UNIVERSITY OF NAIROBI

MAINTENANCE MANAGEMENT
OF GREEN BUILDINGS IN NAIROBI COUNTY.

BY

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DECLARATION

I declare that this is my original work and has not been presented to any other university or institute of higher learning for examination or academic purposes.

Signature_____ **_____**

BISHER FAWAZ (Author) **DATE**
REG. NO B50-76781/2009

This research proposal has been presented for examination with my approval as the University supervisor.

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DEDICATION

I dedicate this project to my wife Elizabeth for her love and dedicated support,

To my son Benzima and daughter Leila for brightening up our lives and bringing constant joy to the family,

To my mother Nuru for all her prayers and continuous encouragement.

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First and foremost, to Allah, for it is in seeking him that I get my inspiration and have come to cross the many bridges of frustration.

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Although, all the above and others not mentioned helped in some ways in this study, I should stress that any inherent flaws in no way reflect their contribution and as such I take full responsibility for any errors or short comings herein.

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ABSTRACT

The shift from conventional building to sustainable 'green' building requires a change in the management of maintenance works. Green buildings significantly differ from conventional buildings in many aspects from design, materials used, equipment and maintenance requirements. The maintenance management practices of four green buildings were put under the microscope namely the Standard Chartered Bank building in Westlands, the Coca Cola building in Upper hill, the Strathmore University Business School in Madaraka and the UNEP building at Gigiri in Nairobi. However, the UNEP buildings had not yet been completed by the time of the study and therefore the researcher focused on the remaining three buildings. The three buildings were chosen because they were the only buildings in Nairobi to publicly declare their green status and openly use their green status to gain competitive advantage over competing firms in their respective industries. The three buildings therefore comprised the target population. The aim of this research was to establish the maintenance management process in these green buildings. The research was guided by four objectives namely: to establish the planning process in the maintenance of green buildings in Nairobi County; to identify the type of maintenance practices used in green buildings in Nairobi County; to establish the extent to which the maintenance works of green buildings in Nairobi affects their appraisal and to establish the strategies that improve the quality of maintenance works in green buildings in Nairobi County. The research was guided by relevant literature on maintenance of green buildings.

The research employed a cross-sectional descriptive research design and the respondents constituted the management of green buildings, regulatory association officials and professionals in the built environment who were involved in the design and construction and those currently involved in their management and maintenance.

The major research findings revealed that green buildings in Nairobi were seen to be rated based on how well they met criteria set by the Leadership in Energy and Environmental Design Rating System. The system awarded credit points to various aspects of the building that include: sustainable sites; water efficiency; energy; materials and resources and indoor environmental quality. The conclusion derived from the research is that maintenance

management is critically important in green buildings if they are to maintain their green ratings.

Based on the research findings, the following recommendations were made: the involvement of the maintenance team with respect to site selection should ensure that green buildings are not put up on sites that are environmentally sensitive; the maintenance team should be well trained on materials use and recycling; the maintenance team should also test the functionalities of all aspects of green buildings during commissioning before intended occupants move in; over time, building performance should be assured through measurement, adjustment, and upgrading and the management of the green buildings in Nairobi should invest in research on practical and effective operational and maintenance strategies for energy and water efficiency, conserving natural resources and protecting internal air quality among others.

As concerning future areas of research the researcher recommends focus on perceptions, knowledge, value and risk management of Green buildings in Kenya; opportunities available for professionals in the built environment and specifically maintenance managers to receive specialized training to enhance their knowledge in relation to each of the salient features of green building and research on the direct environmental, social and financial benefits Green buildings can bring to Kenya.

CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

A key global challenge of the twenty-first century is how to tackle climate change and reduce greenhouse gas emissions (United Nations, 2007). With buildings estimated to account for approximately half of all annual energy and greenhouse gas emissions, one potential solution is to ensure that the design, construction and maintenance of the built environment is environmentally sustainable (Brown, Southworth & Stovall 2005; Commission for Architecture and the Built Environment, 2007). Fortunately, there is a strong business case for sustainable or "green" buildings, with a substantial body of work outlining the environmental, economic and social benefits; for example, a recent survey of over 800 green building owners, developers, architects, engineers and consultants in Canada and the USA concluded that "green was good for asset value", with green buildings perceived as outperforming conventional commercial buildings in terms of occupant wellbeing, building value and return on investment (Davies, 2005). Less clear, however, is whether and how existing buildings, which make up the bulk of commercial office accommodation, should be retrofitted and refurbished for sustainability.

In the last decade, there has been significant international interest and support from governments, the construction and property development industry, private organizations and the general public for fostering a sustainable and climate-friendly built environment through building "green", carbon-reducing buildings."Green building" is a term used to describe a building that is more energy and resource efficient, releases less pollution into the air, soil and water, and is healthier for occupants than standard buildings. These are buildings which by an integrated and holistic approach to location, siting, design, specification and use of energy and resources, seek to minimize their environmental impact. Crucially, through the integration of innovative and efficient technologies, sustainable design approaches and environmentally sensitive site planning practices, the ecological footprint of new buildings is significantly reduced at a minimal financial cost (Kozlowski, 2003; Lucuik, 2005).

When the green movement started, a need appeared to rate practices and products in order to compare and contrast best practices. These would lead toward sustainability in construction through a series of principles aligned with the International Council for Research and Innovation in Building and Construction's (CIB's) seven principles of sustainable construction: reduce – resource consumption; reuse – resources; recycle – use recycled resources; protect – nature; eliminate – toxins; economics – apply lifecycle costing; and quality – focus in creating high performance buildings (Kibert, 1994).The implementation of these principles required a method for assessing the application with an open mind to innovation and experimentation, as well as rating the process and final product (Jawali and Fernández-Solís, 2008).

The Chartered Institute of Building defined the building maintenance as work undertaken to keep, restore or improve every facility, i.e. every part of a building, its services and surrounds to an agreed standard, determined by the balance between the need and available resources. It requires all departments in an organization to co-operate in ensuring that the assets of the organizations are planned, provided, maintained, operated and disposed off at the lowest total cost to the organization (Tan and Teo, 1998).

All buildings start to age from the moment they are completed and put in use (Arditi and Nawakorawit, 1998). Thus, maintenance is needed throughout the entire period that the building remains in use or in occupation, so that the various facilities are kept to stand consistent with overall policy (Lee and George, 1993) and to ensure its optimal performance over its life cycle (Olanrewaju*et al.*, 2009). It is also essential to ensure that buildings are used effectively and economically as possible (Lee, 1984).

Sharma S C (1998) reiterates that the function of building maintenance is to keep the facilities and the building in optimum operating conditions so that the intended functions are performed satisfactorily. The aim of maintenance is to reduce the frequency and severity of failures so as to ensure the availability, efficiency and performance of the existing plant, equipment and building at a maximum level and to the standard of acceptance.

In green buildings, the ultimate goal of all the new technology and processes is "the intelligent building" which involves operating and maintaining the intelligent systems that comprise those buildings — including HVAC, plumbing, electrical, renewable energy systems and sources, information technology, control systems and management software.

This means that operations professionals must have a comprehensive set of skills, training and experience to operate those systems in a cost-effective manner. Thus sustainability experts stress the importance of maintenance in ensuring that buildings systems operate in an environmentally friendly and energy-efficient manner.

1.1 Statement of the Problem

Currently, there is a green movement in the construction industry worldwide. Companies are striving to obtain certifications which show they have addressed the environmental impact of a building. Inherent in green construction is the concept of sustainability in the sense that green buildings need to be self sufficient in terms of energy conservation, water use and conservation, healthy and safety issues, ventilation and general operations. It has been reported that companies will innovate to greener processes (RICS, 2004) if incentives are in place. The incentives being provided in the construction industry range from financial incentives such as higher rental rates or property tax rebates to reputation in the community. McMullen (2001) observes that many companies are pursuing sustainability because they are finding business value in it. Miller *et al.* (2008) investigated over 2.4 million properties and determined that tenants are willing to pay higher base rents for greener buildings.

The intent of green buildings is to promote high performance, healthful, durable, and affordable and environmentally sound practices. Thus facility organizations and owners of buildings have seen the importance of green operations and maintenance in order to cut down on maintenance budgets since energy efficiency is no longer an option but a necessity. In addition, Gregory (2011) stresses that we can make the greenest products in the world, but all of that is negated if they are not properly installed and maintained. Green buildings are designed for easy operations and management which can realize cost savings of up to 10% compared to conventional properties. Effective operations and maintenance techniques coupled with non-toxic cleaning methods are healthier both for the building occupants as well as the maintenance workers themselves.

Little research has been done with regard to maintenance management of green buildings and as such the researcher sought to address the existing knowledge gap. As companies move toward sustainable construction and design, it is becoming increasingly important that they

have available managerial tools and methodologies to gauge and to help not only maintain but improve their 'green' performance. It is said that the difference in cost between a conventional and green building is marginal but the difference in performance is quite significant. With the green movement being a novel concept in Kenya and with very few buildings boasting green status in Kenya, serious questions in the maintenance management of these buildings beg. First and foremost, what criteria are used to determine whether a building is green? Are there laid down benchmarks in the design and construction process for a building to qualify as being green? Most importantly how does one maintain this building to ensure it remains green? Is the maintenance management process of a green building similar to that of a conventional building? Can the status of a building drop from green to ordinary due to poor maintenance? Based on these questions there is need to examine the maintenance management of green buildings in Kenya with specific reference to Nairobi County. Nairobi County being the capital city of Kenya, most of the local companies have their headquarters here and multinationals equally have their regional offices here. There has been a construction boom within the County hence the need for investors to consider constructing green buildings and their maintenance because they are beneficial in terms of performance, cost effectiveness in the long run and may get rewards such as carbon credit which improves their corporate image.

1.2Purpose of the Study

The study intended to establish the maintenance management process of green buildings in Nairobi County, Kenya.

1.3Objectives of the Study

The objectives of this study were:

1. To establish the planning process in the maintenance of green buildings in Nairobi County.

2. To identify the type of maintenance practices used in green buildings in Nairobi County.

3. To establish the extent to which the maintenance works of green buildings in Nairobi County affects their appraisal.

4. To explore strategies to improve the quality of maintenance works in green buildings in Nairobi county.

1.4 Research Questions

1. What activities and strategies are taken into consideration when planning maintenance works on a green building in Nairobi County?

2. What types of maintenance practices are used in green buildings Vis-a-Vis conventional buildings? Which of these practices are used in green buildings in Nairobi County?

3. How does maintenance work on a building affect its status as a green building in Nairobi County?

4. What strategies can be employed to improve the quality of maintenance works in green buildings in Kenya?

1.5 Significance of the Study

It is hoped that this research will develop awareness amongst the stakeholders in the construction industry in the design and implementation of effective maintenance management for green buildings. This will in turn enhance energy efficiency and other sustainability initiatives through green operations and maintenance thus cutting down maintenance budgets. The findings of the study may also help in enlightening staff working in green buildings on how to participate more in the operation and maintenance of these buildings.

The findings of the study may also be used by lobbyists of the 'green movement' to push for legislation for mandatory construction of green buildings in Nairobi County and for the retrofitting of conventional buildings to green buildings. In addition the findings of the study will also be a springboard for stakeholders in the construction industry to dive into the pool of sustainability literacy and awareness. To academicians and professionals in the construction industry, the research will help them understand the need for sustainable professional practices that safeguard people's lives and their future.

1.6 Assumptions of the Study

The study was guided by the assumptions that all ethical considerations had been adhered to and the findings of the study would not be harmful; the sample was representative of the population; the data collection instrument had validity and measured the desired constructs; the respondents answered the questions correctly and truthfully.

1.7 Limitations of the Study.

This study was limited by a lot of bureaucracy and procedure in accessing some of the resourceful areas for data collection leading to a long duration. Access to some of the selected case studies involved a lot of procedures for security reasons given that the selected green buildings are international or regional offices in Africa.

Some of the data such as drawings or specifications for the case studies was held back by the owners or facility managers of the green buildings due to security reasons. On official request, the sketches of the buildings were done where necessary and observation checklists used to record data.

The green buildings under the study which had been publicly declared as green buildings were actually in the process of certification and had not fully attained green building status. There was no green building in Nairobi County at the time of the study that had fully attained the status of being certified as green building from a global perspective.

1.8 Delimitations of the Study

The study focused on maintenance management other than other aspects of building management. This was because while other aspects of building management were not greatly affected by whether a building was green or not, maintenance management required special expertise. In addition because the output of maintenance works can affect the certification of a building as green hence the researcher chose to focus on maintenance management.

The study also focused mainly on commercial buildings and not other types of buildings. This therefore implies that the study findings cannot extend these buildings. Nevertheless the findings were relevant to enhance better maintenance management for green buildings within Nairobi County and those envisioning going green.

1.9 Definition of Significant terms

1.9.1 Green Building: It refers to a structure and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle. That is from siting to design, construction, operation, maintenance, renovation and demolition. (Wikipedia – Green Buildings, 2011).

1.9.2 Sustainable Architecture: This refers to a general term that describes environmentally-conscious design techniques in the field of architecture. It seeks to minimize the negative environmental impact of building enhancing efficiency and moderation in the use of materials, energy and development space. (Mohamed MM El-Wassimy, 2011).

1.9.3 Maintenance: This refers to a set of organised 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 (British Standards, 1993).

1.9.4 Maintenance Management system: The Maintenance Management System (MMS) is a computerized database designed to optimize the management of deferred maintenance and capital improvement activities throughout the Service by using standardized procedures to document and prioritize field facility and equipment needs and to report accomplishments. It is a management tool for planning and budgeting deferred maintenance, capital improvement, equipment repair and replacement, and construction projects. (Don Sapp, 2010)

1.9.5 LEED: This refers to Leadership in Energy and Environmental Design as adopted by the U.S. Green Building Council in certification of buildings. (Lee, W.L. and Burnett, J., 2008)

1.9.6 Intelligent Building: This refers to a building that integrates people, process and technology in an efficient and sustainable manner through the use of high levels of integrated technology (Matar, Georgy& Ibrahim, 2008).

1.9.7 HVAC: Is an abbreviation that refers to Heat, Ventilating and Air-Conditioning systems. These systems are used for indoor and automotive environmental comfort (Gilman, 2007).

1.9.8 VOC: Is an abbreviation referring to volatile and organic compounds. These are organic chemicals that have a high vapour pressure at ordinary, room-temperature conditions.

Their high vapour pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air (Mendell, 2007).

1.9.9 LCA: This is a technique to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling) (Cooper, 2006).

1.9.10 IAQ: This refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants (Spengler, 2001).

1.10 Outline of the Study

The study has been organized into five chapters. The first chapter gives the background, research questions and justification of the study. It also gives the reader an understanding of the research problem. The second chapter reviews literature of the same management problem by different authors. This gives the reader an understanding of the different dimensions of the research problem. The third chapter explains the methodology of the research where it highlights the research design, defines the population of the study and explains the sampling techniques used. This chapter also describes the data collection methods, instruments and the type of analysis used. The fourth chapter presents the findings of the analyzed data and gives relevant interpretation of the same. The fifth and final chapter discusses the findings and compares it with the literature review while relating this to the study objectives.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter gives a brief review of some studies focusing on maintenance management in the construction industry. The chapter gives relevant literature concerning the different facets of building maintenance management. The chapter also presents a conceptual framework that shows the interrelationship between the dependent and interdependent variables.

2.2 History of Building Maintenance

Buildings have been considered as one of the most valuable assets of a nation to provide people with shelter and facilities for work and leisure. As time passes by, maintenance of buildings becomes an invaluable process in retaining the value and quality of a building (Vijverberg, 2002). Building maintenance accounts for over half of the total output of the building industry (Wordsworth, 2001). In Britain, building maintenance activities have reached a level of 50 per cent of all annual construction activities (Kherun*et al.*, 2002; Shohet, 2002). In Hong Kong, the gross value of general trades such as decoration, repair and maintenance, and construction work at minor work locations has increased over the past five years. Governments all over the world have considerable expenditure directed toward maintenance and operation projects (Al-Arjani, 2002).

The maintenance of buildings plays an integral role in the whole design and construction process of buildings (Shabha, 2003). Recent research efforts have been put on the study of performance management, which is actually a core element of maintenance management (Zhu *et al.*, 2002). In fact, maintenance management requires a variety of skills, technical knowledge and site experience in order to identify and satisfy maintenance needs (CIOB, 1990). Study for maintenance projects using the performance approach can provide opportunities to improve cost, risk and quality management of the properties concerned in the long run (Straub, 2002).

According to Shenoy and Bhadury (1998), in the period of pre-World War II, people thought of maintenance as an added cost to the plant or facility which did not increase the value of finished product. Therefore, the maintenance at that era was restricted to fixing the unit when it breaks because it was the cheapest alternative. During and after World War II at the time when the advances of engineering and scientific technology developed, people developed other types of maintenance, which were much cheaper such as preventive maintenance. In addition, people in this era classified maintenance as a function of the production system.

Nowadays, increased awareness of issues such as environment safety, quality of product and services makes maintenance one of the most important functions that contribute to the success of the industry. World-class companies are in continuous need of a very well organized maintenance programme to compete world-wide. In order to ensure that the services are smoothly carried out by the developer, the purchasers are obliged to pay maintenance charges to developer. In addition, they need to abide to the house rules which are developed to control, standardize and ensure safety and healthy living conditions to minimize inconveniences (Weng, 2000).

The condition and quality of buildings is one of the most fundamental components of the quality of life. The vast majority of people spend over 95 per cent of their time in or next to a building of one kind or another, so in this sense, the built environment has become our "natural" environment (Lee and Wordsworth, 2001). Hence, maintenance strategy is essential as to aim at maximizing the fixed assets of a company or organization (Lee and George, 1993). According to Zailan (2001), maintenance management is the physical aspect of property management. Tiun (2009) has defined property management as an activity that covers wide range of activities such as property development, facilities management, project management, property portfolio management, human resources management, space management, risk management and also investment management and it must be carried out by the qualified property manager. Kyle *et al.*, have explained in depth that the successful property manager must be able to function effectively at five different levels of maintenance operations as follows: preventive, corrective, routine, cosmetic and deferred maintenance.

The Chartered Institute of Building has listed numbers of steps that can be taken to facilitate more efficient management building as follows: maintenance of records of sites, buildings,

engineering services, service agreements, renewal dates, redecoration and costs; working to standard procedures; making greater use of maintenance planning, including service standards and response times; training managers, supervisors and maintenance operatives more effectively; examining methods by which work is put out to contract and contract procedures; effecting good lines of communication and dissemination of information, especially about methods and techniques which help to reduce unit costs and common failures which increase them.

Unfortunately, not every property manager or agent can perform all of the above tasks efficiently and professionally. Majority of the property managers are inexperienced, especially those from subsidiary companies established by the developers. The property managers have a free hand in managing properties under their care, thus the management practiced is based on their own guideline and standard since there is no standard guideline in property management resulted in various problems and miseries suffered by the purchasers (Tiun, 2009). To make things worse, most of the problems in strata-related management and maintenance are due to lack of sense of belonging, vandalism and individualistic. Therefore, there is a need to take prompt action to overcome these problems in order to instill a valuable and quality living experience in high-rise living (Tiun, 2009).

2.2.1Types of Maintenance Practices

The survival of any building is underpinned by regular maintenance, with recognition of this made as early as the mid-nineteenth century by John Ruskin and William Morris. William Morris, founder of the Society for the Protection of Ancient Buildings (SPAB), had specifically identified maintenance as a method of retaining the value embodied in the historic fabric, stating “stave off decay by daily care” (Society for the Protection of Ancient Buildings, 2008). Almost a century and a half later, maintenance is still accepted as the most sustainable and suitable way to conserve buildings (Dann and Cantell, 2007).

Many published papers on maintenance management (for example Underwood and Alshawi (2000)) have suggested the use of a computer-aided integrated approach. Hassanain *et al.* (2001) proposed a review of conceptual models used in facility management. One of the main characteristics of this approach, as suggested by the model developed by Kim and Haas (2000),

is a high level of automation. These methods propose to analyze various building components to establish maintenance plans and allocate resources. They optimize maintenance plans for a specific element-roof (Attoh-Okine and Appea, 1999, façade (Mendes Silva and Falorca, 2009), air-conditioning (Kwak*et al.*, 2004), etc.), according to a single criterion (often economical). However, these methods suffer many drawbacks. Ashayeri (2007) has noted that a maintenance operations environment is usually traditional and reluctant to change. It is thus difficult to implement a highly automated method that is different from what is traditionally used by facility management services. This point is further aggravated by the complexity of methods and tools that are only understood by experts. Yet, decision-makers are rarely building experts. Furthermore, the preferences of decision-makers are not taken into account in these tools. Decision-makers may be reluctant to use decision support for fear of having a computer dictate their choices. Pfeffer and Sutton (2006) explained that decision makers may be afraid of losing part of their prerogative. Another problem, due to the complexity of these methods, is that they concern generally one building component at a time. Therefore, in a context where we consider the whole building and where we may have hundreds of buildings, the use of highly automated methods can be very expensive in time and resources. Finally, although these methods may be relevant for an exhaustive low-level analysis, they are not adequate to support a decision-making process at a building stock management level.

In maintaining a building, there are usually several strategic options available to management, and many alternative decisions to be considered. There is, for example, the possibility of reducing the demand for maintenance by addressing the actual cause of failure and identifying its consequences. For instance, it may be necessary to decide whether to repair or replace an item, and whether to carry out periodic maintenance at fixed intervals or simply to respond to the requests of the users. Thus, building maintenance can be divided into three strategies: corrective; preventive; condition-based.

2.2.1.1 Corrective Maintenance

Corrective maintenance is the simplest type of maintenance strategy, where an element in a building is used until it breaks down. It covers all activities, including replacement or repair of an element that has failed to a point at which it cannot perform its required function. Corrective maintenance is sometimes referred to as failure-based or unplanned

maintenance. Corrective maintenance tasks often take places in an ad hoc manner in response to breakdowns or user requests (David and Arthur, 1989). Thus, corrective maintenance can be extremely expensive for two reasons: the failure of an item can cause a large amount of consequential damage to other elements in the building. For example, failure of the roof could cause damage to the ceiling and the interior of the building; failure of an item can occur at a time which is inconvenient to both the user and the maintaining authority. This can make manpower and spare parts planning extremely difficult. However, corrective maintenance is still an important part of any maintenance management strategy, as we shall see later in this paper. It is from such work that we can gather vital predictive information. This type of maintenance is subdivided into three types. Firstly there is Remedial maintenance, which is a set of activities that are performed to eliminate the source of failure without interrupting the continuity of the production process or activities in a facility. Secondly, there is deferred maintenance, which is a set of corrective maintenance activities that are not immediately initiated after the occurrence of a failure but are delayed in such a way that will not affect the production process. Finally there is Shutdown corrective maintenance, which is a set of corrective maintenance activities that are performed when the production line is in total stoppage situation.

2.2.1.2 Preventive Maintenance

Preventive maintenance was introduced to overcome the disadvantages of corrective maintenance, by reducing the probability of occurrence of failure and avoiding sudden failure. This strategy is referred to as time-based maintenance, planned maintenance or cyclic maintenance. Preventive maintenance tasks are performed in accordance with a predetermined plan at regular, fixed intervals, which may be based for example on operating time. Such a strategy is frequently applied to external or internal paint work. The following are the advantages of preventive over corrective maintenance (Raymond and Joan, 1991): maintenance can be planned ahead and performed when it is convenient to the building's user; maintenance costs can be reduced by avoiding the cost of consequential damage; downtime, the time that an element of the building or the whole building is out of service, can be minimized so the habitability of the building can be increased; and the health and safety of the user can be improved.

Nevertheless, preventive maintenance has some disadvantages which must be minimized (El-Haram, 1995. Firstly, planned maintenance is performed irrespective of the condition of the building elements. Consequently, a large number of unnecessary tasks will be carried out on elements that could have remained in a safe and acceptable operating condition for a much longer time. In addition, the condition of an element may end up worse than it was before, as a result of human error during the execution of the maintenance task .Lastly planned maintenance tasks are usually very demanding in terms of spare parts and labour.

Over the years, researchers have subdivided preventive maintenance into different kinds according to the nature of its activities. Firstly there is routine maintenance which includes those maintenance activities that is repetitive and periodic in nature such as lubrication, cleaning, and small adjustment. Secondly there is Running maintenance which includes those maintenance activities that are carried out while the machine or equipment is running and they represent those activities that are performed before the actual preventive maintenance activities take place. Thirdly there is opportunity maintenance which is a set of maintenance activities that are performed on a machine or a facility when an unplanned opportunity exists during the period of performing planned maintenance activities to other machines or facilities. Fourthly there is window maintenance which is a set of activities that are carried out when a machine or equipment is not required for a definite period of time. Finally there is shutdown preventive maintenance, which is a set of preventive maintenance activities that are carried out when the production line is in total stoppage situation.

2.2.1.3 Condition-Based Maintenance

Condition-based maintenance is defined as: “Maintenance carried out in response to a significant deterioration in a unit as indicated by a change in monitored parameter of the unit condition or performance” (Kelly and Harris, 1978). The condition-based maintenance concept recognizes that a change in condition and/or performance of an item is the principal reason for carrying out maintenance. Thus, the optimal time to perform maintenance is determined from a condition survey used to determine the actual state of each constituent item in a building. In this strategy, maintenance tasks are determined and planned by efficiently monitoring the building’s elements such as walls, floors, roof and service equipment such as boilers, pumps,

and heating system, to identify which element or piece of equipment requires maintenance before a major failure occurs. To gain the full advantage of applying condition-based maintenance, the condition of an item must be monitored to identify whether there is any evidence of change from a normal to an abnormal condition. This can be done by selecting the parameter which best describes the condition of the item and monitoring changes using suitable condition monitoring tools. Condition assessments can vary from simple visual inspections to more advanced inspections using a variety of condition monitoring tools and techniques.

2.3 Maintenance Management

Maintenance management (MM) is defined as all the activities of the management that determine the maintenance objectives or priorities, strategies, and responsibilities and implement them by means such as maintenance planning, maintenance control and supervision, and several improving the methods including economic aspects in the organization (Dekker, 2001).

Still other definitions consider MM as the management of all assets owned by a company, based on maximizing the return on investment in the asset (Wireman, 1998). According to Wireman (1998) MM would include, but would not be limited to, the following: preventive maintenance (PM), inventory and procurement, work order system, computerized maintenance management systems (CMMS), technical and interpersonal training, operational involvement, proactive maintenance, reliability centered maintenance (RCM), total productive maintenance (TPM), statistical financial optimization, and continuous improvement. Each of these initiatives is a building block of the MM process. Another approach to MM definition is offered by Duffuaa, Raouff& Campbell (2000). They indicate how a maintenance system can be seen as a simple input—output system. The inputs are the manpower, management, tools and equipment and the output is the equipment working reliably and well configured to reach the planned plant operation. They show that the required activities for this system to be functional are maintenance planning (philosophy, maintenance workload forecast, capacity, and scheduling), maintenance organization (work design, standards, work measurement, and project administration) and maintenance control (of works, materials, inventories, costs, and quality oriented management).

2.3.1 Traditional Maintenance Management Systems

A prime aim of maintenance is to preserve a building in its initial stage, as far as practicable, so that it effectively serves its purpose. The main purposes of maintaining buildings are to retain value of investment; maintain the building in a condition in which it continues to fulfill its function; and to presenting a good appearance. Property is increasingly being seen as a key resource by organizations which are not primarily in the property industry. Due to the inflexibility of buildings, owner and occupiers need to have clear strategies to manage, control and develop it profitably. Most of the property management companies still use the traditional maintenance management system for managing a building. The traditional maintenance managed process was a fragmented process that categorized maintenance merely as either planned or unplanned (Chanter & Swallow, 2000). Planned maintenance was mostly either preventive or corrective (in case of emergencies).Preventive maintenance was conducted according to a pre-determined schedule or based on the condition of a particular building part or facility. On the other hand unplanned maintenance was applied only when emergencies occurred (Chanter & Swallow, 2000). Historically, facilities were ageing and constantly being renovated in a piecemeal fashion where actions were taken at different times or ways rather than being carefully planned from the beginning. Many renovations were limited in scope due to funding restraints and many times result in cosmetic change with few or no infrastructure improvements. This fragmentation further led 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 (Amaratunga, 2000). Hinks (2004) observes that in the traditional maintenance management context, managers were uninterested in considering any facets of maintenance management performance below an established indicator level. They also do not generally consider any management process as they relied more on reactive actions based on clients' or users' complaints. It can be broadly concluded that the managers prefer carrying out reactive maintenance works rather than proactive works and at times do not consider clients satisfaction or indeed the service performance. There is also an increasing concern that maintenance management has been unprofessionally applied by the maintenance managers in many cases.

The traditional maintenance management system is still relevant and appropriate to be used in any current building condition. However, in recent years, the need to manage the different

facets of maintenance more effectively has gained added importance due to changing operational technologies, and the changing organizational role of maintenance. Maintenance management in the private and public sector has been rapidly changing throughout the years (Horner, El-Haram &Munns, 1997).

The selection of maintenance system to be operated in the building should therefore take into consideration the life cycle of the building materials, services installation provided, space function or activities to be carried out in that particular building. In some cases, when the material has reached the 'wear and tear' condition, the maintenance work is then required to rectify that defect. Therefore, it is very important to ensure that the design team understands materials performance in order to reduce the running cost during building operation. Using so called 'heavy duty' materials and yet producing high quality building fabric. Knowing the physical and detail life span of the materials will allow the maintenance team to forecast the budget allocated for replacement work and plan the maintenance work as per schedule. A detail record of the previous maintenance work, will act as a benchmark to the future maintenance activities where decision is made through this. Referring to the previous records will assist the maintenance team to overcome and provide an effective remedial works. In spite of planned maintenance, emergency maintenance will involve urgent and immediate work prior to the problem. It is to avoid the resultant consequences to other activities which may cause severe failures. By considering those planned and unplanned maintenance, the management should provide a realistic budget and come out with some emergency plans in dealing with uncertainties cases. Therefore, the implementation of an effective maintenance practice must inculcate some indicators to improvise the traditional maintenance management system to reach the needs and nature of the work.

It is highly desirable but hardly feasible to produce buildings that are maintenance-free, although much can be done at the design stage to reduce the amount of subsequent maintenance work. All elements of buildings deteriorate at a greater or lesser rate depending on material and methods of construction, environmental conditions and the use of the building (DoE 1972). Maintenance work has also been categorized as "predictable" and "avoidable"(Mills 1980). Predictable maintenance is regularly periodic work that may be necessary to retain the performance characteristic of a product, as well as that required to

replace or repair the product after it has achieved a useful life span. Avoidable maintenance is the work required to rectify failures caused by poor design, incorrect installation or the use of faulty materials. The function of maintenance can be divided into three groups namely: cleaning and servicing, rectification and repair and replacement (Miles &Syagga, 1987). Timely expenditure on the first two can postpone the need to replace materials or components, a very expensive business. Cleaning and servicing should be carried out regularly and may be combined with a system of reporting faults when they become apparent, thereby avoiding the need for more expensive repairs or even replacement at a later stage (Miles & Syagga,1987).

2.3.2 Maintenance Works in Conventional Buildings

Building maintenance is a major activity in most countries. Building maintenance is a subject, which has attracted growing interest in recent years. Maintenance however, has always been inextricably associated with buildings, from the earliest times when men sheltered from the elements in primitive huts up to the present day, when civilized man can erect skyscrapers and glass palaces using modern building materials such as concrete, steel, glass and synthetics. Man has always been confronted with the question of upkeep (Bos, 1999).The function of building maintenance is to maximize the aesthetic and economic values of a building as well as increase the health and safety of the occupants. Building maintenance in conventional buildings has specific objectives. The most basic objective is to ensure that the facility is presentable where this is achieved through daily cleaning and housekeeping. On top of that maintenance in conventional buildings serves to prevent premature failure of the facility and its systems and components where this is normally realized through development and execution of regularly scheduled maintenance actions. Additionally, complete major repairs based on lowest life cycle cost are normally carried out. Stephen (2000) observes that most traditional maintenance management systems advocate for the operation of facility utilities in an economical manner without neither expressing how nor using the supporting technology (for example use of low-flush toilets to conserve water in green buildings. Maintenance works in conventional buildings also involve accurate cost estimation techniques to ensure low cost solutions to maintenance problems. On top of that materials and spare parts are maintained at a proper level to support timely repairs. It also involves scheduling and planning work in advance and allocating and anticipates staff requirements to meet planned and unplanned

events. Maintenance management in conventional buildings also involves monitoring the progress of maintenance works and continually seeking workable engineering solutions to maintenance problems.

2.3.3 Modern Approach to Maintenance Management

According to Ramly, A. (2006), design plays a major role in determining the conditions of the building after completion, mainly in aspects of defects and maintenance. Indirectly design influences the performance and physical characteristic of building and its durability to with stand against environmental condition, social interfaces such as graffiti and vandalism. The link between design and maintenance should therefore not only be seen from the point of increasing the repair work or cost involved, but it also needs to consider the impact of design on structure and material installed as well as the life cycle of each component of building. Under traditional maintenance management systems it was considered that only old buildings are subject to maintenance because of material decay, wear and tear and weathering but in contemporary time, thanks to designers, developers and construction teams as the concept has totally changed. Now even newly built structures are subject to intensive maintenance and sometimes require revised design and reworks. A poor/faulty design is not only concerned with designer of building but also concerned with construction team. Even the gap between these two professions has resulted in public concern and public confidences in both professional are undermined. Foo (1989) highlights the issue of faulty design as, in recent years many defects, premature maintenance and failure are occurring in relative new buildings. Thus this situation has resulted in much public concern and it reached at a point that public confidence in both professionals and construction sectors are undermined. However, it would be justified to declare that even new and modern designs of the building are more vulnerable to get infected with plague of unplanned maintenance, if their respective design has not been considered skillfully in terms of maintenance. Zavadskas, E. (1998) presents the correlation between design of building and its life cycle. A better building life is only accessible with skillful design consideration at design stage and is an important issue to its owner and dedicated designer. It begins when owner or client presents the set of requirement to designer and he /she defines the demands for building and specify the limitation. At this stage maintenance strategies and objectives should be considered and means should be determined to allow the building to enjoy

longer life cycle. And if the decision regarding maintenance issue and their means are considered well before the construction phase, it will prevent the building to fall into the pool of bad design and this timely decision helps to enhance the life cycle of building.

According to Ahmad (2003), the surrounding environment, the needs and characteristics of its users and climatic conditions mostly influences traditional building designs. In recent times, although designs are more concerned with client requirements and the actual building objectives, a lot of attention is being given to sustainability and the climate. The United Nations Framework Convention on Climate Change (2007) brought the issues to the attention of governments. The building industry uses a substantial amount of resources and, accordingly, has a large impact on the environment (Chan and Lau, 2005; OECD, 2003; Qian*et al.*, 2007; Zhang, 2004). It is now well recognised that efficiency improvements in energy used by the building industry would make a major contribution to meeting such national objectives as increasing energy-efficient investments, improving the security of the energy supply, enhancing productivity and competitiveness, reducing the release of greenhouse gases, and lowering the local environmental costs of energy supply and use. At the international level, energy efficiency is being promoted to mitigate climate change, decrease global warming and improve air quality (Meyers, 1998). The significant environmental impact of building activities has given momentum to the "green building (GB) movement". Green or sustainable building is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition (EPA GB, 2004). GB brings together a vast array of practices and techniques aimed at reducing the impact of the building industry on energy consumption, the environment and human health. The energy consumed in the building sector accounts for a large part of total consumption in most countries (Chan and Lau, 2005; OECD, 2003; Qian*et al.*, 2006; Zhang, 2004).

The understanding of a good building design always relates to the shape of the building and its appearances. In many occasions, this perception has neglected the actual function of why the building was built in the first place. This holds very true especially where green buildings are concerned. A research by Arditi (1999) has shown that design plays a major role in determining the condition of buildings after completion, especially in the aspects of defects and maintenance. Indirectly, design influences the performance and physical characteristics of the

building and its durability to stand against environmental elements, noise and social interferences such as graffiti and vandalism. Therefore, the link between design and maintenance should not only be seen from the point of increasing number of repair works or cost involved, but it needs to consider also the impact of a design on structure and materials installed as well as the life cycle for each of the components or elements of the building.

Green buildings are significantly different in terms of design, materials, orientation and maintenance needs. They also have to be built to specific standards and possess certain salient features to be certified as 'green'. These features include life cycle assessment (LCA); sitting and structure design efficiency; energy efficiency; water efficiency; materials efficiency; indoor environmental quality enhancement; operations and maintenance optimization and Waste Reduction. They also have to maintain high standards of these features during their lifetime. As a result, the concept of maintainability is crucial at the design stage of a green building.

2.4 Challenges of Maintenance Management in Green Buildings

Green building projects are inherently different from their conventional counterparts from a technical perspective. They require the use of special materials and building practices to achieve sustainability. They can also require extensive documentation and reporting if environmental certification is a project goal. The unique characteristics of green construction require adjustments to traditional project management practices to minimize risks and improve the chances of delivering the project within acceptable costs. The majority of these adjustments reflect an increased need for cross-discipline coordination on-site selection, construction techniques and building systems and subsystems early in project life cycle. Traditional construction management methodologies, which are often described as linear and fragmented processes, can cause rework later in the project, specifically in green construction projects. It is less expensive to address green issues early in the project life cycle than to work them in during project implementation. In fact, the timing of those decisions can significantly impact the rates of return on short-term construction costs and operating costs over the long term (McGraw-Hill Construction, 2006).

The construction industry is faced with the challenge to replace or renovate buildings to minimize environmental impact, for example, achieving carbon neutrality, while at the same time yielding a respectable financial return on investment. Some people are calling for reducing fossil fuel consumption of buildings by 50 percent by the year 2010 with a goal of achieving carbon-neutral buildings by 2030 . This requires new approaches to designing new buildings and renovating existing buildings. For example, the *Leadership in Energy and Environmental Design Green Building Rating System* LEED, developed by the **U.S. Green Building Council** (USGBC), provides a suite of standards for environmentally sustainable construction.

There is a growing awareness worldwide on the importance of the maintenance of constructed facilities (Cane et al.1998; Van-Winden and Dekker, 1998; Underwood and Alshawi, 1999). Maintenance experts and modern building owners especially in developed countries like United State, France and Singapore have become acutely aware that the conventional in-house maintenance practices are too fragmented to cope with the high technology building services. Their in-house staff also lacks the resources, skills and knowledge to meet the rising expectations of the users and to provide the quality service required for this new generation of intelligent building (SohCheeKeong, 1997). This is due to the growing complexity of buildings, the increasing proportion of systems in them and the higher level of service (Chew *et.al*, 2004). A critical issue for Green Buildings is the consideration of maintenance works at the design stage of a project. The challenge then becomes the way in which the maintenance activity should be addressed. Maintenance planning should start at the design stage of any building project and should continue throughout the life of that building. In this, the building owner and or user, must play an active part. This lack of continuity is unfortunate, for much relevant information for future reference can be obtained if a proper feedback system can be devised (Ahmad,2003). The problem is that many buildings are destroyed not by outside forces such as weathering factors like heavy rains or drought but by insufficient/improper design during the design stage, through bad housekeeping, inadequate maintenance and neglect during its full operation.

2.4.1 Goals of Green Building

Green buildings are designed to meet certain objectives such as protecting occupant's health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment. Numerous Countries or Regions have developed green building programs aimed at promoting more sustainable buildings. At the crux of each program is the use of an integrated design approach, and a point's scheme that allots credits for building design features deemed to improve sustainability. These schemes have been thoroughly explored and compared previously (Cole 1998; Crawley et al. 1999; Todd et al. 2001; Bosch et al. 2003; Fenner et al. 2008; Lee et al. 2008). The most common are BREEAM, LEED, Green Star and HK BEAM.

The Building Research Establishment first released the United Kingdom's Building Research Establishment Environmental Assessment Method (BREEAM) in 1990. The current version was released in 2006 (Building Research Establishment). The United States Green Building Council (USGBC) developed the Leadership in Energy and Environmental Design, LEED program (US Green Building Council 2008) several years later and it is now being used across North America (suitably adjusted for local codes and climates). In 2003 the Green Building Council of Australia released their environmental rating scheme, called Green Star (Green Building Council Australia 2008). The Hong Kong Building Environmental Assessment Method (HK-BEAM) was released in 1996. Revisions to the original releases have been made, as experience in their use grows. All use a point or credit system throughout the design process, rewarding sustainable practices within various categories.

2.4.1.1 Life Cycle Assessment (LCA).

A life cycle assessment assists to avoid a narrow outlook on environmental, social and economic concerns by assessing a full range of impacts associated with all the stages of a process. This includes the extraction of raw materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. Impacts taken into account include embodied energy, global warming potential, resource use, air pollution, water pollution and waste. LCA is rewarded to some extent in the Green Globes rating system and is part of the new American National Standards based on Green Globes, *ANSI/GBI 01-2010: Green Building*

Protocol for Commercial Buildings. It is also included as a pilot credit in the LEED system while the state of California has included LCA as a voluntary measure in its 2010 draft Green Building Standards Code. Although LCA is often perceived as overly complex and time consuming for regular use by design professionals, research organizations such as BRE in the United Kingdom and the Athena Sustainable Materials Institute in North America are working to make it more accessible.

2.4.1.2 Siting and Structure Design efficiency.

Professionals will attest to the fact that the foundation of any construction project is rooted in the concept and design stages. The concept stage is usually one of the major steps in a project life cycle since it has the largest impact on cost and performance. In the design of environmentally optimal buildings, the objective is to minimize the total environmental impact associated with all life-cycle stages of the building project. However, building as a process is not as streamlined as an industrial process and varies from one building to the other due to the multitude of materials and components each constituting various design variables to be decided at the design stage. A variation of every design variable is likely to affect the environment during all the building's relevant life-cycle stages. According to Green Building (2011) it is essential to start by selecting a site well suited to take advantage of mass transit. Then protect and retain existing landscaping and natural features through selecting plants that have low water and pesticide needs, and generate minimum plant trimmings hence saving water and time. The use of recycled content paving materials, furnishings and mulches help to close the recycling loop.

2.4.1.3 Energy Efficiency.

Green buildings usually include measures to reduce energy consumption – both the embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment. Since a high performance building uses less energy, the embodied energy has assumed much greater importance and may make up as much as 30% of the overall life cycle energy consumption. Studies such as the U.S. LCI Database Project show that buildings built primarily with wood will have a lower embodied energy than those built primarily with brick, concrete or steel. In order to reduce the operating energy use, high-efficiency windows and insulation in walls, ceilings and floors

increase the efficiency of the building envelope (barrier between conditioned and unconditioned space). Other strategies include the use of passive solar building design as implemented in low-energy homes. Designers orient windows, walls and place porches and trees to shade windows and roofs during the summer while maximizing solar gain in the winter. In addition, effective window placement for day lighting can provide more natural light and lessen the need for electric lighting during the day. On site generation of renewable energy through solar power, wind power, hydro power or biomass can significantly reduce the environmental impact of the building.

According to Green Building (2011) most buildings can reach energy efficiency levels far beyond the requirements in the green building standards. A number of strategies contribute to this goal. Firstly, passive design strategies can dramatically affect building energy performance. These measures include building shape and orientation, passive solar design, and the use of natural lighting. Secondly, develop strategies to provide natural lighting since studies have shown that it has a positive impact on productivity and well being.

2.4.1.4 Water Efficiency.

One of the key objectives of green buildings is reducing water consumption and protecting water quality. A critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself. To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified and reused on-site. The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing. Waste-water may be minimized by utilizing water conserving fixtures such as ultra-low flush toilets and low-flow shower heads. Bidets help eliminate the use of toilet paper, reducing sewer traffic and increasing possibilities of re-using water on-site. Point of use water treatment and heating improves both water quality and energy efficiency while reducing the amount of water in circulation. The use of non-sewage and grey water for on-site use such as site-irrigation will minimize demands on the local aquifer.

2.4.1.5 Materials Efficiency.

Some of the building materials that are considered to be “green” include lumber from forests that have been certified, rapidly renewable plant materials like bamboo and straw, insulating concrete forms, stones, recycled stone, recycled metal and other products that are non-toxic, reusable, renewable and/or recyclable such as Linoleum, sheep wool, panels made from paper flakes, compressed earth block, adobe, baked earth, linen, sisal, wood fibre, etc. EPA (Environmental Protection Agency) for International regions and NEMA (National Environmental Management Authority) for Kenya, suggest the use of recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects. Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded in their transportation. Where possible, building elements should be manufactured off-site and delivered to site, to maximize on the benefits of off-site manufacture including minimizing waste, maximizing recycling (due to manufacturing in one location), high quality elements, better occupational health safety management, less noise and dust.

2.4.1.6 Indoor Environmental Quality Enhancement. (IEQ)

In the category for Indoor Environmental Quality (IEQ) in LEED standards, one of the five environmental categories was created to provide comfort, well-being and productivity of occupants. The LEED IEQ category addresses design and construction guidelines especially for indoor air quality (IAQ), thermal quality and lighting quality. Indoor Air Quality seeks to reduce volatile organic compounds (VOC) and other air impurities such as microbial contaminants. Buildings usually rely on designed ventilation systems (passive, natural or mechanically powered) to provide adequate ventilation of cleaner air from outdoors. Most building materials and cleaning / maintenance products emit gases, some of them toxic, such as many VOCs including formaldehyde. These gases may have detrimental impact on occupant’s health, comfort and productivity. Avoiding these products increases a building’s IEQ. LEED and Green Star rating contain specifications on use of low-emitting interior while BREEAM limits formaldehyde emissions, no other VOC.

Control of moisture accumulation (dampness) is also important to indoor air quality where mould growth and presence of bacteria and viruses, dust mites and other organisms are taken

care of. Water intrusion through a building's envelope or water condensation on cold surfaces on the building's interior can enhance and sustain microbial growth. A well-insulated and tightly sealed envelope will reduce moisture problems but adequate ventilation is necessary to eliminate moisture from indoor sources such as human metabolic processes, cooking, bathing, cleaning and other activities. Creation of a high performance luminous environment through the careful integration of daylight and electrical light sources will improve on the lighting and energy performance of a structure.

Specification of materials in spaces should also take account of the occupants for example solid wood products may be specified for flooring where occupants are allergic to dust. Wood is considered to be hypo-allergenic and its smooth surfaces prevent the buildup of particles common in soft finishes like carpet. The Asthma and Allergy Foundation of American recommends hardwood, vinyl, linoleum tile or slate flooring instead of carpet. The use of wood products improves air quality by absorbing or releasing moisture in the air to moderate humidity. Interactions among all the indoor components and the occupants together form the processes that determine the indoor air quality.

2.4.1.7 Operations and Maintenance Optimization.

Regardless of how sustainable a building may have been in its design and construction, they can only remain sustainable it they are operated responsibly and maintained properly. It is important to ensure that operations and maintenance (O&M) personnel are part of the project's planning and development process in order to retain the green criteria designed at the onset of the project. Every aspect of green building is usually integrated in the operations and maintenance phase of a building's life. The addition of new green technologies also falls on the operations and maintenance staff as well as the green practices such as recycling and air quality enhancement. According to Green building (2010), green building measures cannot achieve their goals unless they work as intended. Building commissioning includes testing and adjusting the mechanical, electrical and plumbing systems to ensure that all equipment meets design criteria. It also includes instructing the staff on the operation and maintenance of equipment. Over time, the building performance can be assured through measurement, adjustment and upgrading. Proper maintenance ensures that a building continues to perform as designed and commissioned.

2.4.1.8 Waste Reduction.

Green buildings seek to reduce waste of energy, water and materials used during construction. During the construction phase, one of the key goals is to reduce the amount of material going to landfills. Well-designed buildings help to reduce the amount of waste generated by the occupants as well by providing on-site solutions such as compost bins to reduce matter going to landfills. In order to reduce the impact on wells or water treatment plants, “Greywater” wastewater from sources such as dishwashing or washing machines can be used for subsurface irrigation. They can also be treated for non-potable purposes such as flushing toilets and washing cars. Another alternative is the conversion of waste and wastewater into fertilizer or collecting human waste at the source and running it to a semi-centralized biogas plant with other biological waste thus producing liquid fertilizer. This concept was demonstrated by a settlement in Lubeck Germany in the late 1990s. Practices like these provide soil with organic nutrients and create carbon sinks that remove carbon dioxide from the atmosphere, offsetting greenhouse gas emission. Production of artificial fertilizer is also more costly in energy than this process.

2.5 Conceptual Framework

The conceptual framework below shows the relationship between the independent and dependent variables. The independent green building variables are also the same variables for good maintenance management practices. The researcher therefore explained each of the variables to the respondents for clarity in the sense that the composite effect of the independent green building variables influenced maintenance management of these buildings. Each of the variables is explained further after the conceptual framework.

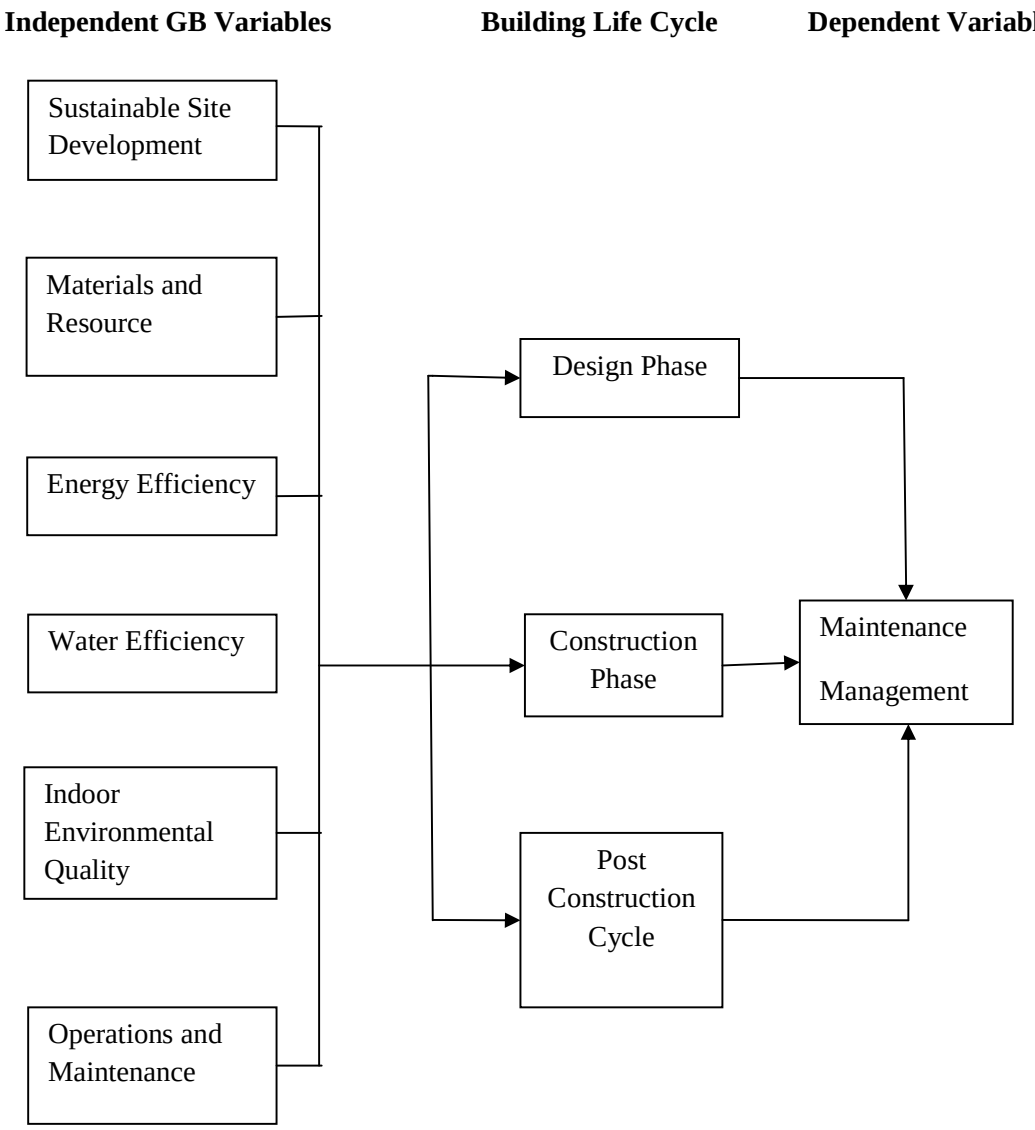

Figure 1: Conceptual Framework (Source: Author, 2012)

2.5.1 Sustainable Site and Development

Green buildings are put up on sites that are not environmentally sensitive. The challenge for maintenance management in Green Buildings is to ensure that the project site shall have safe building exteriors that preserve the surrounding ecosystem. The maintenance team has to ensure that the project site maintains natural storm water flows by promoting infiltration. The maintenance team has to ensure that the site is accessible and ensure that alternative modes of transportation into the site that reduce pollution are kept in good shape.

2.5.2 Material and Resource

The challenge for the maintenance team with regard to materials is to ensure building materials utilization and resource efficiency i.e. materials reuse, minimizing consumption and depletion of materials and other resources; especially those from non-renewable resources. The maintenance team has to ensure that strategies for conserving resources like reusing existing building; establishing goals for landfill diversion and adoption of a construction waste management plan are in place and function smoothly. They also have to ensure that recycling shall have less waste going to the landfill. Because site work shall incorporate substantial amounts of salvaged materials, the maintenance team needs to understand how to fix them when they are due for repair.

2.5.3 Energy Efficiency

The challenge for the management team in ensuring energy efficiency is to reduce the total energy consumption of the facilities. They have to ensure that the equipment that support sustainable energy sources like solar panels, geothermal machinery and wind turbines are in optimal working condition.

2.5.4 Water Efficiency and Conservation

The goal of this criterion is to manage water sustainability. The maintenance team has to ensure that systems that reduce the amount of portable water consumption used in the building are working efficiently. They also need to ensure reduction of the burden on the wastewater system and efficient re-use of non-portable water resources to the extent possible. The maintenance team also needs to ensure the minimization of the load on municipal storm water system.

2.5.5 Indoor Environmental Quality

The goal of this criterion is to provide indoor (interior) environments that enhance wellbeing, health and are conducive for occupant comfort and productivity. Buildings in which people spend their time must correspond to the needs of their users and shall guarantee a high level of well-being. Practices that improve Indoor environmental quality include developing and implementing an indoor air quality (IAQ) management plan for construction and pre-occupancy phases of the building specifying low- VOC materials and product in construction documents; and designing the building to maximize interior day lighting, ventilation and views. The maintenance team has to ensure the following aspects of the internal environment are functioning properly; building architecture in terms of the geometry of the building and rooms or spaces, materials adopted, selected colour scheme, perceived room temperature, humidity in the room, air quality in the room (contents of the air in the room / hazardous substances), External - Internal air ventilation and air circulation, natural and artificial lighting, building acoustics, noise emissions and technical installations and furnishing.

2.5.6 Operation and Maintenance

Green building measures shall achieve their goals only when they work as intended. Building commissioning includes testing and adjusting the mechanical and electrical systems to ensure that all equipment meets design criteria. It also includes instructing the staff on the operation and maintenance of equipment. Over time, building performance shall be assured through measurement, adjustment, and upgrading. Proper maintenance shall ensure that a building continues to perform as designed and commissioned. The building administration shall ensure a continuous monitoring of the consumption of energy and materials, and shall help the user or the operator to minimize these by the use of appropriate notices and advice. Visualization (monitoring) of the consumption of materials is to be aimed for.

2.6 Hypothesis

Independent green building variables ranging from sustainable site and development, materials and resources, energy efficiency, water efficiency and conservation, indoor environmental quality and operations do not have a significant effect on maintenance management of green buildings in Nairobi County.

2.7 Operationalization Table (Source: Author, 2012)

Variables	Performance Indicators	Assessment Criteria	Category of Measurement
Sustainable Site	Site Selection	Area	Ordinal
	Site Disturbance	Noise and pollution levels	Nominal, Ordinal
	Landscaping management	Spatial features distribution	Ordinal
	Erosion Control	Soil Tests	Ordinal
	Development Density	Spatial Distribution	Ordinal
	Community Connectivity	Ease of Interaction	Nominal
	Transportation Access	Ease of Access	Nominal, Ordinal
	Parking Availability	Spatial Distribution	Ordinal
Materials and Resources	Source of Materials	Renewable/Local or Foreign	Ordinal
	Material Selection	Renewable	Ordinal
	Material Utilization	Consumption/ Depletion levels	Ordinal, Nominal
	Waste Management	Disposal Techniques	Nominal
	Recycling	Waste consumption levels	Nominal
	Purchasing Policy	Profits, Return on Investment	Nominal, Ordinal
Energy Efficiency	Equipment Performance	Metering outputs	Ordinal
Water Efficiency	Water Use	Consumption by volume	Ordinal
	Rainwater Harvesting	Harvested H_2O volume	Ordinal
	Innovative Wastewater Use	Consumption, Technology	Ordinal, Nominal
Indoor Environmental Quality	Indoor Air Quality	Ventilation rate	Ordinal
	Room Temperature	Thermal comfort	Ordinal, Nominal
	Lighting	Visual Comfort	Ordinal, Nominal
	Building Acoustics	Noise Levels	Ordinal, Nominal
	Building Aesthetics	Design, Colour Schemes	Nominal
Operations and Maintenance	Maintenance Team Qualifications	Knowledge, Experience and Education	Ordinal, Nominal

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

This section discusses the methodology that was used in acquiring and synthesizing the study data. The elements discussed are; research design, target population, sample and sampling technique, research instruments, validity, reliability, data collection procedures and techniques.

3.2 Research Design

The study was carried out using a cross-sectional descriptive survey. According to Cooper and Schindler (2003), a study design is descriptive when it is concerned with how a variable produces change in another, and cross sectional if it is done at only one point in time or over a short period, collecting of data pertaining to the variables in a population or sample is done at a point in time. This design is appropriate for the study since the research was concerned with establishing how maintenance management works are carried out in green buildings in Kenya. The design had the ability to allow for data collection, analysis and reporting within the prescribed duration for academic purposes. Similar studies have successfully used this design (Keitany, 2009; Kimeu, 2008; Lwali, 2008; Naibo, 2006 and Nyaga, 2007).

A common goal of survey research is to collect data representative of a population. The researcher uses information gathered from the survey to generalize findings from a drawn sample back to a population, within the limits of random error.

3.3 Target Population

The purpose of this study was to examine maintenance management in green buildings in Kenya with specific reference to Nairobi County. Therefore the target population of the study comprised of all green buildings in Nairobi County. Three completed building projects in Nairobi that publicly claim to have observed and maintained Green Building Standards during and after construction were included in the study. Specifically, these were the Standard Chartered Bank in Westlands, the Coca Cola building in Upper hill and the Strathmore University School of Business in Madaraka. The choice of the three buildings was arrived at

based on the fact that they had been completed and had embraced the maintenance management practices under study to a great extent. The United Nations Environment Programme (UNEP) new building was not yet complete during the period of the study and therefore it was not in the target population. Key informants in these buildings comprising of the owner - users of these projects, regulatory association officials and professionals in the built environment who were involved in the design and construction and those currently involved in their management and maintenance were considered relevant respondents for the study. Specifically this included the Owner - User, Architect, General Contractor, Engineer, Construction Manager, Facility Manager or Maintenance Manager, the Green Building Consultant and three officials from AAK, NEMA and Nairobi City Council for each case. The population was therefore composed of 1 owner - user represented by a senior manager of the institution, 1 facility manager / maintenance manager, 6 professionals involved in the design, construction maintenance and Green Consultancy, and 3 regulatory body officials for each case. This added up to a population of 11 respondents for each project and therefore a target population of 33 respondents. The owners / users of the buildings were the senior most official of the organization or a representative of the senior management. Since most of the projects were done in collaboration with local professionals, in the case where foreign professionals were involved and could not be contacted their local liaisons were contacted.

3.4 Sampling Procedures

The study used the stratified sampling technique. Respondents were organized into four strata: the owners - users, the design and construction team, the facility and maintenance management team and the regulatory body professionals.

Information of the users, who in this case were the senior most official of the institutions, was obtained from their websites. Where a senior manager was not available the sample frame was obtained from the employee list in the Human Resources department of that institution. The next available senior official was selected from the frame and included into the sample. The population of owners - users in this stratum was 2. The sample frame for the facility managers was also obtained from the employee list in the Human Resource Department. The sampling technique also attempted to yield 3 facility managers from this stratum.

The sample frame of the design and construction team was obtained from the list of professionals involved in the project as laid down in the contract documents. Where access to the contract documents was not possible this information was obtained from the institutions website and other secondary data like journals. Where foreign companies were involved but unavailable to give feedback on the questionnaires their local partners were included in the sample. The sampling technique yielded a total of 11 respondents in this stratum.

The sample frame of the regulatory officials was obtained from the list of regulatory officials who were directly involved in the projects. One official from the AAK, NEMA and the Nairobi City Council was included in the sample for each organization. The sample technique was expected to yield a sample size of 9 respondents for this stratum but actually yielded 7.

Table 3.1: Sampling Frame

Sampling Unit	**Targeted Respondents**	**Actual Respondents**
Owner - User / Top Manager	3	2
Facility Managers /Maintenance Manager	3	3
Regulatory Officials	9	7
Design and Construction Team	18	11
Total	**33**	**23**

(Source: Author, 2012)

3.5 Data Collection Method.

The study used a semi-structured questionnaire comprising of open and close-ended questions to collect primary data in tandem with the study objectives. The data was collected through personal administration or self administered with the help of research assistants where the questionnaires were dropped and then picked depending on the convenience of the particular respondents. Prior consent was sought from the respondents before administering the questionnaires.

The questionnaires were completed by the respondents who in this study were the Owners - Users, Architects, General Contractors, Engineers, Construction Managers, Facility Managers or Maintenance Managers, the Green Building Consultants and officials from the AAK, NEMA and Nairobi City Council. Interviews were also used which consisted of oral questions by the interviewer and oral responses by the members of these bodies. The interviews were conducted with the help of an interview guide.

3.5.1 Data Collection Instruments.

The study relied mainly on primary data. An 18 item questionnaire was prepared and sent out to identify respondents in the different strata. Several types of questions were presented on the questionnaire. There were multiple choice /single response questions for mutually exclusive responses. There were also multiple choice, multiple responses for independent responses. The questionnaire also had likert scale questions where there are varying degrees of attitudes and extents of opinions on a specific statement or position. Depending on the questions, the data collected was numerical, categorical or scaled. The purpose of the questions was to identify characteristics of the respondents and to identify maintenance management practices in the Green Buildings under study. A cover letter was attached to the questionnaire to outline the aims and objectives of the study to the respondent. An interview guide was also used and it was meant to seek clarification on questionnaire responses.

3.5.2 Data Analysis

This study mainly relied on primary data .The data collection tool (questionnaire) comprised of open ended and close –ended questions. Close- ended questions gave quantitative data which was analyzed using quantitative techniques. Open-ended questions were analyzed using qualitative techniques. The two approaches allowed comparison of the study findings with the existing literature.

The questionnaires were edited for completeness before coding. Once coded the questionnaires were entered into the Statistical Package for Social Sciences (SPSS) version 17 computer package. Descriptive statistics was used to describe and make sense of the data. The descriptive statistics included the frequencies, percentages and means and standard deviations. The research findings were presented using tables and graphs.

3.6 Validity of the Study and Research Instruments

Validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are. Prior to the using of the questionnaires to collect data it was tested by conducting a pilot survey on 10 construction and real estate professionals who were not part of our sample to ascertain its content validity. The pilot study was carried out to check the effectiveness of the data collection tool i.e. appropriateness of the language used in the questionnaire as well as determining the difficulty of the items in the instruments. The researcher then made the necessary modifications of the tools thus improving the level of the instruments' validity.

3.7 Reliability of the Research findings

Reliability is the extent to which results are consistent over time and an accurate representation of the total population under study. The data was be collected using well tested and accepted procedures which have and can yield consistent data if used on similar studies. The test retest method was used to ascertain the reliability. Test-retest measures consistency from one time to the next. In the piloting the research instrument was given twice to the same group of people. If the results are consistent, the scores should be similar. If they are not consistent the instruments will be modified.

3.8 Chapter Summary

The chapter started by outlining the research design, the survey method was selected because the study focuses on more than one case in the population. The target population of the study comprised of all commercial green buildings in Nairobi County which had been completed and were in use. The respondents comprised of all owners - users of the Green Buildings, its design and construction team, Green Building Standards consultants and officials of the regulatory bodies. The respondents were divided into strata from which a sample size was selected. The chapter then proceeded to outline the procedure for data collection and outlined the method for data analysis.

CHAPTER FOUR

DATA ANALYSIS AND INTERPRETATION

4.0 Introduction

This chapter presents the analysis of data collected from the administered questionnaires. 33questionnaires in total were administered but the researcher managed to obtain 23 completed questionnaires representing a 69.7% response rate. The questionnaire contained questions that addressed the objectives of the study.

4.1 Projects Background information

Majority (47.8%) of the respondents were from the Strathmore Business School Building, followed by those from Standard Chartered Bank Building at 39.1% and the Coca Cola building at 13.1% as shown in table 4.1 and figure 4.1 below. The Coca Cola building was constructed in February 2009, the Standard Chartered building in June 2010 and the Strathmore building in March 2011.

Majority of the respondents in the study were engineers, construction managers, facility managers and maintenance managers as shown in Table 4.1 below:

Table 4.1: Projects Background information (Source: Author, 2012)

Project	**Frequency**	**Percentage**
Coca Cola Building	3	13.0
Standard Chartered Bank Building	9	39.1
Strathmore School Building	11	47.8
Total	23	100.0

4.2 Green Building Standards Program Certification

The researcher wanted to find out which Green Building Standards the buildings under study conform to. The study revealed that all the buildings were associated with the Leadership in Energy and Environmental Design (L.E.E.D) certification.

Table 4.2: Green Building Standards (Source: Author, 2012)

Certification	**Frequency**	**Percentage**
Leadership in Energy and Environmental Design (L.E.E.D)	22	95.7
Building Energy Efficiency (B.E.E)	0	0
Building Research Establishment Environmental Assessment Method (B.R.E.E.A.M)	0	0
Green Star (Green Building Council of Australia)	0	0
Hong Kong Building Environmental Assessment Method (HK-BEAM)	0	0
Non response	1	4.3
Total	23	100.0

4.3 Importance of Working towards Maintaining Green Building Certification.

The researcher wanted to find out the main reasons why green building certification is sought. The study revealed that environmental stewardship and gaining competitive advantage were the two most prime influential reasons for seeking and maintaining green building certification with 60.9 % of the respondents citing this. Cost savings on energy and water was also found to be the second most influential reason for pursuing and maintaining green building certification with 52.2% of the respondents citing this. Validation through third party review was the third main reason for influencing pursuit of this certification while 34.4% of the respondents were of the opinion that requirement by government was the least influential reason in working towards and maintaining Green Buildings Standardization certification. In contrast pursuing

and maintaining green building certification as a requirement by the government was found not to influence that decision at all. The table below explains the situation.

Table 4.3 Motivation to go Green (Source: Author, 2012)

Reason	Most Influential	Very Influential	Some Influence	Little Influence	Not Influential
Environmental stewardship	60.9	39.1			
Cost Savings on Energy and Water	47.8	52.2			
To Gain Competitive Advantage	34.8	60.9	4.3		
To Enjoy State and Local government incentives	22	26	22	30	
Requirement by Government	13	30.4	4.3	17.4	34.4
Validate achievement through third party review	47.8	47.8	4.3		

4.4 Stage of Project When Considerations Were Made For Maintenance of the Facility.

The study revealed that most green building projects make considerations for the maintenance of the facility at the design stage with 96% of the respondents asserting this for the projects they had handled. Only 4% of the respondents said they make these considerations after the design phase.

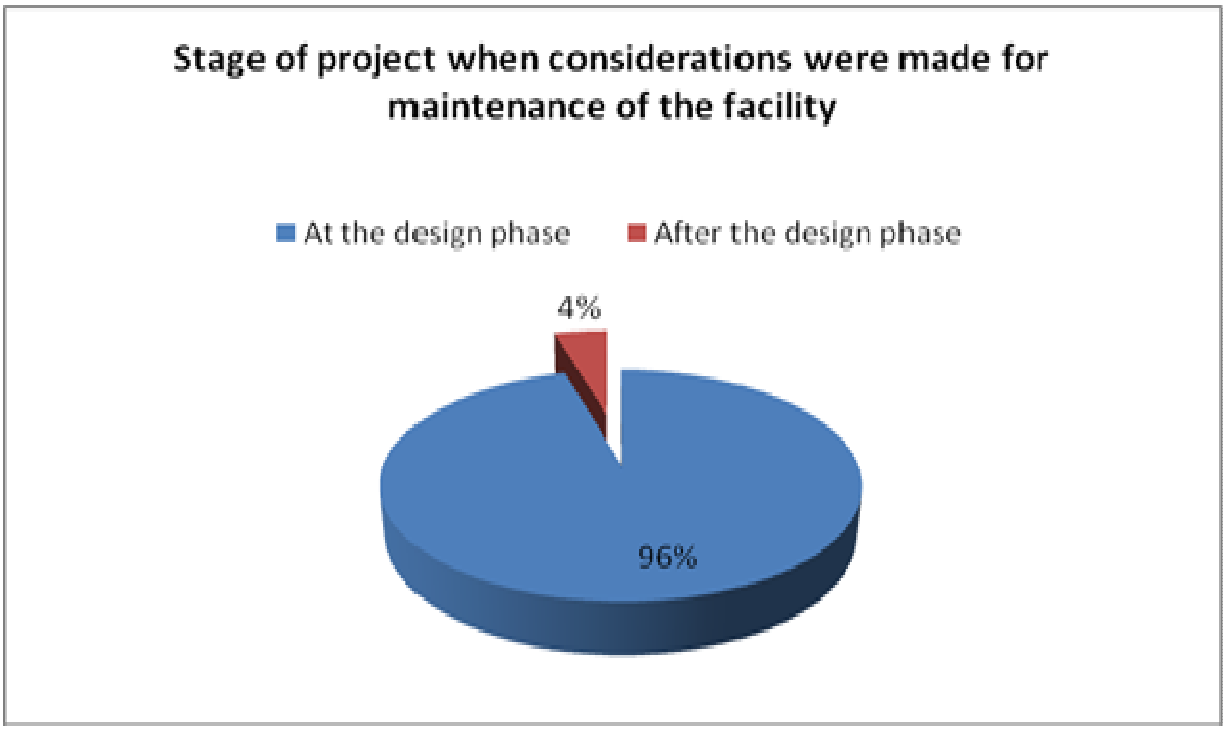

Figure 4.0: Considerations for Maintenance *(Source: Author, 2012)*

4.5 Salient Feature of Green Buildings Given Most Attention.

The study found out that 52.2% of the respondents were of the opinion that energy efficiency and water efficiency were the salient feature given most attention with regard to maintenance during design stage as shown in table 4.4:

Table 4.4 Green Building Salient Features (Source: Author, 2012)

Salient feature	**Frequency**	**Percentage**
Internal air quality	10	43.5
Energy efficiency	12	52.2
Project site sustainability	4	17.4
Water efficiency	12	52.2
Material utilization	3	12.9

4.6 Maintenance Strategy.

The study sought to find out which maintenance strategy was mostly adopted by the Green Buildings under study. All the respondents indicated that the building's facility managers had adopted preventive maintenance as the main strategy for their facilities.

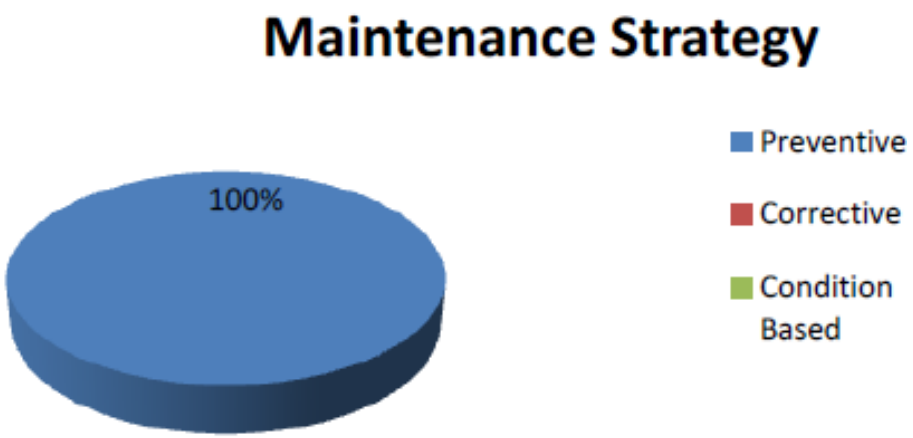

Figure 4.1 Maintenance Strategies (Source: Author, 2012)

4.7 How Green Building Aspects Affect Choice of Maintenance Strategy.

The study sought to find out which aspects of green building mostly affect the choice of a maintenance strategy. All the four aspects of green building were on at least to a great extent affecting the choice of the maintenance strategy. This was cited by at least 91% of the respondents. Ensuring the comfort of the building users was cited by 69.6% of the respondents as the most common aspect that influences maintenance strategy to the greatest extent. Pollution reduction and occupants' health were also found to be the most common aspects of green building that have the greatest influence on the choice of maintenance strategies with 65.2% and 55.5% of the respondents having cited this.

Table 4.5 Perceived Benefits and Choice of Strategy (Source: Author, 2012)

Consideration	Very Great Extent	Great Extent	Moderate Extent	Little Extent	Not at all
Occupants Health	55.5	43.5			
Comfort	69.6	26.1			4.3
Productivity	52.2	39.1	8.7		
Pollution Reduction	65.2	30.4	4.3		

4.8 Main Consideration Given To Any Products used In the Maintenance of Green Buildings.

The study found out that 52.2% of the respondents were of the opinion that non-toxicity products was the main consideration given to any products used in the maintenance of Green Buildings as shown in d figure 4.2 below.

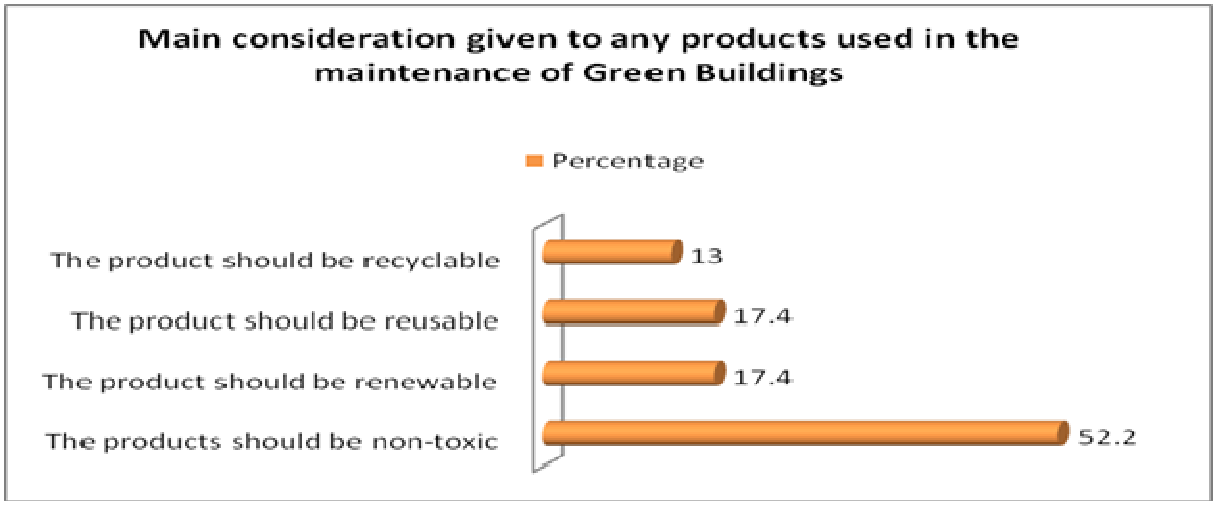

Fig 4.2: Products used in Green buildings maintenance (Source: Author, 2012)

4.9 Maintenance Considerations during the Design Phase.

The study sought to find out what key maintenance considerations are given importance during the design phase of a green building. It was revealed that 52% of the respondents were at least, to a great extent of the opinion that designing the facility with expectations of expansion to allow ease of maintenance was the most important consideration at the design stage. Providing strategic and adequate transport routes for replacing equipment and allowing installations was cited by at least 79% of the respondents as a main maintenance consideration during the design phase of a green building. The study revealed that developing a maintenance manual at the design stage was considered important only to a great extent by 61% of the respondents while inviting maintenance proposals from maintenance support vendors was considered important only to a moderate extent by 48% of the respondents. Figure 4.3 below demonstrates this.

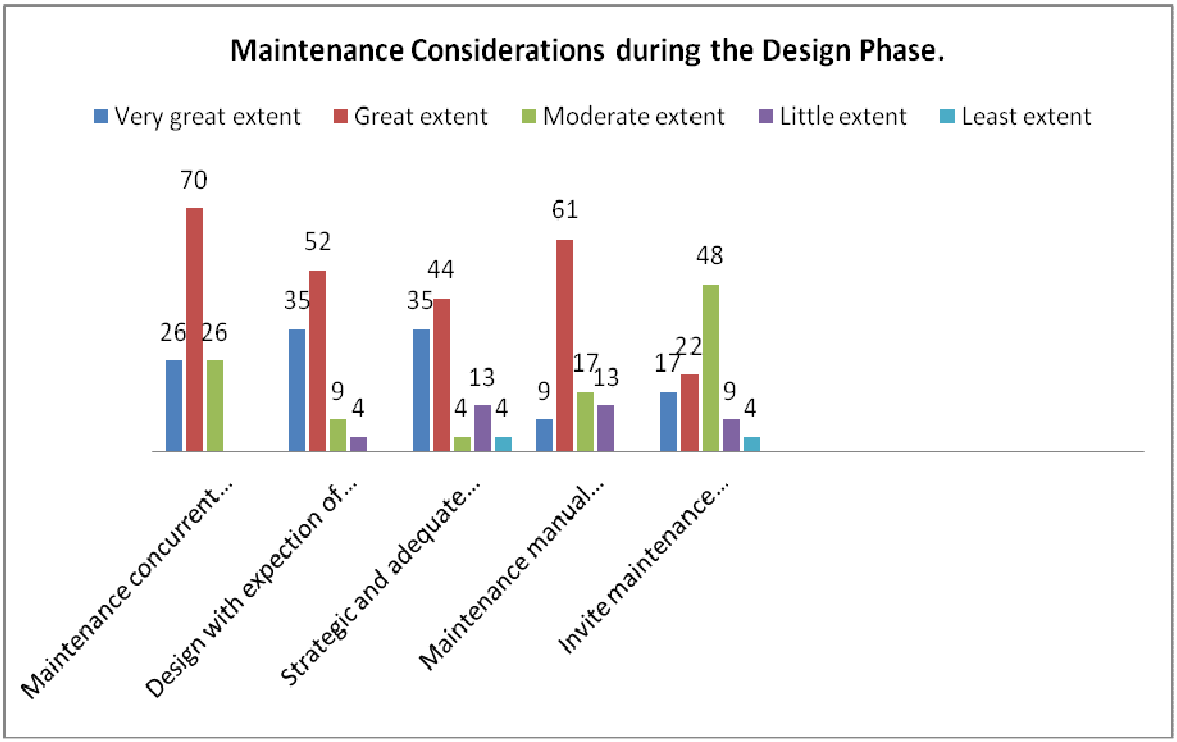

Figure 4.3: Maintenance Consideration at Design Phase (Source: Author, 2012)

4.10 Planning For Maintenance Staff.

The study sought to find out the extent to which importance is given to planning for maintenance staff at the design stage of a green building. 44% of the respondents were of the opinion that maintenance service was an independent dept function of IT to a moderate extent, 65% of the respondents indicated that maintenance was an in-house department or was

outsourced to a very great extent, 48% of them indicated that the maintenance staff was involved at the design stage to a moderate extent, maintenance of staff involved in site tours and observations throughout the construction process at 48% to a little extent and 48% of them were of the opinion that the maintenance staff had input in the project documentation to a great extent. These findings are as shown in the figure 4.4 below.

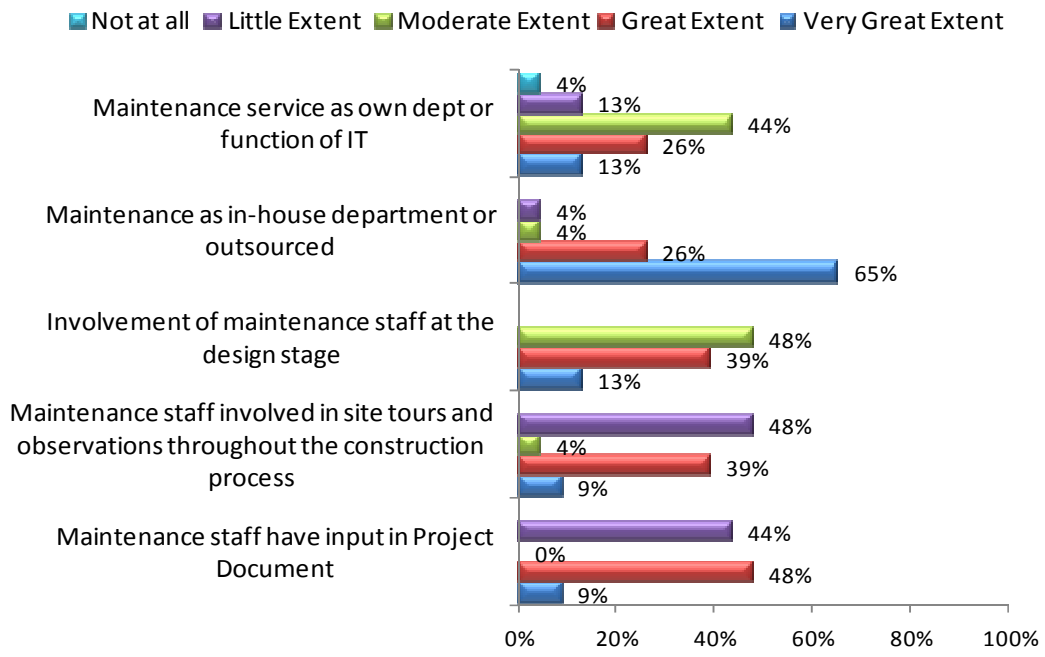

Fig 4.4: Planning for Maintenance Staff (Source: Author, 2012)

4.11 Maintaining the Project Site Green.

The study sought to find out which facility management aspects posed a challenge in maintenance management in helping the site to remain green. It was revealed that 48% of the respondents indicated that the proper location of the building on the site to protect and restore natural features posed a challenge to a very great extent. The study also unearthed that 44% of the respondents were of the opinion that minimization of pollution, noise and vibration when carrying out maintenance works posed a challenge to the maintenance management team to a very great extent. In addition it was revealed that 35% of the respondents each indicated that moderation of the impact of microclimate on the surrounding public place posed a challenge to the maintenance management to both great and very great extents. The figure below summarizes all the findings.

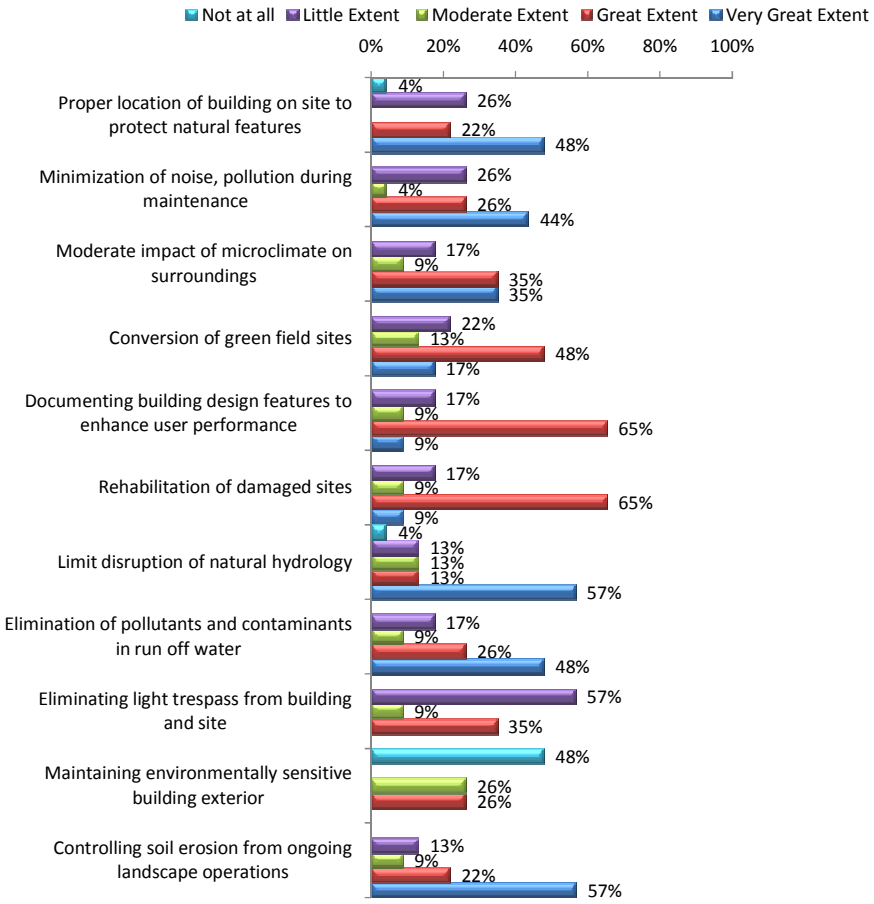

Figure 4.5: Site Sustainability (Source: Author, 2012)

4.12 Maintenance, Building Materials and Resources Efficiency.

The study wanted to establish the extent to which utilization of building materials and resources posed a challenge to the maintenance team. Proper waste management and recycling was found to pose a very great challenge to the maintenance team in the utilization of building materials and resources with 65% of the respondents holding this position. Reduction of waste during maintenance works and reducing waste from building occupants also posed very great challenges to the maintenance team with 52% and 48% of the respondents holding these positions respectively. In contrast, provision of accessible waste storage facilities and reducing processing of virgin resources and materials were found to pose little challenges by 22% and 26% of the respondents respectively.

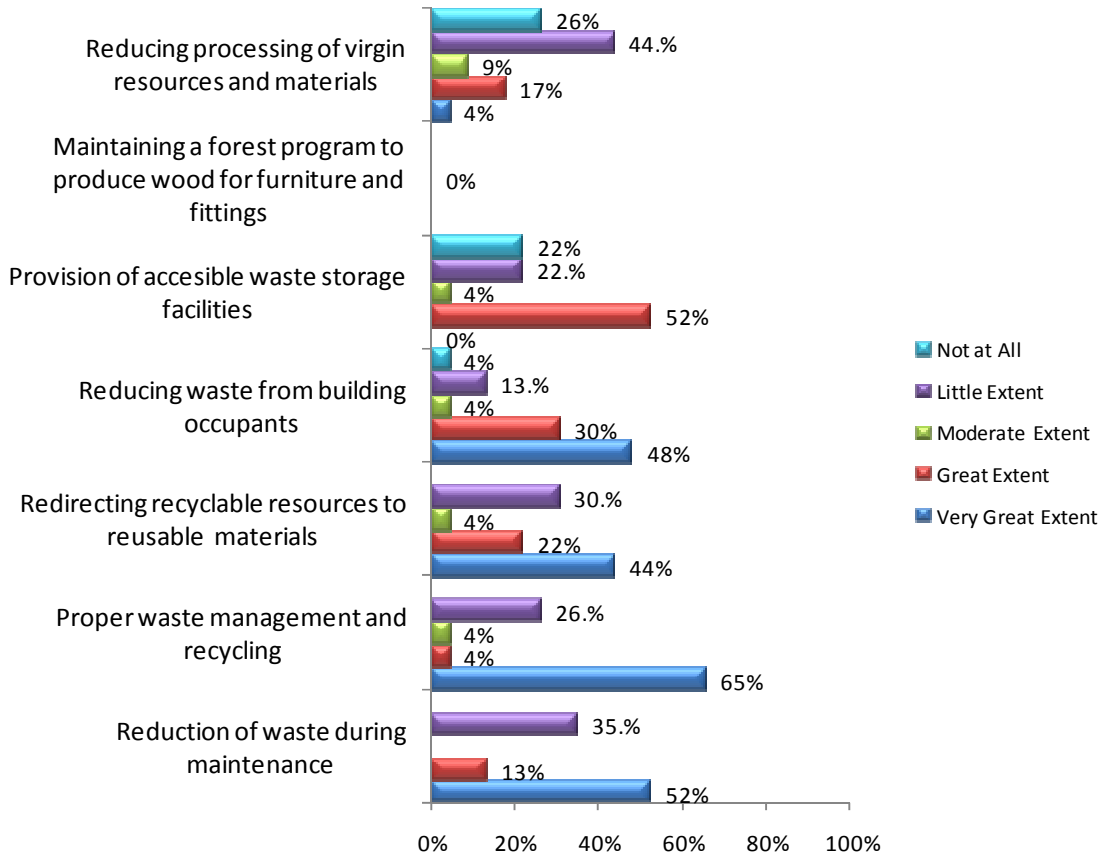

Figure 4.6: Materials and Building Efficiency (Source: Author, 2012)

4.13 Maintenance and Energy Consumption

The study sought to find out whether maintenance practices help reduce energy consumption in green buildings with a view to helping it maintain its green status. Various aspects on energy conservation were considered and how they posed a challenge to the maintenance management team. It was revealed that 48% of the respondents indicated that reduction of energy consumption thus reducing CO_2 emissions to the atmosphere posed a challenge to the management team to a very great extent as did maintaining a thermally comfortable environment by reducing the use of air conditioning that was indicated by 52% of the respondents. The study also revealed that 44% of the respondents indicated that design, installation and calibration of building elements and systems to operate as intended posed a challenge to the maintenance management team to a very great extent as did 39% of the respondent who indicated that ensuring CFC reduction in HVAC equipment by proper maintenance posed a great challenge to the maintenance management team to a very great extent. Additionally, it was found out that 48% of the respondents indicated that monitoring energy consumption of key building service through electrical metering and sub-metering posed a challenge to the maintenance management team to a great extent. The graph below summaries the findings:

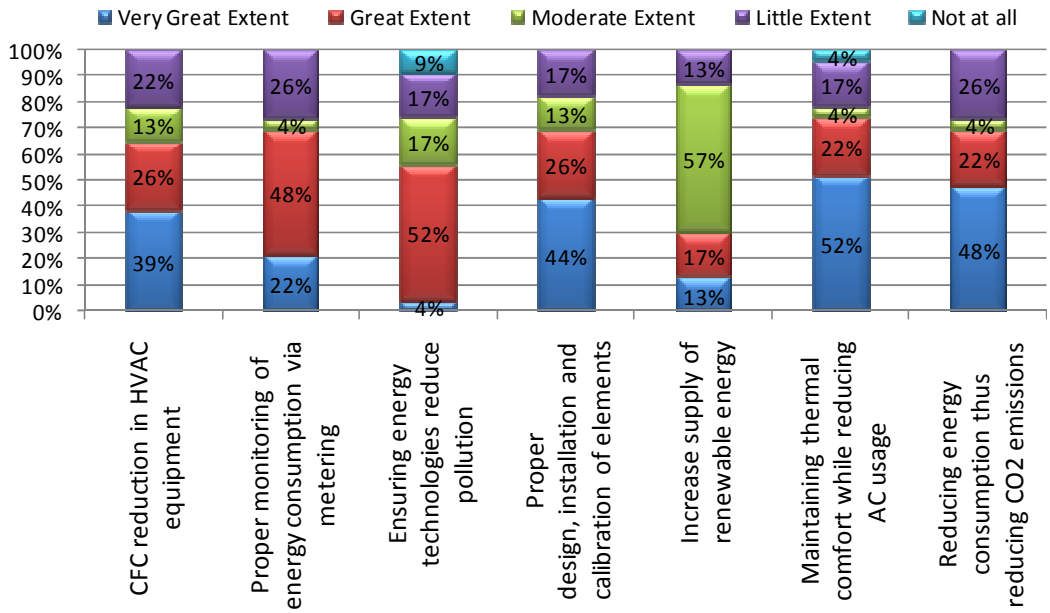

Figure 4.7: Energy Consumption (Source: Author, 2012)

4.13 Maintenance and Water Conservation and Efficiency.

The study wanted to find out how maintenance practices help to uphold the water conservation and efficiency features of a green building. It was found out that increasing borehole recharge through proper maintenance practices posed the greatest challenge to water efficiency as was cited by 52% of the respondents. Understanding water consumption patterns, ensuring water related fixtures and fittings are well maintained and maintaining design systems that monitor and manage water consumption were also found to pose a very great challenge by 44%, 39% and 39% of the respondents respectively. Ensuring rain water harvesting through proper maintenance of roof drainage pipes and storage tanks was found to be challenging in helping a site remain green only to a great extent by 44% of the respondents. The study also revealed that 39% of the respondents were of the opinion that reducing the generation of waste water did not pose any challenges at all to the water conservation and efficiency effort at all. The figure below summarizes these findings.

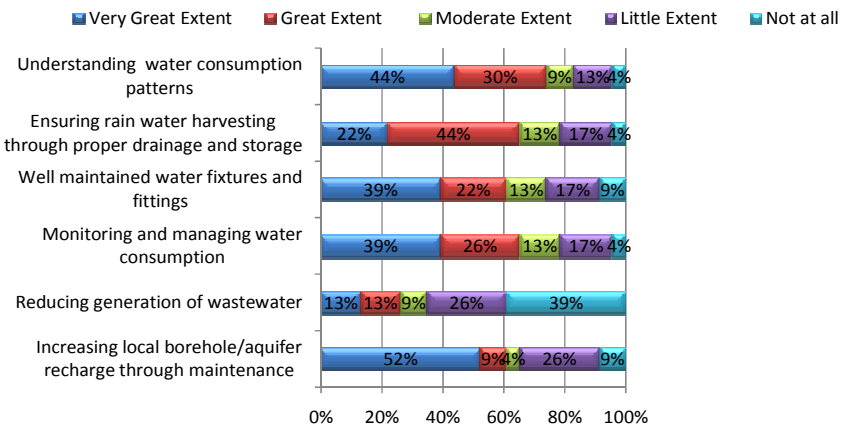

Figure 4.8: Water Efficiency (Source: Author, 2012)

4.14 Maintaining Internal Air Quality

The study wanted to understand the challenges the maintenance team faces in ensuring their green buildings uphold the standards of internal air quality. It was unearthed that reducing the quantity of indoor air contaminants from low emitting carpet and flooring systems and minimizing potentially hazardous particulates and chemical pollutants posed very great challenges to the maintenance team as was cited by 61% and 52% of the respondents respectively. Reducing the quantity of indoor air contaminants from low emitting adhesives and sealants and reducing the quantity of indoor air contaminants from low emitting paints and coatings were cited by 70% and 65% of the respondents as posing challenges but only to a great extent. The table below summarizes these findings:

Table 4.6: Internal Air Quality (Source: Author, 2012)

	Percentage of Respondents (%)				
Statement	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**
Ensuring cross ventilation for all public and circulation space	34.8	34.8	4.3	21.7	4.3
Ensuring minimal exposure to Tobacco Smoke to building occupants, indoor surfaces and ventilation systems	17.4	30.4	26.0	21.7	4.3
Response monitoring of carbon dioxide levels to ensure delivery of minimum outside air requirements.	4.3	30.4	17.4	21.7	26.1
Reduction of air quality problems associated with renovation and maintenance processes.	4.3	30.4	30.4	21.7	13.0
Reduction of the quantity of indoor air contaminants from low emitting adhesives and sealants.	8.7	70	13.0	8.7	0
Reduction of the quantity of indoor air contaminants	8.7	65	8.7	13.0	0

from low emitting paints and coatings					
Reduction of the quantity of indoor air contaminants from low emitting carpet and flooring systems.	61	8.7		30.4	0
Reduction of the quantity of indoor air contaminants from low emitting composite wood.	13.0	4.3	43.5	30.4	4.3
Minimize potentially hazardous particulates and chemical pollutants.	52	4.3	39.1	0	0
Maintaining internal noise levels at an appropriate level	0	0	0	0	0
Reduce risk of mould growth	0	0	0	0	0

4.15 Barriers Encountered In the Green Building Certification Process.

The study wanted to establish the barriers encountered as part of the Green Building Certification process. It was revealed that 47.8% of the respondents were of the opinion that the cost of executing Green Building practices was the greatest hurdle towards attaining Green Building Certification. The cost of the certification and inability to meet Green Building Certification pre-requisites were also each cited as among the greatest hurdles to attaining the certification by 39% of the respondents. Conforming to Green Building Standards documentation was cited by 56.5 % of the respondents as a very challenging barrier to Green Building Certification. The figure 4.9 below summarizes these findings.

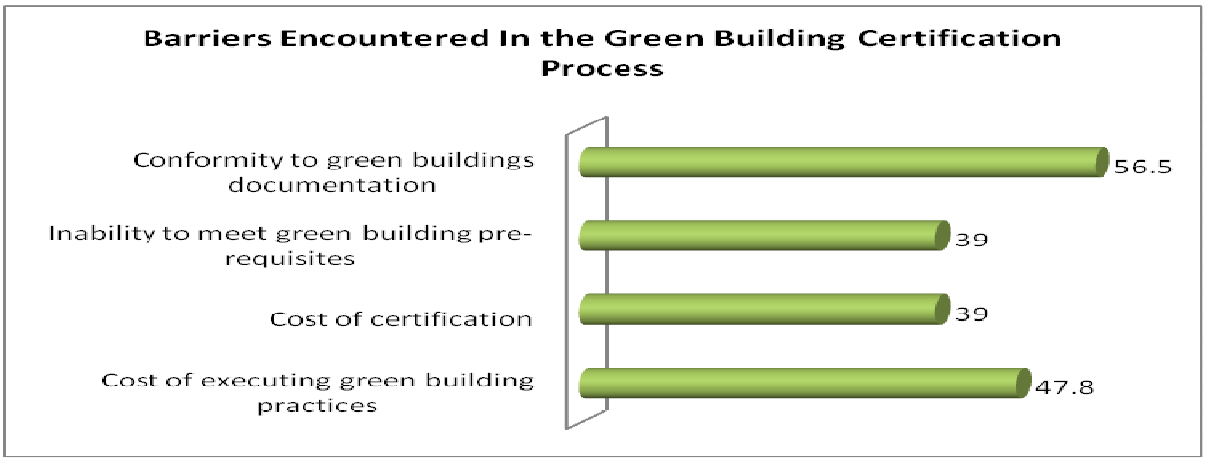

Figure 4.9 Barriers Encountered In the Green Building Certification Process

4.16 External Barriers making Green Building Certification Process Difficult.

The study wanted to establish the external barriers that hamper ease of acquiring Green Building certification. Firstly the respondents offered that it was difficult to meet the complex and rigorous international standards and processes. Secondly the study revealed that the international standardization of Green Building requirements posed a huge hurdle as some of the processes and materials demanded were too costly, inappropriate for third world economies or unavailable. Thirdly, the lack of a local certification and general lack of education and awareness of green building principles was a major hindrance to attaining Green Building Certification. On top of that, it was found out that majority of the green buildings are certified by external councils hence become a problem to regulate their maintenance locally.

4.17 Difference in Maintenance Work between Green Buildings and Conventional Buildings.

The study wanted to establish the major differences in maintenance works between Green Buildings and Conventional Buildings. The study revealed that in green buildings, maintenance work is carried out by specially trained personnel while in conventional buildings unskilled labour is mostly employed. To this end, in green buildings, there is an annual environmental audit impact to establish the efficiency of green practices. The study also found out that in green buildings the maintenance function is continuous and the maintenance staff is constantly on the job while in conventional buildings maintenance work is intermittent and carried out randomly. Additionally the study found out that maintenance materials used in green buildings

are usually superior in environmental performance to those used in conventional ones. It was also revealed that cleaning re-agents used in green buildings are environmentally friendly whereas the case is different in conventional buildings. Lastly, the study findings further revealed that in green buildings embrace the lean sigma concept to a great extent whereas in conventional buildings the concept is applied to a small extent. The lean sigma concept advocates for minimal utilization of resources for effective service delivery.

4.18 Hypothesis Testing

In order to test the significant relationship between the independent green building variables and maintenance management of green buildings in Nairobi County, the Pearson product moment correlation was used. Our data were combined and analyzed to check the relationship and strength of the relationship. The analysis was as presented below in Table 4.7. With regards to indoor environmental quality and operations maintenance, there was considerably a moderate positive correlation between the variables. Further, there is a relatively strong relationship between sustainable site development, energy efficiency and maintenance management of the green buildings. However a strong positive relationship is reported between materials and resources and maintenance management of green buildings in Nairobi County. This is shown by the indicated values of r in Table 4.7. Based on these study findings we fail to reject the null hypothesis because the study findings revealed that there was a positive significant relationship between the independent green building variables and maintenance management of green buildings in Nairobi County.

Table 4.7: Correlation Coefficients for Variables (Source: Author, 2012)

Independent Green Building Variables		
Sustainable site development	Pearson Correlation	.689*
Materials and resources	Pearson Correlation	.968*
Energy efficiency	Pearson Correlation	.663*
Water efficiency	Pearson Correlation	.763*
Indoor environmental quality	Pearson Correlation	.573*
Operations and maintenance	Pearson Correlation	.584*

Correlation is significant at the 0.05 level (2-tailed).

CHAPTER FIVE

SUMMARY OF MAJOR FINDINGS, DISCUSSIONS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the findings conclusions and recommendations based on the responses from the respondents.

5.2 Summary of Major Findings

The findings of the research were in accordance to the objectives of the study and were summarized in the Table below:

Table 5.1: Summary of major findings (Source: Author, 2012)

Objectives	**Findings**
To establish the planning process in the maintenance of Green Buildings in Nairobi County.	• Motivation to go green is firstly mainly influenced by environmental stewardship and achieving cost savings on energy and water. • Green buildings make considerations for maintenance at the design stage. • Energy and water efficiency are the two salient features given greatest attention when planning for Green building maintenance. • Choice of maintenance staff to determine provision of maintenance is given great attention when planning for storage facilities in Green Buildings. That is storage for the staff and tools or equipment on site. • In Green Buildings maintenance manual is developed at the design stage and maintenance is planned to be executed concurrently with normal operations.

To identify the type of maintenance practices used in Green Buildings in Nairobi County.	• All Green buildings adopt a preventive maintenance strategy. • Occupants comfort is the key driving aspect affecting choice of maintenance strategy. Pollution reduction and occupants' health are also key aspects. • Non toxicity is the main consideration given to products used in maintenance of Green Buildings
To establish the extent to which maintenance works of Green Buildings in Nairobi County affect their appraisal.	• Proper waste management, recycling and reduction of waste during maintenance are a big challenge to Green Building appraisal with regard to materials and resource use. • Maintaining thermal comfort without using AC and reducing CO_2 emissions are the greatest challenges in maintaining the status of buildings as green. • Increasing borehole recharge, monitoring and managing water consumption and maintaining water fixtures and fittings are the greatest challenges faced by the maintenance team with regard to water efficiency in Green Buildings. • Reduction of air contaminants from carpets and floors and minimizing chemical pollutants from Green Buildings by the maintenance team affects their appraisal.
To explore strategies to improve the quality of maintenance works in Green Buildings in Nairobi County.	• Education and awareness of Green Building standards to maintenance team. • Increase linkages between the maintenance team and the rest of the project team. • Local authorities should get accreditation to certify green buildings.

5.3 Discussions

The discussions in this research work were done in line with the study objectives. The relationships between the independent variables and the dependent variable were discussed. The dependent variable in the study was maintenance management. The independent variables in the study are the salient features of Green Buildings namely; sustainable site development, materials and resource, energy efficiency, water efficiency, and indoor environmental quality.

5.3.1 Maintenance Management and Green Buildings

According to Shenoy and Bhadury (1998), in the period of pre-World War II, people thought of maintenance as an added cost to the plant or facility which did not increase the value of finished product. Therefore, the maintenance at that era was restricted to fixing the unit when it breaks because it was the cheapest alternative. During and after World War II at the time when the advances of engineering and scientific technology developed, people developed other types of maintenance, which were much cheaper such as preventive maintenance. In addition, people in this era classified maintenance as a function of the production system. Nowadays, increased awareness of issues such as environment safety, quality of product and services makes maintenance one of the most important functions that contribute to the success of the industry. From the background of this study it was noted that buildings accounted for approximately half of all annual energy and greenhouse gas emissions, and that one potential solution is to ensure that the design, construction and maintenance of the built environment is environmentally sustainable (Commission for Architecture and the Built Environment, 2007). The concept of Green Building thus came into being and this necessitated a new approach in the execution of maintenance works because green buildings have significantly different requirements from conventional ones.

The conventional practice of construction, design and building management has had detrimental impacts on the environment resulting from high standards of living, suburban sprawl, and lack of growth controls, decentralization of communities and other ineffective planning measures. In a step forward from conventional practices, the green building movement came up with the application of design, construction, maintenance management and demolition practices that minimize the impact of buildings on environmental, economic and social resources. This need to save energy and mitigate environmental problems fostered a

wave of green building innovation that included novel techniques of conducting operations and maintenance. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

This study sought to understand how maintenance management is carried out in green buildings in Nairobi County, Kenya. Giving due consideration to the fact that a building has to conform to and maintain certain design and functional standards to be rated as green, the study further sought to understand how the maintenance function enables a green building maintain its 'green status'. There are nine different rating systems for the design, construction and operation and maintenance of buildings, homes and neighborhoods. These ratings are continuously evolving in order to incorporate emerging green building technologies.

According to Kharafi National (2007), one such rating system is the Leadership in Energy and Environmental Design (LEED**).** LEED promotes a whole building approach to sustainability by recognizing performance in location and planning, site development, water savings, energy efficiency, materials selection, indoor environmental quality, innovative strategies and priorities in regional issues. It also measures and enhances the sustainability of buildings by establishing metrics and rating systems to measure and recognize buildings based on their performance in the three main dimensions of sustainability which include society, environment and economy. Projects certified under the LEED rating systems demonstrate that they have addressed the elements that enhance these three areas in a balanced way. It is further suggested that the LEED rating systems are tools a design team uses to ensure that it designs, constructs and accounts for a project's green features properly. The LEED process ensures that the whole building process is value engineered from the start.

5.3.2 Planning Process in the Maintenance of Green Buildings in Kenya.

The study sought to have a holistic understanding of maintenance works in green buildings at the design stage, construction and the post construction stages. Key to this approach was understanding the motivation behind the need to go green as this actually preceded the planning process. The study revealed that across all the buildings the main motivation behind going green was environmental stewardship. The facility managers of the three institutions (i.e the Coca Building in Upper hill, Standard Chartered building in Westlands and Strathmore

Business School in Madaraka), offered that they wanted to be at the forefront in the effort towards environmental conservation. Their decision to go green stemmed from an awareness of the benefits of green buildings to the environment. To this end, from the literature review Ahmad (2003) observes that the surrounding environment, the needs and characteristics of its users and climatic conditions mostly influences traditional building designs. In recent times, although designs are more concerned with client requirements and the actual building objectives, a lot of attention is being given to sustainability and the climate.

The second most important motivation was found to be the expected cost savings on energy and water. Mark Kruzan (2011) reiterates that although the initial costs of building green may be higher than those of conventionally designed buildings, the savings generated in energy, water and maintenance, offer quick investments returns and ultimately revenues. Additionally, as the business world gets more and more competitive, organizations that are perceived to carry an environmental agenda may have an edge over those that do not. The study also revealed that over 90% of the respondents said that gaining competitive advantage was very influential in their decision to go green. By way of example Coca Cola Company uses a lot of resources from the environment as its raw material (the Kola nut) and depletes the soil of essential minerals through its farming programs. The company therefore feels obliged to observe 'Green Principles' in all they do to help conserve the environment, this they say gives them an edge over other competing manufactures. The study also revealed that government incentives do very little to influence the decision to go green. This could be attributed to poor incentive programs by the government or lack thereof.

According to Susan R J (2011), a Maintenance Plan is a written document that prioritizes and sets a schedule for regular and ongoing maintenance of a building, monument, or designed landscape. The plan also serves as documentation of work since when buildings are neglected, defects can occur which may result in extensive and avoidable damage to the building fabric or equipment. With specific reference to green buildings the result may be the loss of the green rating.

The findings of the study revealed that in all the green buildings included in the sample (i.e. the Coca Building in Upper hill, Standard Chartered building in Westlands and Strathmore

Business School in Madaraka), considerations for maintenance of the facility were made at the design stage of the project. Green buildings have unique maintenance requirements directly as a result of its design and orientation, materials and resources used in its construction and desired functionality features. The maintenance team is thus required to give its input at the design stage through maintenance manual so that provisions are made out for ease of execution once the project is complete. Across all the buildings, the study found out that at the design stage the salient features of green buildings that were given most attention with regard to maintenance were energy efficiency, water efficiency and internal air quality. It was seen in the literature review that the core issue around the green movement and sustainability issues with relation to buildings is the reduction in emission of $C0_2$, protecting water catchment areas and reducing pollution. Therefore, it comes as no surprise therefore that these three aspects were given most attention. Rozita (2006) points out that maintenance planning should start at the design stage of any building project and should continue throughout the life of that building. In this, the building owner and or user must play an active part. In the same coin, the study revealed that that 85% of the respondents were at least, to a great extent of the opinion that designing the facility with expectations of expansion to allow ease of maintenance was the most important consideration at the design stage. Designing the facility to allow maintenance to be carried out concurrently with normal operations was cited by at least 70% of the respondents as a main maintenance consideration during the design phase of a green building. The study revealed that developing a maintenance manual at the design stage was considered important only to a great extent by 61% of the respondents while inviting maintenance proposals from maintenance support vendors was considered important only to a moderate extent by 48% of the respondents.

The findings of the study also gave an insight into the planning process for the maintenance staff. Greatest importance was given to whether the maintenance staff was going to be in house or outsourced to vendors. This was attributed to the fact that the decision of whether to outsource or not would inform the decision whether to have storage facilities for the staff and tools on site, and have it included in the overall design of the facility. Importance was also attached to having maintenance staff input on the Project Document and having them involved through all the phases of the project but only to a great extent by 48% and 39% of the respondents respectively.

5.3.3 Types of Maintenance Practices used In Green Buildings in Kenya.

It was noted in the literature review that the survival of any building is underpinned by regular maintenance. The study wanted to establish the maintenance strategies and practices used in green buildings in Nairobi County. It was found that while the maintenance team might actually use corrective and conditioned based maintenance, it is preventive maintenance that is mostly adopted by green buildings in Nairobi. From the literature review it can be seen that preventive maintenance was introduced to overcome the disadvantages of corrective maintenance, by reducing the probability of occurrence of failure and avoiding sudden failure (Raymond and Joan, 1991). Preventive maintenance tasks are performed according to a predetermined plan and this is consistent with the finding that maintenance considerations are made at the design stage. A major setback of this strategy, however, is that it leads to a large number of unnecessary tasks as maintenance task may be carried out on elements that are not due for fixing.

It is important to add that for this type of maintenance to be efficient in green buildings there is a need for the staff to have proper understanding of green building standards. This is mainly because maintenance of green buildings requires specialized equipment that can tolerate the workload of the environment. Maintenance staff working on green buildings also needs to have the required qualifications and skills which the maintenance manager should constantly upgrade through trainings. The activities involved in preventive maintenance include replacements, adjustments, major overhauls, inspections and lubrications. The study also revealed the different kinds of preventive maintenance carried out in green buildings. Firstly, there is routine maintenance which includes those maintenance activities that are repetitive and periodic in nature such as lubrication, cleaning, and small adjustment. Secondly there is running maintenance which includes those maintenance activities that are carried out while the machine or equipment is running and they represent those activities that are performed before the actual preventive maintenance activities take place. Thirdly there is opportunity maintenance which is a set of maintenance activities that are performed on a machine or a facility when an unplanned opportunity exists during the period of performing planned maintenance activities to other machines or facilities. In addition there is window maintenance which is a set of activities that are carried out when a machine or equipment is not required for a definite period of time. Lastly there is shutdown preventive maintenance, which is a set of

preventive maintenance activities that are carried out when a machine or equipment is in total stoppage situation.

The study also wanted to understand how the perceived benefits of green buildings affect the choice of the maintenance strategy. All the perceived benefits of green buildings were cited by 90% of the respondents at least to a great extent to influence the choice of the maintenance strategy. However, comfort was the single most perceived benefit that influenced the choice of the maintenance strategy the most with 70% of the respondents holding this view. Pollution reduction was the second perceived benefit that affected the choice of the maintenance strategy with 65% of the respondents holding this view. Occupants health and employee productivity were other perceived benefits of green buildings that that influenced the choice of the maintenance strategy the most with 56% and 52% of the respondents holding this view respectively.

The study also found out that the main consideration given to products used in maintenance of green buildings is that they should be no-toxic. This view was held by slightly over 50% of the respondents. Reusability and renewability of products were each cited by 17.4% of the respondents as main considerations for products used for maintenance in green buildings. That a product should be recyclable was only considered a main consideration by 13% of the respondents.

5.3.4 Extent to Which Maintenance Works in Green Buildings Affect their Appraisal.

From the literature review it was noted that numerous countries and regions have developed green building programs aimed at promoting more sustainable buildings. At the crux of each program is the use of an integrated design approach and a point's scheme that allots credits for building features designed to improve sustainability. These key features were pointed out to be siting and structure design, energy efficiency, water efficiency, and materials efficiency internal air quality and operations and maintenance optimization. The challenge for the maintenance team therefore becomes to execute maintenance works effectively in order that every time the building is evaluated it earns sufficient credits to uphold its green status. Without a doubt, poor maintenance can result in the degrading of a green building. It is in this

light that the researcher wanted to delve into the extents of the challenges the maintenance team faces in order to maintain this green status.

Rask and Kato (2008) found in their study based on 12 Green Star-rated buildings and their occupants, that 100 per cent of employers and employees alike thought that the green building was “better than expected with all things considered” and the majority of occupiers signaled that they would not like to relocate to a non-green office building. In the same study, Rask and Kato (2008) found that 80 per cent of business managers believed staff absenteeism had decreased since they moved into the new Green Star-rated building.

Workers' increased satisfaction, health and productivity in green buildings are mainly the result of better airflow, increased amounts of natural light and views, use of less-toxic building materials and furnishings, reduction of glare, increased thermal comfort, satisfying noise levels and individual controllability of systems (www.gbca.org.au). Wilkinson, Reed & Jailani (2011) pinpointed that thermal comfort and lighting are the main attributes linked to workers' increased productivity and satisfaction in green buildings.

Firstly, the study revealed that controlling soil erosion from the landscape was the most challenging task for the maintenance team with 57% of the respondents holding this view. This could be attributed to the lack of proper knowledge on how to prevent sheet water from storms after construction or runoff water during and after construction. On top of that felling of trees to pave way for construction also leaves open spaces vulnerable to soil erosion where sheet flow from storm-water exceeds the holding power of existing vegetation. The maintenance team should reinforce the root and stem structures of vegetation on steep slopes to curb against soil erosion. They should also invest in sediment filtration devices known to reduce soil loss caused by storm-water runoff and traps soil particles while allowing water to pass through, protecting waterways, sidewalks, and roads from sediment accumulation. Secondly and along this vein, the study revealed that it was tough for the maintenance team not to interfere with the natural hydrology when selecting the location and designing the site, this view was held by 57% of the respondents.

Thirdly, the study revealed that proper location of the building on site to protect natural features and vegetation was cited by 48% of the respondents as challenge to a very great extent to the maintenance team. The ideal North-South building orientation to maximize on sunlight may necessitate the cutting down of vegetation which may have an adverse effect on the surrounding eco-system. On the other hand, not interfering with the natural features on site may lead to a sub-optimal design that may compromise other features and perceived benefits of green buildings. Some of the perceived benefits of green buildings include noise and pollution reduction; however, maintenance works are usually a rackety affair. Forty four percent of the respondents cited minimization of noise and pollution during maintenance as a problem that may affect appraisal of their building. Other key challenges to the maintenance team that manifested but only to a great extent were the rehabilitation of damaged sites and documentation of building features to enhance building performance these were each cited by 65% of the respondents. Indeed, the actual construction activity may cause so much damage to the building site so much so that that the maintenance team may not be able to rehabilitate it to green standards. Felling of hardwood trees and improper disposal of debris are some of these activities that may pose a challenge to the maintenance team. In the same token, cost savings in energy and water are usually achieved by educating building occupants on proper usage. However, high occupancy turnover, uncooperative staff and poor communication skills may pose a challenge in explaining building features to users to achieve maximum cost savings.

Another salient feature of green buildings is material and resource efficiency. For a building to be considered green it must use eco-friendly materials from renewable sources. The ability to recycle and reuse its waste products also affirms its green status. Indeed the greatest challenge faced by the maintenance team as cited by 65% of the respondents is recycling and proper waste management. The second greatest challenge with regard to materials and resources for the maintenance team was found out to be the reduction in waste during maintenance this was cited by 52% of the respondents. Reducing waste from building occupants and redirecting recyclable resources to reusable materials were among two other greatest challenges faced by the maintenance team as was cited by 48% and 44% of the respondents respectively. The maintenance team should fully engage the design team to ensure that all building materials are cut to standard sizes to avoid waste and also to ensure the building is designed for deconstruction i.e. to make it easy for the dis-entanglement of systems for example, materials bolted together instead of glued. Additionally the maintenance team should have a system to

gauge the salvage value of waste material to know what is best for re-use and recycling. Provision of accessible waste storage facilities was also found to be a great challenge for the maintenance team. This may be attributed to the lack of input of the maintenance team into the design process on provisions to be made for storage facilities. Additionally, it may also be as a lack of proper litter and sewage disposal facilities by the Nairobi City Council.

A key feature of green buildings is their ability to reduce energy consumption thereby reducing greenhouse gas emissions. All elements of the building shell; foundation, framing, roof structure and windows play key roles in defining the potential energy savings for a building. The challenge for the maintenance team is to ensure energy consumption is kept at a minimum while ensuring all functions across the organization are running optimally. The study revealed that 48% of the respondents indicated that reduction of energy consumption thus reducing CO_2 emissions to the atmosphere posed a challenge to the management team to a very great extent as did maintaining a thermally comfortable environment by reducing the use of air conditioning that was indicated by 52% of the respondents. On top of that 44% of the respondents cited proper design, installation and calibration of elements as a key challenge in ensuring energy consumption is kept at a minimum. CFC reduction in HVAC was also cited as very great challenge to the maintenance team. Generally among all the potential challenges with regard to energy efficiency were challenging to at least to a great extent by 50% of the respondents save for increasing the supply of renewable energy which was only found to be moderately challenging. The greatest energy use in buildings goes to supporting heating ventilation and air condition (HVAC) systems. The maintenance team should ensure the HVAC systems are installed properly.

Yet another key objective of green buildings is reducing water consumption and protecting water quality. The research also wanted to establish how well the maintenance team work to keep the credit points of green buildings high with regard to water efficiency. It was found out that increasing borehole recharge through proper maintenance practices posed the greatest challenge to water efficiency as was cited by 52% of the respondents. This was consistent with the assertion in the literature review that a critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself. Secondly the study revealed that one of the other greatest challenges they face is understanding the water consumption patterns. This view was held by 44% of the respondents and could be attributed to

climatic conditions leading to erratic demand for water. In the same vein, critical challenges faced by the maintenance team in helping the site remain green as each cited by 39% of the respondents were in maintaining water fixtures and fittings and in monitoring and managing water consumption. When for example there is a sudden drought, water-intensive landscapes may wither and become eyesores .The maintenance team should have linkages with the meteorological department and collect data on overall water consumption by the building in order to harvest and store enough water while efficiently regulating consumption in dry times. This will also critically inform the decision of the need to have additional water storage and water regulating facilities and equipment. Daily consumption records of the different water uses in the building should also be kept to point out areas of wastage and directing them to areas of need if any. The fixtures and fittings used in low flush toilets, borehole pumps and automatic ground sprinklers are expensive to replace. The maintenance team should ensure they recommend the highest quality brands to the procurement department to ensure a lower incidence of replacements and repair. On the contrary was found not to be a problem at all by 39% of the respondents.

Equally important in maintenance management for green buildings is the Internal Air Quality (IAQ). From the literature review IAQ seeks to reduce volatile organic compounds (VOC) and other air impurities such as microbial contaminants. Buildings usually rely on designed ventilation systems (passive, natural or mechanically powered) to provide adequate ventilation of cleaner air from outdoors. The study wanted to understand the challenges the maintenance team faces in ensuring their green buildings uphold the standards of internal air quality. It was unearthed that reducing the quantity of indoor air contaminants from low emitting carpet and flooring systems and minimizing potentially hazardous particulates and chemical pollutants posed very great challenges to the maintenance team as was cited by 61% and 52% of the respondents respectively. This could possibly be attributed to the lack of the specialized detection sensors that can indicate the degree of pollution. It was noted in the literature review that dust from shoes is the major means through which carpets and floors are contaminated. While cleaning the floors in all the buildings is done continuously throughout the day, contaminants in the air are a lot harder to get rid of. For low emitting materials such as carpets and wooden floors, the maintenance team should replace them with comparative products with

low volatile organic compounds (VOC). In addition, close to 70% of the respondents were of the opinion that ensuring cross ventilation for all public and circulation spaces was a challenge to the maintenance team at least to a great extent. IAQ supports building occupants' health, safety and comfort. To provide such an environment the maintenance teams should ensure that they ensure proper functioning of the HVAC systems to increase ventilation effectiveness and prevent short-circuiting of air-flow delivery. Techniques available include use of displacement ventilation, low velocity and laminar flow ventilation (under flow or near flow delivery and natural ventilation. Operable windows with an architectural strategy for natural ventilation should also always be adjusted into position.

To allow ease of maintenance the maintenance team should include proactive design details that will eliminate some of the common causes of indoor air quality problems in buildings. They should also introduce standards into the design process early. Incorporate references to targets in plans and specifications. In addition they should ensure the ventilation system outdoor air capacity can meet standards in all modes of operation. On top of that they should locate building outdoor air intakes away from loading areas, building exhaust fans, cooling towers, and other sources of contamination. Operational testing should be done and included in the building commissioning report.

The study also revealed that 30.4% of the respondents cited reduction of air quality problems associated with renovation and maintenance processes as a challenge to the maintenance management team to a great extent and a similar percentage cited the same reason but only to a moderate extent. The maintenance team should specify containment control strategies including protecting the HVAC system, controlling pollutant sources, interrupting pathways for contamination and enforcing proper housekeeping. The maintenance team should also specify the construction sequencing to install absorptive materials after the prescribed dry or cure time of wet finishes to minimize adverse impacts on IAQ.

5.3.5 Strategies to Improve the Quality of Maintenance Works in Green Buildings.

It was noted in the literature review that the function of building maintenance is to maximize the aesthetic and economic values of a building as well as increase the health and safety of the occupants. It was also noted that the basic function of maintenance in conventional buildings is to ensure that the facility is presentable and that this is achieved through daily cleaning and housekeeping. It was further noted by Stephens (2000) that most traditional maintenance management systems advocate for the operation of facility utilities in an economical manner without neither expressing how nor using the supporting technology. This significantly sets apart maintenance of conventional buildings from that of green buildings. First and foremost, the ideological difference between maintenance in conventional buildings and green buildings is that in the latter consideration is made for maintenance at the pre design stage and is carried throughout the project life cycle. It was in this light that the study wanted to identify strategies of improving the quality of maintenance through the various stages of the project life cycle.

The study kicked off by establishing the motivation behind going green and it was revealed that organization want to be at the forefront in pursuing environmentally sustainable practices. All the organizations in the sample cited environmental stewardship as the biggest influencer for going green. To this end, the maintenance team should be engaged in the entire life cycle of the project as they are responsible for ensuring the green status is upheld. During the site selection stage the maintenance team in collaboration with geotechnical engineers should ensure that they design a sediment and erosion control plan that conforms best to NEMA and the Green Building Standards that their certification subscribes to (LEED, for Strathmore, Coca Cola and Standard Chartered buildings). Measures such as silt fencing, sediment traps, construction phasing, stabilization of steep slopes and maintaining vegetated ground cover should be pursued. To fully earn the respect of environmental activists the maintenance team should also lobby against the use of any prime agricultural land, parks and land that provides habitat for any species that is threatened or endangered. This can be achieved by proper screening of the land before purchase.

The study revealed that the cost of executing Green Building practices was the greatest hurdle to the maintenance team in ensuring the site remains green. The discussions above have revealed that for every product used in maintenance of green buildings there are cheaper alternatives either by the same manufacturers or competing ones. The procurement department should therefore work closely with the maintenance department to ensure that products sourced are assessed through a cost-benefit criterion to achieve greater gains at minimal costs. The cost of the certification was also cited as being costly. The building owners should petition regulatory bodies in the built environment to have the local environmental authority (NEMA) to seek accreditation and offer less pricey local LEED certifications. Another problem cited that the maintenance team can improve on was aligning their documentation to Green Building standards. The facility and or maintenance managers of these buildings should attend LEED accredited training workshops to have fuller understanding of the documentation requirement. This will also give them insights into other sustainability issues that they may not have been aware of and increase their understanding of emerging sustainable issues and technologies. The accreditation will also solve the problem of beefing up the knowledge of green building certification prerequisites which was also cited as being among the greatest challenges. The training should be passed down to the entire maintenance staff to increase their overall understanding of green building goals and how their role plays into it. The maintenance department should, although not cited as a huge barrier, enhance team cooperation through team building activities. This enables the maintenance team to improve communication, relationships, confidence and trust among the team members. Team building may also serve to reduce friction between maintenance team and other departments while improving team based decision making.

5.4 Conclusion

The conclusion derived from the research is that maintenance management is critically important in green buildings if they are to maintain their green ratings. Green buildings in Nairobi were seen to be rated based on how well they meet criteria set by the Leadership in Energy and Environmental Design Rating System. The system awards credit points to various aspects of the building that include; sustainable sites, water efficiency, energy, materials and resources and indoor environmental quality. Buildings may start off as green but fall by ~~on~~ the wayside in keeping with sustainable practices that uphold the environment agenda and thus

lose their green rating. The function of the maintenance team was thus found to be very critical in the appraisal of green buildings. This was proven by the fact that a lot of thought and consideration is given to the planning of maintenance works which was seen to begin at an early stage when choosing the location for the project. The main strategy in the execution of the maintenance strategy was found to be preventive. In green buildings, the strategy is executed continuously and sometimes concurrent with normal operations. Maintenance works in green buildings was found to be very specific and targets each salient feature of the green building that were identified as sustainable sites, water efficiency, energy, materials and resources and indoor environmental quality. The challenges of conducting maintenance works on these features were identified and strategies for improvement suggested in the preceding discussions. The maintenance function was thus seen as very important in upholding Green Building Standards and in the enjoyment of all the perceived and real benefits of sustainable green practices. Further, based on the hypothesis testing, we fail to reject the null hypothesis because the study findings revealed that there was a positive significant relationship between the independent green building variables and maintenance management of green buildings in Nairobi County.

Laura Ann (2011) argues that the topic of green building has expanded outside the environmental community and has become a hot issue among mainstream building industry professionals. One of the most common discussions continues to be in regards to the costs and benefits associated with green building. Critics charge that the costs of green building are prohibitive—often 10-20 percent more than conventional practices. They also claim that guidelines are difficult to follow and that many "certified" buildings do not perform as expected. Advocates uphold that the costs are negligible when compared to the value recaptured through water and energy savings, health benefits and environmental impacts. Proponents also cite that many of the methods and products used to create a more sustainable environment are simply matters of good design, so it's not any more complicated to achieve.

Fortunately, as pointed out by Laura Ann (2011) statistics are proving to support the positive impacts of green building. As a result, sustainable building programs are becoming mainstream, more certified projects and products are entering the marketplace, and the public is experiencing first-hand the significant effect they can have on the environment. As more

people embrace sustainability, the benefits will continue to outweigh the costs and advocacy for green building will become even more prevalent.

The logic is simple and compelling where the building sector is the single largest contributor to global greenhouse gas emissions with one third of global energy use taking place in offices and homes. This figure is set to double by 2030 unless urgent action is taken hence one of the key considerations for Kenya in vision 2030. The design and construction of new buildings and the refitting of existing ones represent one of the key low cost ways of combating climate change while reducing electricity bills and dependence on fossil fuels. Along with green transportation, buildings are thus a central part of a transition to a Green Economy and a sustainable 21st century.

5.5 Recommendations.

Based on the research findings, the researcher makes the following recommendations:

The involvement of the maintenance team with respect to site selection should ensure that green buildings are not put up on sites that are environmentally sensitive. This makes it easier for the maintenance team to preserve the surrounding eco-system, maintain natural storm water and ensures alternative modes of transportation into the site that reduce pollution. Proper site selection will also significantly reduce maintenance costs.

The maintenance team should be well trained on materials use and recycling. This will ensure their input at the design stage leads to resource efficiency throughout the lifetime of the project. The maintenance team therefore should be vetted according to their knowledge base and experience during recruitment.

The maintenance team should also test the functionalities of all aspects of green buildings during commissioning before intended occupants move in. Building commissioning should include testing and adjusting the mechanical and electrical systems to ensure that all equipment meets design criteria. It should also include instructing the staff on the operation and maintenance of equipment. Over time, building performance should be assured through measurement, adjustment, and upgrading.

The management of the green buildings in Nairobi should invest in research on practical and effective operational and maintenance strategies for energy and water efficiency, conserving natural resources and protecting internal air quality. Further, the management of green buildings in Nairobi should hire in-house Green Building consultants to head or work alongside the maintenance manager.

All the maintenance staff working in Green Buildings should undergo regular training on Green Building standards and have certifications of the Green Building certification their building adheres to. Trained and certified Green building maintenance staff should in conjunction with the design, construction and project management team develop the maintenance plan and hiring of maintenance staff for a particular green building should largely be pegged on their understanding of its maintenance plan.

5.6 Limitations of the Study

In executing this study the researcher faced the following challenges that pronounce the findings of this study should not be taken as wholly writ: There was generally a lack of extensive prior research done on this topic and the discussions in the literature view may have made more reference to conventional buildings than green buildings; the number of the units of the analysis was small but significant relationships were established and the findings are representative of the entire population; and as such the researcher faced great challenges in accessing the respondents as they work in busy organizations and the nature of their jobs are also characterized by numerous meetings and travels.

The study mainly focused on commercial buildings in Nairobi County and therefore generalization could not extend to other buildings in the entire county. This made it difficult to obtain information from the few green buildings within the County because of a narrow scope.

The green buildings under the study which had been publicly declared as green buildings were actually in the process of certification and had not fully attained green building status. There was no green building in Nairobi County at the time of the study that had fully attained the status of being certified as green building from a global perspective.

5.7Areas for Further Research

Following the study herein, the researcher recommends further research to be done on perceptions, knowledge, value and risk management of Green buildings in Kenya. This will help establish the extent of penetration of knowledge on green buildings by professionals in the built environment and will enable professionals in the fields of management better understand and manage the benefits of green building.

Further research is recommended on the opportunities available for professionals in the built environment and specifically maintenance managers to receive specialized training to enhance their knowledge in relation to each of the salient features of green building. This will enable specialization of roles in the handling of the unique problems that green buildings present in terms of maintenance.

Lastly, research should be done on the direct environmental, social and financial benefits Green buildings can bring to Kenya. This will serve as an eye opener for product local manufacturers to include green product lines and encourage a wider and faster acceptance of green living.

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APPENDICES

APPENDIX ONE:

LETTER OF INTRODUCTION

To: Whoever it May Concern,

Dear Sir/Madam

RE: ASSISTANCE TO FILL ACADEMIC QUESTIONNAIRE

I am a master's student in the department of construction management at the University of Nairobi. I am conducting an academic research titled '**Maintenance Management of Green Buildings in Nairobi County'.**

I kindly request your assistance in filling in the attached questionnaire. The objective of the research is to establish whether through proper maintenance practices Green Buildings can maintain their 'green' status.

Your participation in this research would be greatly appreciated but is voluntary. Your confidentiality and anonymity are ensured. Your identifiable information contained in the survey will only be used during the data collection phase of this study. If a survey is less than half completed you may be contacted to verify that it was your intention not to complete the survey, otherwise you will not be contacted. During the analysis portion of the study, you will not be individually identified with your questionnaire or response. All collected data will be aggregated and grouped.

There are no known risks associated with participation in this study. Your responses to the survey may contribute to greater understanding of maintenance management of Green Buildings.

Thank You.

Arch. Bisher Fawaz

APPENDIX II

QUESTIONNAIRE

PERSONAL DETAILS

. Name of Project _____

. Project completion date (if completed) _____

. Your name_____

. Work phone _____

1. In what capacities were (are) you involved with the project? (Tick as appropriate)

a. ☐ Owner

b. ☐ Architect

c. ☐ General Contractor

d. ☐ Engineer

e. ☐ Construction Manager

f. ☐ Green Building Consultant

g. ☐ AAK official

h. ☐ NEMA official

i. ☐ Nairobi City Council official

j. ☐ Maintenance manager

k. ☐ Facility Manager

j Other (please specify) _____

2. Please list the Green Building Standards program certification that your building conforms to.

☐ Leadership in Energy and Environmental Design (L.E.E.D)

☐ Building Energy Efficiency (B.E.E)

☐ Building Research Establishment Environmental Assessment Method (B.R.E.E.A.M)

☐ Green Star (Green Building Council of Australia)

☐ Hong Kong Building Environmental Assessment Method (HK-BEAM)

Other (Please State)_____

3. Rate the importance of each reason for working towards and maintaining Green Building Standard certification. **(Scale1=Most influential, 2=Very influential, 3=Some influence 4=Little influence, 5=Not Influential)**

Reason	Most Influential	Very Influential	Some Influence	Little Influence	Not Influential
Environmental Stewardship					
Cost Savings on Energy and Water					
To Gain Competitive Advantage					
To Enjoy State and Local Government incentives					
Requirement by Government					
Validate achievement through third party review					

Other (please specify and rate);

_____

_____

_____

_____

_____

4. At what stage of the project were considerations made for maintenance of the facility.

Tick where appropriate;

☐ At the design phase ☐ After the design phase.

☐ During the construction phase ☐ Post construction phase

5. Which salient feature of Green Buildings was given most attention with regard to maintenance during the design stage?

- ☐ Internal Air Quality
- ☐ Water efficiency
- ☐ Energy efficiency
- ☐ Material Utilization
- ☐ Project Site sustainability

6. Which is the most commonly used maintenance strategy adopted by the Facility/Maintenance Manager?

- ☐ Preventive Maintenance
- ☐ Corrective Maintenance
- ☐ Condition-Based Maintenance

7. Rate the extent to which the following aspects of your Green Building affect the choice of your facility's maintenance strategy. **(Scale 5=Very Great Extent, 4= Great Extent, 3= Moderate Extent, 2=Little Extent, 1= Not at all)**

Consideration	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**
Occupants Health					
Comfort					
Productivity					
Pollution Reduction					

8. In your opinion which is the main consideration given to any products used in the Maintenance of Green Buildings

- ☐ The products should be non toxic.
- ☐ The products should be reusable.
- ☐ The products should be renewable.
- ☐ The products should be recyclable.

9. The following statements relates to maintenance considerations during the design phase of a building. State according to the given scale the extent to which importance is given to each one when designing the green building.

Consideration	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**	
Failed equipment can be accessed, isolated, replaced or repaired concurrent with normal operations (i.e. without affecting operations.						
Facility is designed with expectation of expansions and upgrades that will allow ease of maintenance.						
Providing strategic and adequate transport routes for replacing equipment and allowing installations.						
A maintenance manual should be developed at the design stage.						
Inviting maintenance proposals from maintenance support vendors.						

10. The following statements relate to embedding maintenance considerations during the design stage of a Green Building. State according to the given scale the extent to which importance is given to each one when planning for Maintenance staff in the design.

Consideration	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**	
Will the maintenance service be a department on its own or will it merely be a function in the IT department.						
Will the maintenance function be outsourced or in-house to determine provisions for on-site storage facilities?						
The maintenance staff should be involved at the design stage of the project.						
Maintenance staff should participate in site tours and observations throughout the construction process.						
Maintenance staff should have an input in the Project documents.						

11. Green Buildings need to be maintained properly if they are to remain green. The following statements relate to maintaining a project site green. To what extent do they pose a challenge to the maintenance management team in helping the site to remain green?

Consideration	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**
Proper location of the building on the site to protect and restore natural features.					
Minimization of pollution, noise and vibration when carrying out maintenance works.					
Moderation of the impact of microclimate on the surrounding public place.					
Conservation of green field sites.					
Documentation of building design features for users to sustain performance during occupancy.					
Rehabilitation of damaged sites.					
Limit disruption of natural hydrology.					
Elimination of pollution and contaminants in runoff water.					
Eliminating light trespass from building and site.					
Maintaining environmentally sensitive building exterior to reduce pollution.					
Controlling soil erosion from ongoing landscape operations.					

12. Green buildings must utilize building materials and resources efficiently to remain green. The following statements relate to material and resource use. To what extent do they pose a challenge to the maintenance management team in helping the building to remain green?

Consideration	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**
Reduction of waste during maintenance works.					
Proper waste management and recycling.					
Redirecting recyclable recovered resources from maintenance operations to reusable materials in appropriate sites.					
Reducing waste from building occupants.					
Provision of accessible waste storage facilities.					
Maintaining a forest program to produce wood for furniture and fittings.					
Reducing processing of virgin resources and materials.					

13. Green buildings must reduce total energy consumption of facilities to be considered green. The following statements relate to optimization of energy performance thereby increasing energy efficiency in green buildings. To what extent do they pose a challenge to the maintenance management team in helping the building to remain green?

Statement	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**
Reducing energy consumption thus reducing CO_2 emissions to the atmosphere.					
Maintaining a thermally comfortable environment by reducing the use of air-conditioning.					
Ensuring the increase of on-site renewable energy self supply.					
Ensuring building elements and systems are designed, installed and calibrated to operate as intended.					
Ensuring grid-source renewable energy technologies to reduce pollution.					
Monitoring energy consumption of key building services through electrical metering and sub-metering.					
Ensuring CFC reduction in HVAC equipment by proper maintenance to reduce ozone depletion.					

14. Buildings must conserve water and be water efficient to be considered green. The following statements relate to managing water sustainability in green buildings. To what extent do they pose a management challenge to the maintenance team in helping the building to remain green?

Statement	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**
Understanding water consumption patterns.					
Ensuring rain water harvesting through proper maintenance of roof drainage pipes and storage tanks.					
Ensuring water related fixtures and fittings are well maintained.					
Maintaining design systems that monitor and manage water consumption.					
Reducing the generation of wastewater.					
Increasing local aquifer/borehole recharge through proper maintenance practices.					

15. Buildings must provide indoor environments that enhance well being and comfort of occupants to be considered green. The following statements relate to practices that improve indoor air quality (IAQ). To what extent do they pose a management challenge to the maintenance team in helping the building to remain green?

Statement	**Very Great Extent**	**Great Extent**	**Moderate Extent**	**Little Extent**	**Not at all**
Ensuring cross ventilation for all public and circulation space.					
Ensuring minimal exposure to Tobacco Smoke to building occupants, indoor surfaces and ventilation systems.					
Response monitoring of carbon dioxide levels to ensure delivery of minimum outside air requirements.					
Reduction of air quality problems associated with renovation and maintenance processes.					
Reduction of the quantity of indoor air contaminants from low emitting adhesives and sealants.					
Reduction of the quantity of indoor air contaminants from low emitting paints and coatings.					
Reduction of the quantity of indoor air contaminants from low emitting carpet and flooring systems.					
Reduction of the quantity of indoor air contaminants from low emitting composite wood.					
Minimize potentially hazardous particulates and chemical pollutants.					
Maintaining internal noise levels at an appropriate level.					
Reduce risk of mould growth.					

16. Rate the following difficulties or barriers encountered as part of the Green Building certification process. **(1=Most challenging, 2=Very challenging, 3=Somewhat challenging, 4=A little challenging, 5=Not a challenge)**

Barrier	**1**	**2**	**3**	**4**	**5**
Green Building Standards documentation.					
Communication/misunderstanding Green Building Standards.					
Unable to meet Green Building certification prerequisites.					
Cost of certification.					
Cost of Green Building Practices.					
Lack of team cooperation.					
Project team turnover.					

17. What external barriers (outside of your company) make maintaining the Green Building certification process difficult?

_____

_____

_____

_____

18. Explain how the maintenance work on your Green Building differs from that carried out in a conventional Building?

_____

_____

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