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Developing a Sustainable Facility Management Model Using a Multiple Regression Analysis Approach: A Case Study of Higher Education Institution

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Abstract: Sustainable facility management (FM) is one of the important thing for higher education institutions (HEIs), particularly in South Africa, because of aging infrastructure, constrained budgets, and deferred maintenance continue to affect the service delivery in a required way. To address the issue, the present study has developed a predictive model for sustainable FM using one of the multivariate technique named multiple linear regression, by collecting the data from 326 participants across five campuses of the Tshwane University of Technology. A self-structured questionnaire was prepared and utilized to collect the responses on FM practices, which were later analyzed using various statistical techniques such as exploratory factor analysis (EFA), Pearson correlation, and multiple linear regression (MRA). With the help of Exploratory Factor Analysis (EFA), six valid construct were confirmed, namely Strategies Used in Facility Management, Lean Six Sigma (LSS), Root Causes of Poor Facility Management, Facility Defaults, Factors Contributing to Poor Facility Management, and the Sustainable Facility Management Scheme. The regression model was found to be statistically significant with F-Statistic =29.247 & p-value<0.001 and accounted for 31.6% of the variation in sustainability outcomes. Strategies used in FM and LSS had positive effects on sustainability, whereas facility defaults, root causes, and poor management factors exerted significant negative influences showing inverse relationship with sustainability outcomes. The findings of the study highlights the importance of utilizing the dual approach which combines the implementation of structured quality frameworks with the resolution of systemic inefficiencies. The present study presents a validated model (via EFA and MRA) to support the facility management decision-making in higher education institutions of India and, therefore, identifies some significant areas for future research, which include leadership, financial mechanisms, and digital facility management technologies.

Keywords: *Facility Management, Higher education, Sustainability, Exploratory Factory Analysis, Multiple Regression Analysis, FM strategies.*

INTRODUCTION

Sustainable facility management (FM) has emerged as one of the strategic focus for higher education institutions (HEIs). One of the reason for that can be said as they confront the increasing demands to maintain the long-term functionality of their infrastructure, improve the satisfaction of the user, and helping to address environmental challenges (Opoku and Lee, 2022). In South Africa and comparable settings, HEIs especially universities face many challenges such as old infrastructure, delayed in the maintenance of these infrastructure, and last but not the least is having constrained operational budgets. All of these, collectively hamper the effective delivery of core services of the higher education institutions (Hong et al., 2020). To address these issues in HEIs, facility management must shift from a reactive, maintenance-focused role to a proactive, data-driven function that helps not only the strategic planning but advances sustainability goals as well.

To realise this transformation, a multivariate technique named as multiple regression analysis was utilized to provides a valuable approach for modelling the relationships between key facility management variables/constructs (IVs) and sustainability performance (DV). This technique enable the identification of predictors that are statistically particularly relevant to energy efficiency, maintenance frequency, user satisfaction, and financial allocation which are supposed to impact FM outcomes to a larger extent (Shohet and Lavy, 2021). Through the findings of these relationships, university administrators and FM practitioners can allocate and utilize the resources more efficiently, especially maintenance activities, and align investments in infrastructure with long-term institutional objectives. As per Baglio et al., (2020), this application of this analytical approach helps one to facilitate evidence-based decision-making and promotes continuous improvement in FM performance.

In the literature, it has been observed that various survey based studies shown the effectiveness of regression analysis technique within the domain of facility management. Lu, Olanrewaju and Tan (2022) applied multiple regression analysis (MRA) to analyze the impact of key operational variables/constructs on facility management (FM) service performance in higher education institutions of Malaysia. Their findings in the Malaysian context show a very strong associations between the constructs such as staff competence, budget allocations, and sustainable service delivery, and thus showing the importance of the value of statistical modelling in enhancing FM strategies. In lieu of these findings, the present study aims to develop a sustainable FM model using multiple regression analysis (MRA) within the context of South African universities, and hence, contributing both methodologically and practically to improve the FM systems in higher education institutions of South Africa.

2. LITERATURE REVIEW

The strategic management of facilities within the higher education institutions (HEIs) of South Africa has added a great importance within high demands for environmental sustainability, operational efficiency, and student satisfaction enhancement. As institutions in the world are shifting themselves for more sustainable operational models; facility management (FM) has been as an important driver of Sustainable campus (Opoku and Lee, 2022). Facility management (FM) now not only limited to routine maintenance and infrastructure but includes energy efficiency, resource conservation, and long-term asset planning as well. Though, many of the universities, particularly those belong to the developing countries still face challenges such as aging infrastructure, insufficiently funded maintenance systems, and inefficient resource allocation (Mazele & Amoah, 2022) and therefore these challenges highlights the need for data-driven frameworks to inform decision-making and support performance evaluation in facility management.

Quantitative methods, particularly multiple regression analysis has been utilized in the literature very frequently with the objective of identifying and modelling the factors, therefore, the current study apply MRA to identify the factors that influence sustainable FM performance. This approach allows the researchers to assess the not only the degree/strength of the relationship but direction of relationships as well between dependent variables/constructs such as sustainability performance and user satisfaction and a wide range of various independent variables/factors, which includes energy consumption, maintenance expenditure, building age, and staff capacity (Shohet & Lavy, 2021). Wilkinson and Reed (2023) has developed a regression-based FM performance predictive model which effectively predicts the levels of asset deterioration using variables/factors such as inspection frequency and repair response times using the MRA technique. Their results allowed the higher education institutions to adjust/modify the priorities in the maintenance so that to enhance performance and hence minimize lifecycle costs. Therefore, it can be said that such models not only allows the predictive planning within the organisations but also offer a robust statistical basis for benchmarking the performance across different campuses.

Within the South African context, there are high level of challenges to modernise these FM systems; however, only very few studies have utilised advanced statistical approaches, such as multiple regression analysis, to support decision-making. Chikafalimani, Kibwami and Moyo (2021) in their study finds that many universities function without the dependable performance indicators or predictive tools, thereby leading into a reactive maintenance culture and limiting their ability as well to allocate resources in a strategic way. A study by Elliott and Shin (2017) found that a no. of student's make a complain that various facilities such as accommodation, laboratories, and service delivery are significantly associated with factors such as maintenance delays and staffing shortages relationships, and the same findings were empirically validated using multiple regression analysis (MRA). Therefore, these findings show the practical application of regression technique such as MRA in facility management of higher education intuitions and point to their broader relevance across different context of the institutions.

Also, multiple regression analysis offers a robust method for analysing the joint impact of various predictors on sustainability outcomes, so that the researcher can identify the most impactful drivers (with the help of regression coefficient). Lu, Olanrewaju and Tan (2022) in their study applied multiple regression analysis (MRA) to analyze the performance of FM sustainability in Malaysian universities, finding that maintenance budgets, staff training, and building condition scores were the significant determinants of the user satisfaction and environmental efficiency. This approach allows institutions to move ahead rather than using simple descriptive analysis by producing actionable insights that inform long-term planning, prioritisation, and accountability in facility management.

Despite the availability of these advanced techniques, it has been observed that there is still a shortage of institution-specific, data-driven frameworks that systematically utilize the regression-based insights into operational FM models. Most of the existing FM systems in higher education institutions still depend on historical expenditure patterns and subjective evaluations rather than statistically validated forecasting approaches. In view of this, Mazele and Amoah (2022) contend that addressing this gap showing a necessary shift from intuition-driven to evidence-based infrastructure planning. By incorporating the MRA into FM decision-making supports a more practical & advanced management approach that maps with institutional sustainability goals, enhances performance, and improves the overall experience for both students and staff.

The literature confirms that sustainable facility management (FM) in higher education can greatly benefit from the use of multiple regression analysis. This technique enables universities to identify key performance variables, model complex relationships, and more accurately predict infrastructure outcomes. Although international studies have demonstrated its effectiveness, South African HEIs continue to lag in adopting predictive, analytics-based FM approaches. This study seeks to bridge this gap by developing a sustainable facility management model grounded in multiple regression analysis and adapted to the operational context of higher education institutions in South Africa.

3. METHODOLOGY

This present study utilize a quantitative research design to build a predictive model for prediction of sustainable facility management (FM) performance in higher education institutions (HEIs) of South Africa. Quantitative methods allows the researcher to collect and analyse of numerical data for the purpose of hypothesis testing and determining the relationship among variables/constructs (Creswell & Creswell. 2018). A self-structured questionnaire was designed and used to collect data from key stakeholders of facility management from selected HEIs of South Africa, which includes persons looking after the maintenance, facility managers, and infrastructure administrators. The author used the quantitative research design for this study because it helps us to find a snapshot of perceptions and operational indicators for a specific period, and hence enabling the application of statistical techniques such as multiple regression analysis (MRA) for model development (Saunders. Lewis & Thornhill. 2019).

The target population for the present study is considered the facility management professionals who are working in South African universities. A purposive sampling approach was used to identify respondents with relevant expertise in FM operations and sustainability planning. Data were gathered using a structured questionnaire adapted from validated instruments used in previous FM research (Lu. Olanrewaju & Tan. 2022). The instrument included Likert-scale items measuring key constructs such as classes of facility defaults, factors contributing to poor FM. root causes to poor FM. strategies used in FM and sustainability of FM. Lean. Six Sigma (LSS). Value Steam Mapping and Sustainable FM. A pilot test involving 10 FM professionals was conducted to assess the clarity and reliability of the questionnaire prior to full implementation. Data were collected electronically to enhance accessibility and improve the response rate.

Data analysis was conducted using IBM SPSS (Version 30). Descriptive statistics were first used to summarize the data followed by multiple linear regression analysis to identify the predictors of sustainable FM performance. Regression modelling is particularly suitable for quantifying the strength of relationships among multiple independent variables and a dependent variable, thus supporting the development of a predictive model (Pallant. 2020). The assumptions of regression analysis, namely linearity, independence of errors, homoscedasticity and multicollinearity were tested to ensure model validity. The final model identified statistically significant predictors of sustainability performance, which were then used to propose an empirically grounded FM framework for HEIs.

A multiple linear regression model was used to investigate the relationship between sustainable facility management (the dependent variable) and five (5) independent drivers (independent variables)

The general form of the regression equation was observed as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5$$

Where:

Y = Dependent variable (Sustainable facility management)

β_0 = Intercept (Constant)

$X_1 \ldots X_5$ = Facility management independent variables

β_1 to β_5 = Coefficients for each independent variable

4. RESULTS AND FINDINGS

This section presents the key findings of the study based on the analyses conducted. Tables, figures, and interpretation are included to support and clarify the outcomes. The demographic information of the study respondents is illustrated in Table 1. According to the respondents' distribution among campuses. Arcadia 47 (14.4%). Art 37 (11.3%). Pretoria West 85 (26.1%). Soshanguve 97 (29.8%) and Ga-Rankuwa 60 (18.4%). Given the size of the campuses and the fact that the majority of survey participants were students from Soshanguve Campus, the distribution of respondents per campus is largely consistent. Regarding age group. 266 (81.6%) of the participants were under 25. followed by 59 (18.1%) who were between 25 and 40 and the least number of participants (0.3%) were between 41 and 55. According to the respondents' highest level of education. 6 (1.8%) did not complete matric level. 214 (65.6%) had completed matriculation. 50 (15.3%) had bachelor's degrees. 9 (2.8%) had honours degrees. 1 (0.3%) had masters degrees and 46 (14.1%) had other credentials. such as diplomas. Finally. Table 1 also indicates that the majority of respondents. 284 (87.1%). held various work-related occupations. followed by cleaners. 32 (9.8%) and facility managers (0.3%). rest managers (0.3%) and maintenance coordinators (0.3%).

Table 1: Demographic Details

Variable	Levels: N (%)	Graph
Campus	Arcadia : 47 (14.4%)	
	Art : 37 (11.3%)	
	Pretoria West : 85 (26.1%)	
	Soshanguwe : 97 (29.8%)	
	Ga_Rankuwa : 60 (18.4%)	
Age	Less than 25 years : 266 (81.6%)	
	Between 25 and 40 years : 59 (18.1%)	
	Between 41 and 55 years : 1 (0.3%)	
Level of Education	Less than Matric : 6 (1.8%)	
	Matric : 214 (65.6%)	
	Bachelor's Degree : 50 (15.3%)	
	honor's Degree : 9 (2.8%)	
	Master's Degree : 1 (0.3%)	
	Other Qualifications : 46 (14.1%)	
Job Position	Facility Manager : 1 (0.3%)	
	Facility Controller : 4 (1.2%)	
	Artisan : 3 (0.9%)	
	Rest Manager : 1 (0.3%)	
	Cleaner : 32 (9.8%)	
	Maintenance Coordinator : 1 (0.3%)	
	Other Job Positions : 284 (87.1%)	

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. 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. i.e. 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. i.e. 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 2.

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, 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.

Table 2: 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	7.382	4.238	2.536	2.107	1.905	1.586
% of Variance	21.71	12.464	7.458	6.196	5.603	4.666
Cronbach`s Alpha Coefficient	.880	.896	.858	.863	.849	.807
Constructs Abbreviations	SFM	FCFM	SFMS	LSS	RCFM	CFD

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 2) and are all above the recommended value of 0.5. which implies a stronger relationship between the factor and the observed variable (Hair et al., 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 utilized. The Cronbach`s Alpha Coefficient ranges from 0 to 1. with 0.7 considered to be the lower level of acceptability (Hair et al.. 2010). The study`s Cronbach`s Alpha Coefficient values range from 0.807 to 0.896 suggesting that the measuring instrument was reliable.

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.

Table 3: Correlation Analysis Results

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
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).

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 Lotfian et al. (2025), 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).

It is evident from Table 3 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.

Multiple Linear Regression Analysis

In this study, the multiple linear regression analysis was conducted 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.

Table 4: ANOVA Table

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 illustrates an Analysis of Variance (ANOVA) table that appears to summarize 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.

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.

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 may be used to assess multicollinearity. Multicollinearity is indicated when two independent variables exhibit a bivariate correlation of 0.7 or above (Pallant. 2020). As shown in Table 3, the model is not affected by multicollinearity, since none of the independent variables display bivariate correlations of 0.7 or higher.

Assumption of Normality

According to the normality assumption, the residuals in the Regression Standardized Residual Normal Probability Plot (P–P) should exhibit a linear relationship with the predicted scores of the dependent variable (Pallant. 2016). This assumption can be assessed using the Normal P–P Plot produced by statistical software such as SPSS.

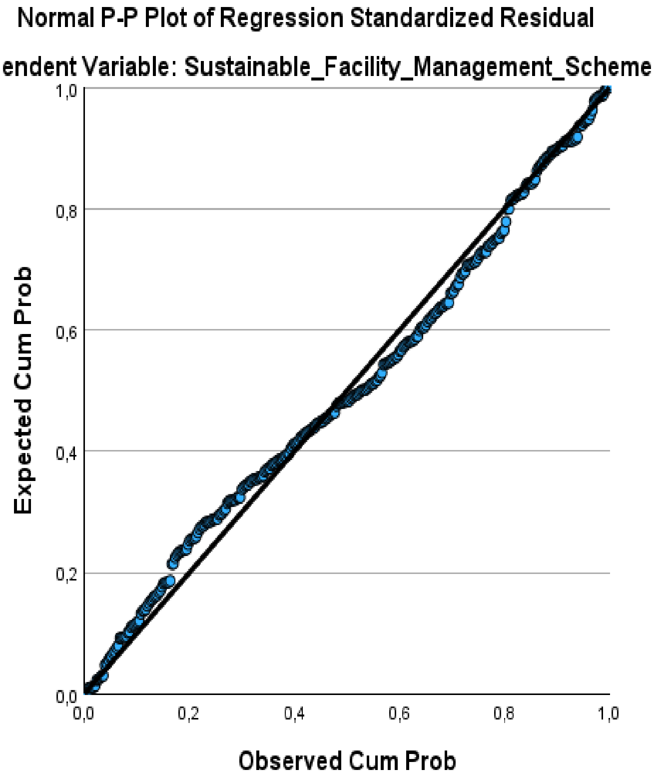

Figure 1: Scree Plot: Normal P-P Plot of Regression Standardized Residual

Figure 1 shows that the residuals closely follow the diagonal line without any notable systematic deviations, indicating that the normality assumption has been satisfied.

Assumption of Homoscedasticity

As per Pallant (2020), the assumption of homoscedasticity, the variance of the residuals for the predicted values of the dependent variable or construct should remain constant for all the predicted values. Heteroscedasticity, which refers to a change in the spread of the residuals across different levels of the predictors, can lead to biased coefficient estimates and affect the p-values accuracy and confidence intervals, making them unreliable. The assumption of homoscedasticity can be evaluated using scatterplot diagram, which can be produced using any statistical software such as SPSS. R. Jamovi etc.

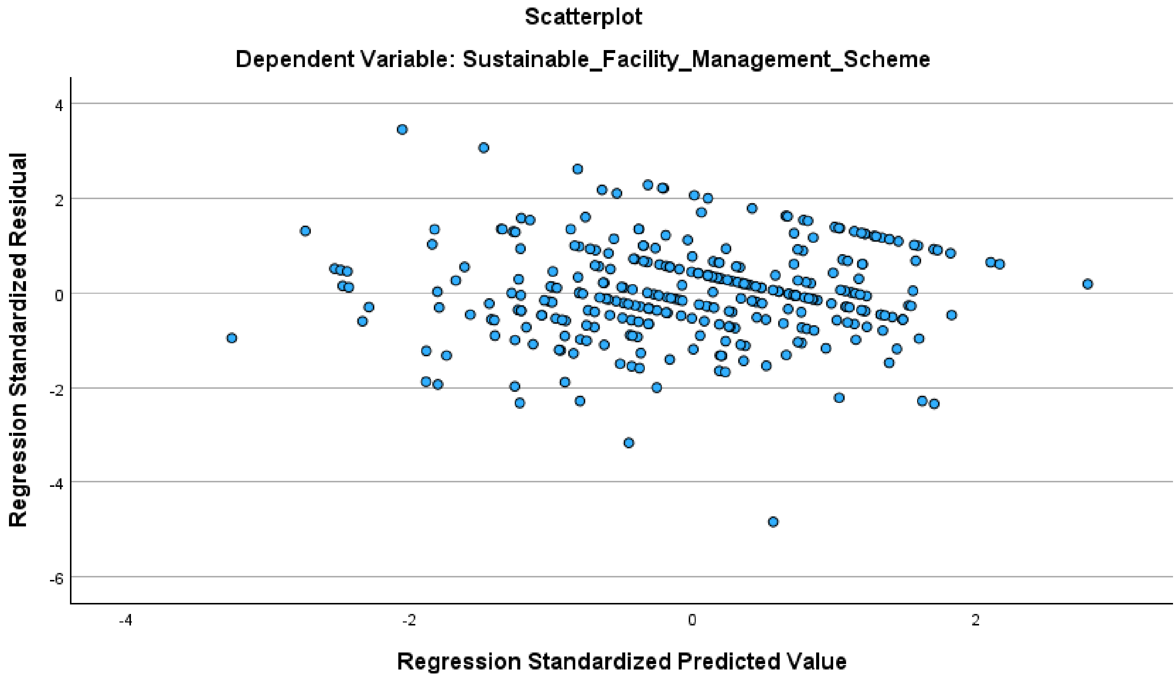

Figure 2: Scatter Plot

As can be shown in Figure 42 there is no discernible pattern in the residuals plotted, suggesting that the model does not suffer from heteroscedasticity.

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 5: Critical values for evaluating Mahalanobis distance values (Source: Tabachnick and Fidell, 2007)

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 5 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 6: Residual Statistics

Residuals Statistics[a]	Minimum	Maximum	Mean	Std. Deviation	N
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
Centered Leverage Value	.001	.058	.016	.012	322

a. Dependent Variable: Sustainable Facility Management Scheme

Table 6 shows that the critical value determining the Mahalanobis distance for five independent variables (as per this study) is 20.52. Table 6 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.

Evaluating the Model

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

Table 7: 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 7 reveals that the multiple linear regression model explains 31.6% of the variance in Sustainable Facility Management 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 Loftian et al. (2025), indicates that the independent 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 explain the variation in Sustainable Facility Management Scheme sufficiently.

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 Facility Management, Classes of Facility Defaults, Strategies Used in Facility Management and Root Causes to Poor Facility Management on Sustainable Facility Management Scheme.

Table 8 depicts that Classes of Facility Defaults (p-value = 0.028). Factors Contributing to Poor Facility Management (p-value < 0.05). Root Causes to Poor Facility Management (p-value < 0.05). Strategies Used in Facility Management (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 Facility Management and Root Causes to Poor Facility Management had a negative influence on the Sustainable Facility Management 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.

Table 8: Regression Coefficients of the Model

Model		Unstandardized Coefficients		Standardized 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

5. DISCUSSION

The findings of this study provide important insights with the help of multiple regression analysis in context of the facility management (FM) in South African Universities of Technology, in respect to the shift toward sustainable FM practices. The demographic profile of respondents indicates that a larger proportion in the age group of the students was below the age of 25 and mainly they belongs to the Soshanguve campus. Most of the participants who were surveyed were found to have matric qualification only, however, a small number were employed in FM-related positions. This points to a possible gap between individuals who experience facility-related challenges on a daily basis and those responsible for managing and maintaining these facilities. It further suggested that existing FM systems may not fully incorporate diverse stakeholder perspectives, which are found to be critical for developing a responsive and sustainable facility management approach.

With the help of Exploratory Factor Analysis (EFA), the study verified the structural validity of six main constructs, namely, Strategies Used in Facility Management, Factors Contributing to Poor Facility Management, Sustainable Facility Management Scheme, Lean Six Sigma, Root Causes of Poor Facility Management, and Classes of Facility Defaults. All the six key constructs show a strong internal consistency as the value of the Cronbach's alpha for all the constructs were found to range between 0.807-0.896. The high value of the KMO test i.e. 0.845, along with the statistically significant Bartlett's Test of Sphericity ($p < 0.001$), validated the suitability of the collected data for conducting the factor analysis. These findings also show that the data collected was reliable and robust and therefore supporting its applicability in similar contexts (for other countries also) and future research on facility management in higher education institutions.

Further, by applying the correlation, the study has identified statistically significant relationships among the study constructs/factors. The Sustainable Facility Management Scheme showed negative correlations with Classes of Facility Defaults ($r = -0.281$), Factors Contributing to Poor Facility Management ($r = -0.388$), and Root Causes of Poor Facility Management ($r = -0.423$). These results indicate that systemic inefficiencies, fragmented processes, and fundamental weaknesses in existing FM practices pose major obstacles to achieving sustainability. Conversely, positive relationships were observed between the Sustainable Facility Management Scheme and both Lean Six Sigma ($r = 0.190$) and Strategies Used in Facility Management ($r = 0.393$). These findings imply that strategic planning and continuous improvement methodologies such as Lean Six Sigma can enhance FM outcomes when properly implemented.

The multiple regression analysis provided further insights into these relationships. The model was statistically significant ($F = 29.247$, p-value < 0.001) and accounted for 31.6% of the variance in Sustainable Facility Management Scheme outcomes. All five predictors, Lean Six Sigma, Factors Contributing to Poor Facility Management, Classes of Facility Defaults, Strategies Used in Facility Management, and Root Causes of Poor Facility Management were found to be statistically significant. Strategies Used in Facility Management ($\beta = 0.200$; p-value < 0.001) and Lean Six Sigma ($\beta = 0.096$; p-value $= 0.028$) had positive effects on the dependent variable, suggesting their contribution as enablers of sustainable FM practices. In contrast, Classes of Facility Defaults ($\beta = -0.108$; p-value $= 0.028$), Contributing Factors ($\beta = -0.216$; p-value < 0.001), and Root Causes ($\beta = -0.238$; p-value < 0.001) exerted negative effects, highlighting underlying operational challenges that impede progress.

Overall, the findings indicate that although strategic interventions and quality improvement approaches such as Lean Six Sigma can improve the sustainability of facility management, their effectiveness depends on addressing underlying systemic inefficiencies and existing operational deficiencies. The relatively moderate R^2 value of 0.316 suggests that additional unmeasured factors such as leadership commitment, institutional governance, and financial investment may also play a significant role in shaping FM sustainability. Consequently, for universities to achieve fully sustainable FM systems, a dual approach is required: one that resolves entrenched operational challenges while simultaneously integrating proactive, evidence-based strategies into routine FM practices.

6. CONCLUSION

This study aimed to investigate the key factors affecting the implementation of a Sustainable Facility Management (FM) Scheme in South African Universities of Technology. Using a comprehensive analytical approach that included exploratory factor analysis, correlation analysis, and multiple linear regression, the study identified six key constructs: Strategies Used in Facility Management, Lean Six Sigma (LSS), Root Causes of Poor Facility Management, Classes of Facility Defaults, Factors Contributing to Poor Facility Management, and the Sustainable Facility Management Scheme. The results confirmed the reliability and validity of these constructs, underscoring their interconnected influence on the development of sustainable FM systems.

The findings indicate that systemic inefficiencies reflected in entrenched defaults, operational weaknesses, and poor management practices continue to pose significant barriers to FM sustainability in the higher education sector. The negative relationships between these inefficiencies and sustainable FM outcomes highlight the detrimental effects of aging infrastructure, insufficient maintenance strategies, and institutional misalignment. Conversely, the study shows that the use of structured approaches such as Lean Six Sigma, along with the adoption of proactive strategies, contributes positively to achieving sustainable FM objectives.

The regression model indicated that although enabling factors such as Lean Six Sigma and FM strategies are important, they are not sufficient on their own unless supported by structural reforms that tackle root causes and systemic barriers. The moderate explanatory power of the model further implies that additional factors such as leadership, stakeholder engagement, funding mechanisms, and institutional culture should be considered in future studies. For South African Universities of Technology to achieve genuinely sustainable FM systems, a dual approach is necessary: one that addresses underlying structural weaknesses while embedding evidence-based planning and process improvement frameworks. Only through such an integrated strategy can universities ensure that their facilities are managed efficiently, sustainably, and in a manner that responds effectively to the needs of all stakeholders.

7. MANAGERIAL APPLICATION

This study provides important guidance for facility managers, administrators, and policymakers seeking to implement sustainable FM in South African Universities of Technology. First, it demonstrates how legacy infrastructure and operational inefficiencies such as inadequate maintenance planning and weak accountability adversely affect FM performance. To address these underlying challenges, managers should apply tools such as maintenance audits and gap analyses to identify and resolve root causes. Secondly, the proven effectiveness of Lean Six Sigma (LSS) highlights the importance of continuous improvement practices. Equipping FM teams with LSS training and implementing tools such as value stream mapping and performance dashboards can support the standardization of processes and enhance service delivery quality. Thirdly, it is essential to align facility management with institutional strategy. Sustainability objectives should be integrated into policies, budgeting processes, and performance frameworks, with support from cross-departmental collaboration. In addition, FM practices should be tailored to the specific challenges of each campus and guided by assessments and user feedback to improve responsiveness. Capacity building and stakeholder engagement are also crucial. Managers should encourage inclusive planning processes, transparent reporting practices, and regular performance evaluations to strengthen accountability and promote shared responsibility for FM outcomes.

8. FUTURE RESEARCH

While this study provides important insights into sustainable facility management (FM) in South African Universities of Technology, further research is still required. Future studies should examine how institutional leadership, governance structures, and organizational culture affect the implementation of Lean Six Sigma within FM practices. Expanding stakeholder participation particularly among technical and managerial personnel would also enhance understanding of operational challenges. In addition, financial sustainability, including issues of budgeting and funding models, requires more in-depth investigation. Longitudinal research is recommended to evaluate the long-term effectiveness of FM strategies. Furthermore, the use of digital technologies such as Building Information Modelling (BIM), the Internet of Things (IoT), and Computer-Aided Facilities Management (CAFM) systems in enabling smart, sustainable campuses aligned with Industry 4.0 should be prioritized in future studies.

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