The Impact of Maintenance Factors on Sustainability of Green Buildings in Nairobi County, Kenya.

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Abstract: *Green buildings are relatively new in the construction industry, especially in Kenya and serious questions regarding their maintenance beg answers as little has been documented. This study therefore, sought to assess the impact of maintenance factors on sustainability of green buildings in Nairobi County. A survey to investigate; maintenance problems, maintenance policies, maintenance strategies and maintenance management tools/techniques in relation to sustainability of green buildings was delimited to a sample size of 25 LEED certified buildings in Nairobi County and 86 registered green building practitioners. The survey achieved 53% response rate and data analysis was carried out using a quantitative approach. The findings indicate that, the maintenance strategy variable seemed not to have a significant relationship with the outcome variable, hence it was dropped from the model. The final logistic regression model shows that, the odds for sustainability of green buildings are 1.44, 3.72 and 2.89 times higher when there is proper management of maintenance problems, adequate maintenance policies and proper maintenance management tools/techniques respectively, holding all other factors constant. The results highlighted the need of a paradigm shift in maintenance management of green buildings hence, the proposed framework in figure 2 that will enable maintenance personnel to execute their work in an efficient manner. From an academic perspective, the findings contribute to the pool of knowledge available in the area of green buildings maintenance.*

Keywords: Green Buildings, Sustainability, Maintenance.

I. INTRODUCTION

Like other infrastructures, green buildings need maintenance to keep their designed performance and to meet the upgraded different functional requirements (Doos et al., 2016). Bombugala and Atputharajah (2010) recognizes green buildings as structures created using processes that are environmentally responsible and resources-efficient through

the building life cycle. Fawaz (2013) defines maintenance as a set of organized activities, technical and administrative, that are carried out in order to retain an item in, or restore it to a state in which it can perform a required function. Green buildings are relatively new in the Kenyan construction industry and their performance in terms of maintenance management have not been adequately documented. Despite a few buildings such as the Dunhill Towers in Westlands boasting with the green status, Fawaz (2013) echoes that, most of the green property management companies still use the traditional maintenance management practices. This is a clear indication of a fragmented maintenance process that leads to inefficiency of mechanical systems, customer complaints due to dissatisfaction with their facility or space environmental conditions and eventually higher utility bills and maintenance costs. Experiences around the world lead us to believe that, maintenance policies are a sure way of maintaining resource-efficient infrastructure that will reap benefits over the whole operational phase of buildings (Mohanty, 2012). The policies provide a management framework to the maintenance personnel to determine appropriate maintenance strategy and managerial tools/techniques (Lee & Scott, 2009). There are usually several strategic options available in maintenance works; corrective, preventive and condition-based maintenance. As companies move toward regular maintenance, it is becoming increasingly important that they make available managerial tools and methodologies to gauge and to help not only maintain but improve their green performance (Fawaz, 2013). To support more planned maintenance approaches (preventive, predictive), innovative approaches such as Building Information Modelling (BIM) have been visualized by Bortolini et al. (2016) as a solution to most of the managerial problems witnessed during maintenance of green buildings. Azahar and Mydin (2014) recommends use of a computerized maintenance management system (CMMS) in order to automate most of the logistical functions performed by maintenance staff and management. Efficient maintenance management of green buildings is coupled with several advantages. Bombugala and Atputharajah (2010) acknowledge that, sound maintenance of the green building concept results into reduction of carbon emissions by 35%, water usage by 40%, the solid waste by 70% and energy usage by 50%. Therefore, a paradigm shift is needed to address the fragmented maintenance process of green buildings as highlighted by Fawaz (2013).

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To fill the existing gap, this study sought to develop a framework which will undoubtedly bring consistency in planning, implementation and monitoring of green buildings maintenance.

II. OBJECTIVES OF THE STUDY

- ✓ To examine the extent to which maintenance problems affects sustainability of green buildings.
- ✓ To establish the extent to which maintenance policies, strategies and management tools/techniques affects sustainability of green buildings.

Source: Author, 2020

- ✓ To formulate a framework to guide the quality of maintenance works in green buildings.

III. RESEARCH METHODOLOGY

The study utilized a survey research design and the sample size was made up of 25 LEED certified buildings in Nairobi County and 86 registered green building practitioners. Two sampling techniques were employed: first, a census for LEED certified buildings and secondly, simple random sampling technique for registered green building practitioners. Questionnaires were the only instruments for data collection and the survey achieved 53% response rate from the facility managers and the registered green building practitioners. Data analysis (descriptive and inferential statistics) was executed using R software version 3.4.3 and the results presented in form of tables, bar charts and mathematical equations.

IV. RESEARCH FINDINGS

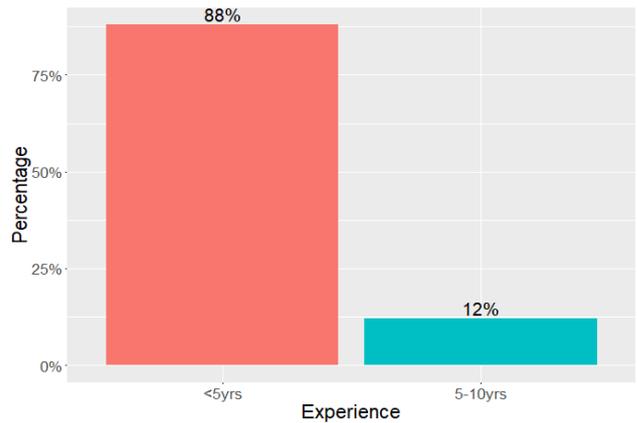### A. Demographic Characteristics of the Respondents

Fig. 1: Respondents Work Experience
Source: Field survey, 2020

Fig.1 depicts that, 88% of the respondents have work experience of less than five years while 12% of the respondents have worked for a period ranging from five to ten years. The high frequency of respondents working less than five years supports the belief that, green buildings are relatively new in the Kenyan construction industry.

B. Correlation Analysis

Table1: Spearman's Rank Correlations for the Variables

	Sustainability	Problems	Policies	Strategies	Tools
Sustainability	1	-0.2045225	-0.02219276	-0.0612082	0.2527113
Problems	-0.20452254	1	-0.0886317	0.2541043	-0.1872761
Policies	-0.02219276	-0.0886317	1	0.2754239	0.2754239
Strategies	-0.06120823	0.2541043	-0.27123	1	-0.5106659
Tools	0.25271128	-0.1872761	0.27542393	-0.5106659	1

A positive relationship between maintenance management tools/techniques and sustainability of green buildings indicates that, a value increase in the predictor variable causes a value increase in the dependent variable. Whereas, a negative relationship between the three variables (maintenance problems, maintenance policies, maintenance strategies) and sustainability of green buildings indicates that, a value increase in the predictor variable causes a value decrease in the dependent variable and vice versa.

C. Binary Logistic Regression

Given the dependent (outcome) variable for the study was dichotomous, binary logistic regression was carried out. The initial analysis of the logistic regression equation (Model 1) included the variable as per the questionnaire and the equation is as shown below.

Sustainability = βproblems + βpolicies + βtools + βstrategies + β$_{0}$ + ε$_i$

Whereby;

Sustainability = Sustainability of Green Buildings
Problems = Maintenance Problems

Policies = Maintenance Policies

Tools = Maintenance Management Tools/Techniques
Strategies = Maintenance Strategies

Model 1 did not provide an overall good fit for the data with a Hosmer Lemeshow goodness of fit test of $\chi 2$ at d.f = 3, 9.2078, p-value = 0.0267 (p <.05) which implies that at α = 0.05 the model does not fit the data. Furthermore, the above model did not yield to a significant coefficient for maintenance strategies. To remedy this a better model was developed by dropping the maintenance strategy variable which seemed not to have a significant relationship with the outcome variable in the model and the following logistic regression equation model (Model 2) was developed.

(1.1)

Sustainability = βproblems + βpolicies + βtools + β$_{0}$ + ε$_{i}$
Model 2 fits the data well at α = 0.05 with a Hosmer Lemeshow goodness of fit test of χ2 at d.f = 2, 5.9879, p-value = 0.05009 (p >.05). Table (2.2) provides a summary of both models.

Table 2: Logistic Regression Models

Variables	Model 1 β		SE	OR	Model 2 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	1.2				
-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%			

Notes:

*=p<.05; ***=p<.001.

SE   Standard Error

OR Odds Ratio

Source: Author, 2020

D. Regression Output Interpretation

The overall significance of the logistic model given by the Likelihood Ratio Test (LRT) is χ2 at d.f = 3, 2795.4, p-value = 2.2 e^-16 (p<.001) implies that at α = 0.05 the maintenance factors contribute significantly to the prediction of the sustainability of green buildings. We can therefore conclude that there is a statistical significance for factors under equation analysis. This can be further confirmed using Wald tests that are used to evaluate the significance of a single coefficient in the model. The Wald tests for each of the coefficients in the model are illustrated in table 3.

The logistic regression coefficients gave the amount of log odds increase/decrease in sustainability of green buildings when maintenance factors of green buildings are taken into consideration. The log odds for the maintenance factors were converted to odds ratios for easy interpretation. The following is a detailed explanation of the odds ratios from table 2.

➢ **Maintenance Problems**
Odds of realizing the benefits of green buildings is 1.44 times lower when maintenance problems are poorly handled compared to the proper management of maintenance problems controlling for all other factors.

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	1	2.44	*	0.1271	1.0904

Notes: *=p<.05; ***=p<.001.
d.f   Degree of Freedom

Source: Author, 2020

➢ **Maintenance Policies**
Odds of realizing the benefits of green buildings is 3.72 times higher when adequate maintenance policies are adopted compared to adoption of poor maintenance policies controlling for all other factors.

➢ **Maintenance Management Tools/Techniques**
Odds of realizing the benefits of green buildings is 2.89 times higher when proper maintenance tools/techniques are adopted compared to the adoption of improper

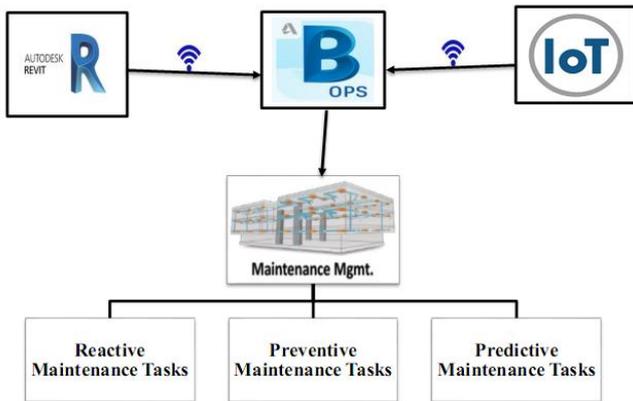maintenance management tools/techniques controlling for all other factors.

> ➤ **Intercept**

The intercept (constant) represents the logit of probability of realizing the benefits of green buildings if all the maintenance factors are absent.

Therefore, the coefficient for the intercept represents a decrease in the log odds by -5.2569 in realizing the benefits of green buildings, given that all the maintenance factors are absent.

V. PROPOSED FRAMEWORK.

The data analysis results informed this study's framework that will enable facility managers and green building practitioners to achieve consistency in planning, implementation and monitoring of green buildings maintenance. This section therefore highlights the components of the proposed maintenance management framework (Fig.2). Ultimately, the facility maintenance management tools named in the framework requires internet (Wi-Fi) to be able to function as intended.

Source: Author, 2020

Fig. 2: Maintenance Management Framework

a) Autodesk Revit As-Built Model

It is acknowledged that, the more accurate and real-time information is available for facility managers, the greater the opportunity for the enhancement of processes throughout the operation and maintenance phase (Matarneh et al., 2018). An as-built Revit model has a critical role to perform as a contributor to a well-designed facilities management (FM) system; by supplying data about all of the spatial and graphical elements, including data that can be used to populate the COBie worksheets (Kensek, 2015). Construction Operations Building Information Exchange (COBie) worksheets improves the facility handover process by providing a non-geometric structured data available for the facility management team use.

b) IoT Beacons & Smart Sensors

Internet of Things (IoT) can be defined as the network of physical devices and objects embedded with electronics, software, sensors and network connectivity which enable these objects to collect and exchange data (Institute of Workplace and Facilities Management, 2018). Today's smart buildings are utilizing beacons and smart sensors to increase maintenance efficiency. There are two major types of Internet

of Things (IoT) sensors in facility management. The first is temperature and humidity control sensors. These devices track environmental changes to keep occupants comfortable without giving them total control of a room's thermostat (McGaw & Miller, 2019). The second type of sensor is machine listening and vibration detection sensors. These sensors are placed on larger mechanical assets and alert facility managers of equipment failures or performance changes. A good example of sensors that can be integrated with BIM 360 Ops is the panoramic power sensors. Beacons are the nodes of the Internet of Things (IoT). In a workplace with dozens of deployed sensors, beacons tie them all together and relay the continuous data they're transmitting (Livnat, 2020). In other words, beacons are meant to bring order to the IoT.

c) Autodesk BIM 360 Ops

BIM 360 Ops is a web-based service that lets maintenance personnel to jumpstart asset maintenance by adding assets from Revit, BIM 360 Field, Internet of Things (IoT) solutions and even spreadsheets. Prior to exporting locations and/or assets it is important to install the BIM 360 Ops Exporter. Assets that can be viewed include: documents and models, maintenance checklists, scheduling and maintenance history. It also includes support for (Work Orders) ticket creation (by smart devices; phone or tablet where for instance maintenance personnel can access and update asset information while in the field without need for paper tickets or hard copy manuals) and management for reactive, preventative and predictive maintenance. BIM 360 Ops allows real time maintenance alerts for work teams and sends the right data to the right personnel at the right time. Information is conveyed through a tidy Graphical User Interface (GUI) that seems focused on usability, displaying only relevant and useful data to the end-users while hiding all the backend stuff for the more advanced user (or admin).

VI. CONCLUSIONS AND FUTURE RESEARCH

The findings indicate that, three maintenance factors (maintenance problems, maintenance policies and maintenance tools/techniques) contribute significantly to the prediction of the sustainability of green buildings. Maintenance policies emerged as the top most factor among those under equation analysis. This is in line with the findings of Mohanty (2012) who echoes that, maintenance policies are a sure way of maintaining resource-efficient infrastructure that will reap benefits over the whole operational phase of buildings. Finally, the results highlighted the need for a paradigm shift in maintenance management of green buildings hence, the proposed framework that will help maintenance personnel to execute their work in an efficient manner. From an academic perspective, the findings contribute to the pool of knowledge available in the area of green buildings maintenance.

The study recommends further research in the following two areas that could not be studied appropriately in the course of this work;

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✓ Since this study addressed the subject of maintenance management in green buildings, it would be interesting to study the same subject in conventional buildings and compare the results.

✓ Future studies are required to look into the aspect of green buildings from a whole project life cycle perspective as this study only concentrated on the operation and maintenance phase.

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