4	0.812							
ES2		0.876						
ES3		0.742						
ES4		0.911						
EcoS1			0.870					
EcoS3			0.839					
LE3				0.842				
LE4				0.828				
ODR2					0.895			
ODR4					0.882			
PI1						0.774		
PI2						0.736		
PI3						0.787		
PI4						0.789		
RCF2							0.816	
RCF4							0.897	
SS1								0.934
SS4								0.743
AVEs	0.718	0.716	0.730	0.698	0.789	0.596	0.735	0.712

As can be seen from Table 8.4, all of the outer loadings are above the suggested threshold of 0.5 and vary from 0.743 to 0.934. The AVE values also above the 0.5 threshold vary from 0.596 to 0.789. Convergent validity of the measurement model is implied by the fact that both the outer loadings and the AVE values are higher than the respective recommended values.

To assess discriminant validity, the correlation between the constructs was compared with the square root of the average variance extracted (AVE). For the discriminant validity to be achieved the square root of the average variance extracted should be above the correlation values (Fornell & Larcker, 1981).

Table 8.5: Discriminant Validity Results using the Fornell-Larcker Criterion

		Leadership Effectiveness	Organisational Digital Readiness	Cultural Adaptability	Environmental Sustainability	Economic Sustainability	Social Sustainability	Relevance and Comprehensiveness of the Framework	Practicality and Implementation
Leadership Effectiveness	Pearson Correlation	0.835							
	Sig. (2-tailed)								
	N	152							
Organisational Digital Readiness	Pearson Correlation	,396**	0.888						
	Sig. (2-tailed)	<,001							
	N	152	152						
Cultural Adaptability	Pearson Correlation	,629**	,434**	0.847					
	Sig. (2-tailed)	<,001	<,001						
	N	152	152	152					
Environmental Sustainability	Pearson Correlation	,534**	,515**	,579**	0.846				
	Sig. (2-tailed)	<,001	<,001	<,001					
	N	152	152	152	152				
Economic Sustainability	Pearson Correlation	,496**	,278**	,603**	,560**	0.854			
	Sig. (2-tailed)	<,001	<,001	<,001	<,001				
	N	152	152	152	152	152			
Social Sustainability	Pearson Correlation	,391**	,294**	,547**	,489**	,536**	0.843		
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001			
	N	152	152	152	152	152	152		
Relevance and Comprehensiveness of the Framework	Pearson Correlation	,123	,321**	,216**	,103	,129	,231**	0.857	
	Sig. (2-tailed)	,132	<,001	,008	,206	,114	,004		
	N	152	152	152	152	152	152	152	
Practicality and Implementation	Pearson Correlation	,138	,284**	,210**	,089	,304**	,383**	,470**	0.772
	Sig. (2-tailed)	,089	<,001	,009	,273	<,001	<,001	<,001	
	N	152	152	152	152	152	152	152	152

** . Correlation is significant at the 0.01 level (2-tailed).

It can be concluded that the measurement model is discriminantly valid, as indicated by Table 8.5, which shows that the square root of the AVEs is greater than the correlation values. The structural model can then be evaluated, as reliability, convergent validity and discriminant validity have all been successfully attained.

8.4.1 Assessment of the Structural Model

The path coefficients, t-values, p-values and the coefficient of determination (R-squared), were analysed to evaluate the structural model as presented in Table 8.6 and Figure 8.1 below:

Table 8.6: Structural Equation Modelling Results

	Original Sample (O)	T statistics (O/STDEV)	P values
Cultural Adaptability -> Practicality and Implementation	-0.043	0.280	0.780
Cultural Adaptability-> Relevance and Comprehensiveness of the Framework	0.082	0.620	0.535
Economic Sustainability -> Practicality and Implementation	0.239	2.149	0.032
Economic Sustainability> Relevance and Comprehensiveness of the Framework	-0.046	0.393	0.695
Environmental Sustainability-> Practicality and Implementation	-0.315	2.440	0.015
Environmental Sustainability -> Relevance and Comprehensiveness of the Framework	-0.166	1.297	0.195
Leadership Effectiveness-> Practicality and Implementation	-0.057	0.502	0.616
Leadership Effectiveness -> Relevance and Comprehensiveness of the Framework	-0.037	0.296	0.767
Organisational Digital Readiness -> Practicality and Implementation	0.323	3.497	0.000
Organisational Digital Readiness -> Relevance and Comprehensiveness of the Framework	0.334	3.621	0.000
Social Sustainability -> Practicality and Implementation	0.372	3.880	0.000
Social Sustainability -> Relevance and Comprehensiveness of the Framework	0.254	2.003	0.045

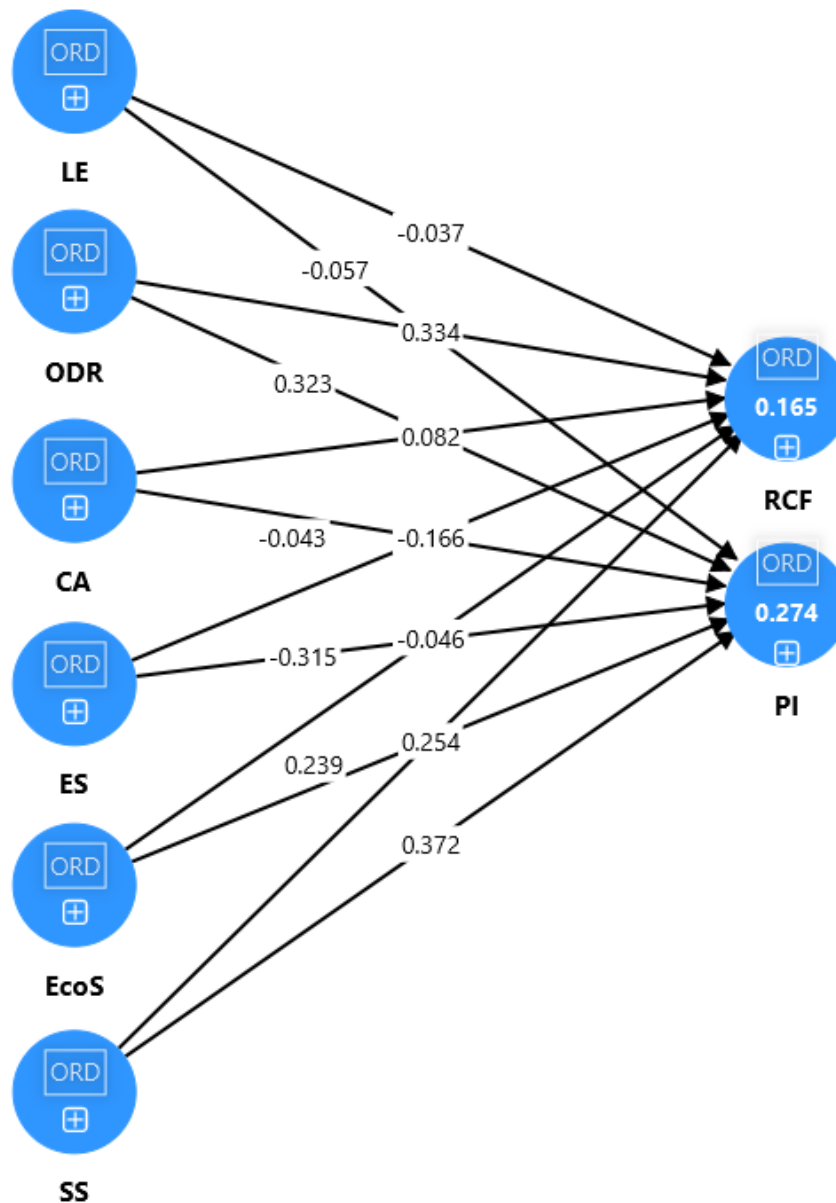


Figure 8.1: The Structural Model

The analysis aims to understand the structural relationships between several independent factors (Cultural Adaptability, Economic Sustainability, Environmental Sustainability, Leadership Effectiveness, Organisational Digital Readiness and Social Sustainability) and two dependent outcomes: Practicality and Implementation and the Relevance and Comprehensiveness of the Framework.

Interpretation of Key Metrics

- Original Sample (O): This value represents the path coefficient, indicating the strength and direction of the relationship between two variables. A positive value means that as one factor increases, the other also increases. A negative value indicates that as one factor increases, the other decreases.
- T statistics (|O/STDEV|): The T-statistic is used to determine the statistical significance of the path coefficient. A higher T-statistic (more than 1.96) generally indicates a stronger relationship.
- P values: The p-value is the most crucial metric for determining statistical significance. A p-value less than 0.05 ($p < 0.05$) is conventionally considered statistically significant, meaning the relationship is unlikely to be due to random chance. A p-value of 0.000 indicates a highly significant relationship.

Key Findings

Factors Influencing Practicality and Implementation

The analysis reveals several statistically significant relationships with the "Practicality and Implementation" outcome:

- Economic Sustainability: There is a statistically significant positive impact ($\beta = 0.239$, $p = 0.032$). This suggests that an increase in economic sustainability is associated with a greater practicality and ease of implementation.
- Environmental Sustainability: A statistically significant negative relationship was found ($\beta = -0.315$, $p = 0.015$). This is an interesting and counter-intuitive finding, indicating that as environmental sustainability efforts increase, the perceived practicality and implementation of the framework may decrease.
- Organisational Digital Readiness: This factor shows a highly significant positive relationship ($\beta = 0.323$, $p = 0.000$). This is a strong indicator that higher digital readiness within an organisation is a key driver for successful practicality and implementation.
- Social Sustainability: This factor also demonstrates a highly significant positive influence ($\beta = 0.372$, $p = 0.000$). With the highest path coefficient and a p-value of 0.000, social sustainability appears to be the most influential factor driving the practicality and implementation of the framework.

Factors Influencing Relevance and Comprehensiveness of the Framework

The analysis also identified statistically significant relationships with the "Relevance and Comprehensiveness of the Framework" outcome:

- **Organisational Digital Readiness:** This factor has a highly significant positive impact ($\beta=0.334$, $p=0.000$). This suggests that an organisation's digital readiness is not only crucial for implementation but also for ensuring the framework itself is perceived as relevant and comprehensive.
- **Social Sustainability:** A significant positive relationship was found here as well ($\beta=0.254$, $p=0.045$). This supports the notion that a focus on social sustainability contributes to the overall perceived relevance and comprehensiveness of the framework.

Non-Significant Relationships

The remaining relationships did not show statistical significance (p-values were greater than 0.05). This means that, based on the data, there is no evidence to support a direct relationship between these factors and the outcomes. These include:

- Cultural Adaptability -> Practicality and Implementation ($p=0.780$)
- Cultural Adaptability -> Relevance and Comprehensiveness of the Framework ($p=0.535$)
- Economic Sustainability -> Relevance and Comprehensiveness of the Framework ($p=0.695$)
- Environmental Sustainability -> Relevance and Comprehensiveness of the Framework ($p=0.195$)
- Leadership Effectiveness -> Practicality and Implementation ($p=0.616$)
- Leadership Effectiveness -> Relevance and Comprehensiveness of the Framework ($p=0.767$)

Conclusion

The Structural Equation Modelling results highlight that Organisational Digital Readiness and Social Sustainability are the most critical factors influencing both the practicality of implementation and the perceived relevance of the framework. In contrast, Cultural Adaptability and Leadership Effectiveness did not present statistically significant effects in the model. The most surprising finding is the negative relationship

between Environmental Sustainability and Practicality and Implementation, which warrants further investigation to understand why efforts in this area may be perceived as making the framework less practical to implement.