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A Maintenance Framework for Sustainability of Green Buildings: A Case of Nairobi County, Kenya

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Stern questions have been raised concerning green buildings, a new fragment in the construction industry, particularly in Kenya where the local content is scanty in respect to their maintenance. In that case, this research was directed towards the assessment of the maintenance factors (maintenance policies, maintenance problems, maintenance management tools/techniques and maintenance strategies) and their effect on sustainability of green buildings in Nairobi County. The study was bound to a sample size of 86 registered green building practitioners and 25 LEED-certified buildings in the County. The response rate of the survey was 53% and a quantitative approach was employed in data analysis. The study results revealed that, maintenance strategy (an independent variable) lacked a significant relationship with the dependent variable and therefore, it was removed from the logit model. The overall logit model indicates that, sustainability of green buildings has higher odds when maintenance problems are properly managed (odds of 1.44), comprehensive maintenance policies are existing (odds of 3.72) and appropriate maintenance management tools/techniques are used (odds of 2.89) while keeping all other factors constant. Consequently, the study recommends a framework to facilitate efficient work execution by maintenance personnel in green buildings. From an academic viewpoint, the study results present more information to the available body of knowledge in the field of maintenance of green buildings.

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INTRODUCTION

According to Doos et al. (2016), green buildings require maintenance to achieve their intended use and meet the various advanced functional requirements. Green buildings are described by Bombugala and Atputharajah (2010) as structures built using processes that are eco-friendly and resource-efficient. Fawaz (2013) recognizes maintenance as an array of coordinated administrative and specialized activities that are executed to re-establish an item to a state in which it can accomplish an obligatory role. The researcher further echoes that, in the Kenyan construction industry, green buildings are quite a new concept and their performance in terms of maintenance is scantily documented. The Dunhill Towers in Westlands is among the few buildings known for their green status; however, conventional maintenance practices are still evident in most green property management firms as described by Fawaz (ibid). This brings about a disjointed maintenance process which results into ineffective mechanical systems, customer grievances due to the dissatisfaction brought about by the conditions of their facility and ultimately higher maintenance expenses and service bills.

From worldwide experiences, people are led to believe that maintenance policies are the surest means of preserving resource-efficient buildings during their operational period (Mohanty, 2012). With the policies, the maintenance practitioners are provided with a management framework that dictates the most suitable managerial

tools/techniques and maintenance strategy (Lee & Scott, 2009). Normally, there are numerous strategic alternatives available for maintenance works. For example, condition-based, corrective, and preventive maintenance. Fawaz (2013) opines that as firms adopt regular maintenance, availing appropriate managerial tools and gauging methodologies is becoming increasingly important in maintaining and augmenting their green performance. In order to encourage additional strategic maintenance methods (predictive, preventive), Bortolini et al. (2016) has envisioned advanced methods such as Building Information Modeling (BIM) as a quick fix to most of the observed managerial issues during maintenance of green buildings. For many of the logistical roles undertaken by maintenance management and staff to be automated, Azahar and Mydin (2014) propose using a computerized maintenance management system. Bombugala and Atputharajah (2010) admit that, well-organized maintenance management of green buildings leads to a reduction in energy usage, solid waste, water usage, and carbon emissions by 50%, 70%, 40% and 35%, respectively. Consequently, a change in paradigm is required to combat the disjointed maintenance process of green buildings (Fawaz, 2013). To sort the overlooked issue, this research is focused on formulating a framework that will probably bring consistency in the aspects of planning, execution and keeping track of maintenance works in green buildings.

STUDY OBJECTIVES

- To establish the relationship between maintenance factors and sustainability of green buildings.
- To develop a framework which will guide maintenance practices in green buildings.

MATERIALS AND METHODS

The research used a survey design on a sample size of 86 registered green building practitioners and 25 LEED-certified buildings in the County of Nairobi. Two methods of sampling were utilized: a simple random sampling method for registered green building practitioners and a census for the LEED-certified buildings. Data collection was carried out using questionnaires which realized a response rate of 53%. Analysis of inferential and descriptive statistical data was made possible by using R software version 3.4.3 and the results were presented as mathematical equations, bar charts, and tables.

RESULTS AND DISCUSSION

Respondents’ Demographic Characteristics

The results showed that 88% of the respondents have less than five years of working experience whereas the remaining 12% of the respondents have a range of five to ten years of job experience. Since most respondents have less than five years of work experience, it aligns itself to the notion that, green buildings are quite a new concept in the Kenyan construction industry.

Correlation Analysis

When sustainability of green buildings and maintenance management techniques/tools have a positive correlation, it is indicative that an increase in the independent variable value creates a domino effect on the dependent variable by increasing its value. However, when the remaining three independent variables (maintenance strategies, maintenance policies, and maintenance problems) together with sustainability of green buildings have a negative correlation, it is indicative that an independent variable value increase causes a value decrease on the dependent variable. On the flip side, an independent variable value decrease causes an increase in value on the dependent variable.

Table 1: Spearman’s Rank Correlations

	Sustainability	Problems	Policies	Strategies	Tools
Sustainability	1.0000000	-0.2045225	-0.02219276	-0.06120823	0.2527113
Problems	-0.20452254	1.0000000	-0.08863170	0.25410431	-0.1872761
Policies	-0.02219276	-0.0886317	1.00000000	0.2754239	0.2754239
Strategies	-0.06120823	0.2541043	-0.27123000	1.00000000	-0.5106659
Tools	0.25271128	-0.1872761	0.27542393	-0.51066590	1.00000000

Binary Logistic Regression

Considering that the research outcome (dependent variable) was dichotomous, the most appropriate regression technique to employ was binary logistic regression. The first logit model (Model 1) entailed variables that were captured in the questionnaire; the equation is as shown below.

$$\text{Sustainability} = \beta(\text{strategies}) + \beta(\text{tools}) + \beta(\text{policies}) + \beta(\text{problems}) + \beta_0 + \epsilon_i \quad (1)$$

Where; Strategies = Maintenance Strategies, Tools = Maintenance Management Tools/ Techniques, Policies = Maintenance Policies; Problems = Maintenance Problems; Sustainability = Sustainability of Green Buildings, β_0 = Intercept & ϵ_i = Error term.

Employing the “Hosmer-Lemeshow goodness-of-fit test” of χ^2 at d.f= 3, 9.2078, p-value = 0.0267 (p <.05) did not give Model 1 a good overall fit for the data which infers that the model does not fit the data at $\alpha = 0.05$. Moreover, for the maintenance

strategies, the model produced a non-significant coefficient. To resolve this issue the maintenance strategy variable was dropped since it appeared to lack a substantial association with the outcome variable in the model. Therefore, a better model (Model 2) was formulated as shown below.

$$\text{Sustainability} = \beta(\text{tools}) + \beta(\text{policies}) + \beta(\text{problems}) + \beta_0 + \epsilon_i \quad (2)$$

The new model fits well with the data at $\alpha = 0.05$ with a “Hosmer-Lemeshow goodness-of-fit test” of χ^2 at d.f = 2, 5.9879, p-value = 0.05009 ($p > .05$). Table 2 provides a rundown of the two models.

Table 2: Logistic Regression Models

Variables	Model 1			Model 2		
	β	SE	OR	β	SE	OR
Constant	-5.3432***	0.2783	0.01	-5.2569***	0.2654	0.01
Problems	0.3587***	0.0098	1.43	0.3639***	0.0093	1.44
Policies	1.2905***	0.0507	3.64	1.3128***	0.0481	3.72
Tools	0.6273*	0.2572	3.05	0.5976*	0.2449	2.89
Strategies	0.1841	0.2677	1.20			
-2LL	1294.2			1397.7		
χ^2	2588.4, df = 4, p<.001.			2795.4, df = 3, p<.001.		
Nagelkerke R ²	28.01%			27.82%		

*** = $p < .001$; * = $p < .05$; OR -Odds Ratio; SE - Standard Error

Regression Output Interpretation

At d.f = 3, 2795.4, p-value = 2.2×10^{-16} ($p < .001$), the Likelihood Ratio Test (LRT) is χ^2 which provides the overall significance of the logistic model that suggests at $\alpha = 0.05$ the maintenance factors remarkably aid in the forecasting of green buildings sustainability. Consequently, it can be concluded that factors in the equation analysis have a statistical significance. The Wald tests can be additional confirmation as it evaluates the worth of each coefficient in the model. Table 3 illustrates the Wald tests for every coefficient.

When considering maintenance factors of green buildings, coefficients of the logistic regression give the log-odds amount, either increase or decrease, in sustainability of green buildings. It was easier to interpret the maintenance factors’ log odds when they were first converted to odds ratios. Here is a comprehensive elucidation of the odd ratios from Table 2.

Maintenance Problems

Green buildings have 1.44 times reduced odds of reaping benefits when maintenance problems are badly controlled compared to properly managing

maintenance problems while keeping all other factors controlled.

Maintenance Policies

There are 3.72 times increased odds of making green buildings valuable when suitable maintenance policies are implemented compared to implementing inadequate maintenance policies while maintaining all other factors constant.

Maintenance Management Techniques/Tools

Green buildings have 2.89 times increased odds of reaping benefits when maintenance techniques/tools are properly adopted compared to approving inappropriate maintenance management techniques/tools while keeping all other factors controlled.

Intercept

This signifies the logit of probability of reaping benefits from green buildings when all the maintenance factors are lacking. Hence, the constant for the intercept signifies a -5.2569 log-odds decrease in reaping benefits from green buildings; assuming that all the maintenance factors are lacking.

Table 3: The Wald Tests

Coefficients	χ^2	d.f	Wald	95% confidence interval	
Constant	392.4	1	-19.8***	-5.7891	-4.7461
Maintenance Problems	746.4	1	27.3***	1.2189	1.4073
Maintenance Policies	1504.5	1	38.8***	0.3457	0.3825
Maintenance Tools	6.0	1	2.44*	0.1271	1.0904

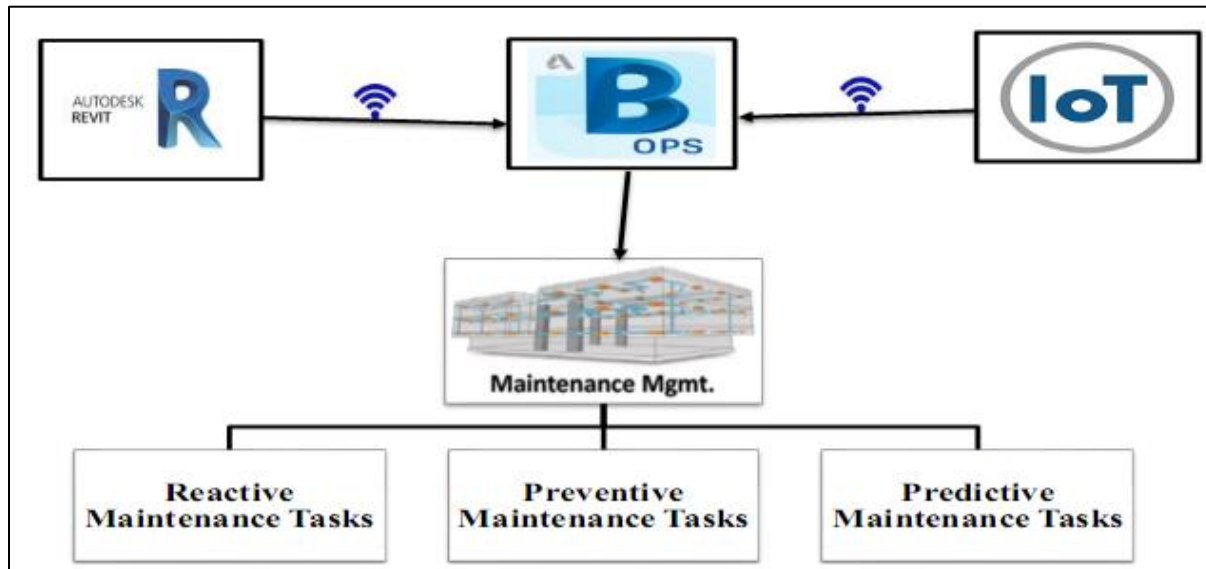
d.f - Degree of Freedom; *** = $p < .001$; * = $p < .05$

MAINTENANCE FRAMEWORK

The framework is informed by the data analysis findings. This framework will allow green building practitioners and facility managers to realize consistency in the aspects of planning, execution and keeping track of maintenance works in green

buildings. This subtopic thus touches on the constituents of the conceptualized framework of maintenance management (*Figure 1*). Internet access (Wi-Fi) is needed for the named maintenance management tools in the framework to operate as purposed.

Figure 1: Maintenance Framework



Source: Author’s own composition, 2022

Autodesk Revit As-Built Model

Accessibility to greater opportunities for process enhancements all through the operation and maintenance phase is made possible when there is current and more accurate information at the disposal of facility managers (Matarneh et al., 2018). As Kensek (2015) argues, one important function of an as-built Revit model is to run as a component to a well-planned facilities management system; through data supply of the graphical and spatial elements, together with data that can fill the Construction Operations Building Information

Exchange (COBie) worksheets. COBie worksheets provide non-geometric structured data, which is accessible to the facility management team to use for a better facility handover process.

IoT Beacons & Smart Sensors

According to the Institute of Workplace and Facilities Management (2018), the Internet of Things (IoT) is described as the mesh of physical objects and gadgets entrenched with network connectivity, sensors, software and electronics which allow these objects to collect and exchange

data. Smart contemporary buildings utilize smart sensors and beacons to improve maintenance efficiency. IoT sensors in facility management are of two main types. The first type is a humidity and temperature control sensor. This gadget keeps tabs on changes in the environment to keep inhabitants relaxed while not bestowing them with full control of a thermostat in a room (McGaw & Miller, 2019). The other type is a machine listening and vibration detection sensor. This device is placed on large mechanical equipment and in case of performance changes or equipment failures they alert facility managers. A panoramic power sensor is a good example that can be consolidated with BIM 360 Ops. The IoT junctions are what is known as beacons. Beacons bind dozens of installed sensors together in a workplace and convey continuous data that sensors transmit (Livnat, 2020). That is to say, the IoT is controlled by beacons, which create order.

Autodesk BIM 360 Ops

BIM 360 Ops is a web-built service that enables maintenance staff to kickstart maintenance of assets through the addition of assets from IoT solutions, BIM 360 Field, Revit and also spreadsheets. Installation of the BIM 360 Ops Exporter is vital before exporting assets and/or locations. Assets that can be seen comprise maintenance and scheduling history, maintenance checklists, models, and documents. It incorporates providing work orders (creating tickets using smart gadgets; tablet or phone where, for example, accessing and updating asset data while in the field can be carried out with the help of maintenance personnel and with no need for hard copy manuals or paper tickets) and management for predictive, preventative, and reactive maintenance (Autodesk, 2022). Instantaneous maintenance can be achieved through BIM 360 Ops which enables signals for work teams and conveys accurate information to precise staff at an exact time. A tidy Graphical User Interface (GUI) is fixated on serviceability when conveying information because only applicable and valuable data is displayed to the end-users although all the back-end stuff is hidden for the more advanced admin or user.

CONCLUSION

The results revealed that, maintenance tools/techniques, maintenance policies, and maintenance problems significantly influence sustainability of green buildings. Amongst the three factors in equation analysis, maintenance policies emerged as the topmost factor. This aligns with Mohanty (2012) research results, which posit that maintenance policies are an unquestionable solution to maintaining the resource-efficient infrastructure which is eventually benefitting in the entire operational phase of buildings. Lastly, the findings emphasised why a change is required in green buildings maintenance management; therefore, the formulated framework will undoubtedly assist maintenance personnel to accomplish their tasks efficiently. From an academic viewpoint, the study results present more information to the available body of knowledge in the field of maintenance of green buildings. The following are study recommendations for further research;

- Being that this research confined itself to maintenance of green buildings, it would be enticing to research on maintenance of conventional buildings and then contrast the results.
- Also, forthcoming research need to examine the facet of green buildings from a perspective of the whole life cycle of the project because this research only confined itself to the maintenance and operation phase.

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