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IMPACT OF MAINTENANCE OPERATIONS IN BUILDINGS PERFORMANCE, KIGALI COMMERCIAL BUILDINGS CASE STUDY

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ABSTRACT: *A building fabric is referred to as environmental cover because it is how the natural or external environment may be adjusted to produce an adequate internal environment for people to live in. When the building is not protected for better performance this affects the building functionalities, values, appearance, and durability. It is thus important to ensure appropriate maintenance to preserve building performance. The main purpose of this paper is to investigate how maintenance operations are done to ensure the performance of buildings in Kigali city. The data used in this study were obtained from primary and secondary sources. The secondary data was attained through an elaborated literature review of various books, articles, and papers related to this research to outlining and describing the chief ideas of this research title. The primary data was compiled through a questionnaire survey that was directed to 95 selected professionals in the construction projects in Rwanda to collect data from the different types of commercial buildings for statistical analysis of the research to test the hypothesis. However, a total of 81 usable responses were received within the scheduled period representing the response rate of 85.26%, which is likely to be representative and acceptable. Data collected from the questionnaire surveys were analyzed using the Statistical Package for Social Scientists (SPSS), excel spreadsheets, and Relative Importance Index (RII), which provide more merit presentations. The research results show that even if the deterioration of commercial buildings exist in Rwanda with Human (RII=80.56%), Chemical (RII=77.47%), Atmospheric (RII=68.83%), Structural (RII=59.26%), and Moisture causes (RII=57.41%), the maintenance operations are undertaken to prevent problems or risks which can happen predictably within the life of a building to ensure service life, reduce costs and increase the value of the building. The planned maintenance concept is used at 40%, unplanned at 24%, collective at 16%, condition-based at 8%, and 12% for the use of all of the concepts together. Hence, as maintenance is done to restore the condition of the building, this means that building performance is affected also. The researcher provided recommendations if this is put under practice; the commercial buildings will be maintained at a high level and increase the productivity of the business because these are business assets. These recommendations include; (i) maintain the building at a regular interval (ii) consider maintenance during the design and construction stage (iii) provide a maintenance plan for building and (iv) to regular maintenance works (v) building maintenance should be done in accordance of standards in building maintenance.*

KEYWORDS: buildings performance, maintenance operation and management, commercial buildings, Kigali City

INTRODUCTION

Background to the Study

The construction industry is one of the most complex and dangerous industries, especially in the execution process. Due to its unique, dynamic, and temporary nature, it requires highly skilled experts to carry out daily construction projects from the initial stage to the entire building [1 -7]. Once the building is built and completed, immediately from that time of completion stage maintenance process begins to be carried out until the future**.** Maintenance refers to hold, keep, sustain, preserve or protect the building to an acceptable standard, which helps to ensure that the resale value of the building is as high as possible. The building should be maintained to sustain its durability and operability. The lack of proper building maintenance policies affects the early aging of component durability performance and the effect of global costs and maintenance operations, which may lead to serious failure risks and shorten their service life [8]. Therefore, it is necessary to formulate appropriate policies for the building maintenance of specific projects to draw improvement strategies when necessary [9]. The purpose of maintenance is to ensure service life, reduce costs and increase the value of the building. Commercial buildings refer to buildings designed, constructed, and operated for any purpose other than residential, manufacturing, or agriculture, including everything from schools to hospitals, offices to grocery stores. These buildings can be dedicated to a single purpose, such as company headquarters, or can be used for public interactive rooms, commercial event spaces, classrooms, work areas, cooking and dining facilities, and even living quarters, such as those found in dormitories. Due to the wide variety of commercial buildings, it may be necessary to have different configurations for the methods used to rate different types of buildings. For those who wish to celebrate diversity, commercial buildings provide ample opportunities [10]. The building fabrics must meet different user needs and professional factors. The designer should determine the required fabric properties based on weather resistance, noise reduction, durability, heat resistance, and other related standards. In addition to comfort and visual requirements, if a maintenance manager or a person with similar technical knowledge joins the design team, many design errors that cause high maintenance costs can also be avoided. No building is maintenance-free, so every building, heritage, or new building needs attention to limit deterioration [11]. Exposure to the elements will eventually deplete all building materials. Therefore, regular inspections can help you find problems early and extend the life of the building together with regular maintenance. In addition, they can help you avoid potentially expensive and destructive repair works that could damage the value of the building. The service life of any building is affected by many factors including the appropriateness of the design, construction details, and construction methods. It also depends on how the building is used and the maintenance policies and practices during its life cycle. Recognizing buildings as assets also provides a strong incentive to maintain their commercial value. The effective management of property maintenance plays an important role in the life cycle of buildings, so it is considered an important factor to achieve the business goals of building owners/users. However, to more accurately understand the demand for better average cleaning procedure data and more detailed detergent content information could be needed [12]. Hence, the maintenance policies should support and integrate with the organization's broader business strategy. In fact, many decisions about property maintenance are based on business rather than technical standards [13].

Maintenance is the most important for a building because it can provide performance and safety for the occupants. Through the study of this article paper, we will be able to identify the impact of maintenance operations on the performance of commercial buildings in Kigali city.

Problem Statement

Most of the commercial buildings in Kigali city cannot guarantee performance due to a lack of maintenance. Defects create hazards leading to serious or fatal injuries. Most defects can be discovered at an early stage through visible or detectable symptoms. If not promptly rectified in time, minor defects can develop into serious ones, leading to failure or sudden collapse, endangering lives and becoming more costly to rectify. Regardless of age, defects in various types of buildings occur in different forms and degrees. However, maintenance recommends that building owners consult with specialists, such as contractors, builders, plumbers, heating and air conditioning professionals, and electricians, when doing any renovations, repairs, or construction on their properties [11]. Ignoring maintenance can lead to cumulative results with rapidly increasing deterioration of the fabric and finishes of a building accompanied by harmful effects on contents and occupants.

Aim and Objectives

This paper aims to investigate how maintenance operations are done to ensure the performance of buildings in Kigali city.

The objectives of this paper will focus on the following;

(1) To have a proper look at the level of maintenance attention that commercial buildings within Rwanda receive.
(2) To examine the causes that lead to the deterioration of commercial buildings
(3) To develop ideas to the role of building maintenance to ensure building performance
(4) To show the role of maintenance and repair policy in the performance of building in Rwanda
(5) To demonstrate the performance requirements of building fabric.

LITERATURE REVIEW

This section briefly discussed the definition of building and maintenance, the concept of building maintenance, the classifications of maintenance, the performance requirements of building fabric, the standard of maintenance, and the economic and social significance of maintenance of buildings.

Definition of Building and Maintenance

A *building* is defined as the roof structure of any enclosed space intended to be used as a shelter (for people, animals, or property) or for recreational, industrial, commercial, or other functions [14]; while *maintenance* is generally defined as a combination of all technical and administrative actions including supervision, intended to retain a building or to restore it to a state in which it can perform the required tasks [15]. In addition, Lateef and Khamidi define maintenance as essential processes and services that began to protect, ameliorate and care for the structure and services of

a building to perform its expected functions throughout its life cycle without fundamentally interfering with its basic features and functions [16-17].

Concept of Building Maintenance

In the construction industry, it is very important to consider the reliability and maintainability of the structure the whole life cycle of a building. The operation and maintenance process is a significant part of the life cycle cost of buildings [18]. Although a lot of work can be done in the design stage to reduce the subsequent maintenance workload, the production of maintenance-free buildings is very ideal but almost impossible. If the maintenance of the building is neglected to a certain extent, all components of the building will more or less deteriorate which depends on the materials and construction methods, environmental considerations, and the use of the building [19].

Current Issues in Building Maintenance Project

The building maintenance management process relies on detailed and early maintenance activities planning including duration, building considerations, building behavior, sustainable design, human comfort situations, elements durability, and cost efficiency [20]. The results of error handling and information management of the building during maintenance activities will affect failure risk factors such as panel connection, reactive aggregate over-design, air entrainment stress, and natural or man-made material factors hazardous characteristics [21]. Many problems lead to insufficient building performance in maintenance projects. It is recommended to resist the conversion to modern knowledge tools in the process of building management, lack of skilled workers, high project costs, shorten the implementation time to meet the requirements of green maintenance services, and lack of awareness of all knowledge. The shortcomings of buildings will affect the maintenance and management practices of construction projects [22]. So, the common issues concerning building maintenance projects are as shown in table 1 below:

Table 1 Issues concerning building maintenance

No	Authors	Issues concerning building maintenance
1	Aktas and Ozorhon [23]	Improper handling of green technology and interactive details
2	Djokoto et al. [24]	Lack of available building maintenance rating systems and labeling procedures
3	Zhao et al. [25]	Deficiency of demonstration projects accessibility
4	Gan et al. [26]	Deficient data on maintenance and management practices of the construction project between the project clients and the contractors
5	Zhao et al. [25]	Deficient coordination between projects client and contractor organization
6	Shi et al. [27]	The problem of reliable green suppliers among team members

When most buildings provide their functional services and meet climate needs, they will from time to time cause the risk of premature failure of the occupants and accidents. The procedures involved in building maintenance includes two phases: the design and execution of the building construction

project. A good maintenance environment and building usage can carry out proper security monitoring of the execution duties [9]. Therefore, at this phase, the process of construction strategy practice will be studied in detail to detail the work-related maintenance and management activities in the construction project.

Types of Building Maintenance

To achieve success within the field of building maintenance, it's additional useful to know the various types of maintenance techniques accessible and how and when to use them in the right way. In fact, the common types of building maintenance are as follows [11], [19], [28-32]:

(1) Planned maintenance: The maintenance executed with forethought management and also the use of records to a planned program. Work to forestall issues that may happen predictably among the lifetime of a building, such as daily cleaning of the floor, weekly for cleansing the window, and a year to ascertain the painting of the building façade.

(2) Unplanned maintenance: The maintenance executed to no planned setup. It means wherever the work of maintenance is executed on an emergency basis or once having a drawback in this building, for instance, once elevator or lift has issues, therefore maintenance desires at that exact time.

(3) Preventive maintenance: The maintenance is carried out at planned intervals or admire prescribed standards to reduce the possibility of project failure or performance degradation. This kind of maintenance will cut back non planned work and permits the illation of overall costs. Preventive maintenance keeps a building operative at pinnacle competency throughout regular scrutiny and repair. The goal is to identify smaller issues based on maintenance costs, in case they become large and expensive.

(4) Corrective maintenance: The maintenance performed after a failure is intended to restore the project to a state where it can execute its required functions. This is the easiest maintenance method since the building components are used until they fail. It covers all operations, including repair components that cannot perform their basic purpose. Therefore, the cost of corrective maintenance can be high because damage or malfunction of a particular item can severely damage other elements in the building.

(5) Emergency maintenance: Maintenance must be carried out immediately to avoid serious effects. Due to events such as gas leaks and wind damage, it is sometimes called routine maintenance. Work that must be done immediately for health, safety, or security reasons; otherwise, it may cause fast deterioration of the structure or fabric, such as roof repairs or broken glass repairs after a storm.

(6) Condition-based maintenance: It refers to preventive maintenance initiated by routine or continuous monitoring to understand the status of the building. Maintenance is a response to severe equipment degradation due to monitored equipment status or performance limitations.

(7) Schedule maintenance: Preventive maintenance performed within a predetermined time interval, number of operations, mileage, etc.

Nature of Building Maintenance

The building owner regards the planned maintenance as a serious problem, but he or she cannot afford to tolerate the damage to his or her building for a period of time [32]. The building maintenance encloses all parts of the building, such as rooms, bathroom windows, walls, and

furniture. The maintenance of buildings is a universal issue and the untimely construction path has been strictly measured to ensure the superiority of the building [33]. The maintenance activities of the building consist of 4 separate main components as shown below [34-36]:

(1) Servicing: Essentially, this is a designated cleaning cycle and cleaning operations are to be performed at a certain frequency and it is sometimes called routine maintenance. Due to the introduction of more complex equipment, more complex service schedules are required. The frequency of cleaning changes. The typical frequency is to clean the floor once a day and once a week; the windows are cleaned once a month; the flues are cleaned every 6 months; decoration and protective paintings are carried out every four years.

(2) Rectification: This work usually occurs in the early stages of the building, mainly due to design defects, inherent failures or inappropriate components, goods damage during transportation or installation, and incorrect assembly. It is an efficient and effective point to reduce maintenance costs because they can be avoided. In theory, all necessary work is to ensure the correct installation of components and materials suitable for its purpose. Usually, the same component must have many functions, such as weatherproof, load-bearing, thermal insulation, and still look good. Failure to perform any of these functions satisfactorily may result in maintenance work. Typical examples are the failure of the floor decoration, floor coverings on the solid concrete ground, floor slabs damage due to moisture penetration, and joints between floor slabs in wall panels to eliminate wind and rain damage. By formulating and using performance specifications and installation specifications, rectification work can be reduced.

(3) Replacement: This is unavoidable because the conditions of use will cause the material to decay at various rates. A large amount of replacement work is not due to physical damage to materials or components, but due to poor appearance. Therefore, acceptable longevity usually involves subjective judgments about the aesthetics of change. In addition, due to the complexity of the environment and the difficulty in determining how much the material will change before being discarded, the measurement of the durability or life span of the material is a very difficult technical problem. Maintenance can also include refurbishment, which includes overhauling the main structure to restore the original design and specifications, or to improve the original design. This may include limited additions and extensions to the original building.

(4) Protection: protection includes the work of controlling functions, comprising the appearance of buildings. Since buildings are susceptible to damage and defects caused by factors such as weather and frequency of use, protection should be provided throughout the life cycle of the building. It can avoid any defects and further damage in the future time. It can ensure the resistance of all parts in use. For instance, exterior surfaces of buildings are painted to control the weather and fungal invasion or function.

Preventive Maintenance Checklist

Preventive maintenance is work that must be performed regularly to minimize the possibility of an accidental breakdown of building components or systems and the need for expensive emergency repairs. Preventive maintenance is always cheaper and easier than repair [31]. Examples of typical preventive maintenance activities are included in the preventive maintenance checklist in the resources section of this report. Every year, your maintenance and repair committee should check this list to ensure that all issues are resolved. Assigning the responsibilities in the list to the super members of the committee or other tenants who can complete the required tasks will make it easier

to complete all the work. In addition, preventive maintenance is a planned work performed according to a plan, and its purpose is to prevent wear and tear or sudden failure of equipment components. To ensure preventive maintenance, the elements you need to check here are shown in table 2 below. If all these elements have been installed or constructed correctly, the building will achieve its construction purpose.

Table 2 Preventive maintenance checklist

Elements	Duties
Roof	• Clean drains and keep them clean • Replace or repair loose or missing coping stones • Check the roof for cracks or blisters, and repair as required • Clean up all stagnant water after rain
Windows and Doors	• Keep all wooden parts repainted • Check putty and replace as required • Lubricate all hinges and locking devices frequently, especially in wet or cold weather • Check latches and locks, and repair and replace them immediately
Plumbing	• Repair the leaking faucet according to the report • Check for leaks in the pipeline and repair them immediately • If the drainage is slow, clean the sink trap and building trap in the basement
Electrical	• Check the appliances and lighting operation • Regularly check tenant wiring and eliminate any fire hazards • Ensure easy access to meters and switches • If your building is equipped with a fuse instead of a circuit breaker, replace the required fuse and maintain sufficient power • Make sure to use the correct amperage fuse • Keep the instrument of meters clean and well lit • Ensure that the cables and conduits are firmly connected to the wall or beam without any overhangs.
Exterior Walls	• Keep the gutters and downspouts to prevent water from flowing out of the outer wall • Check the condition of the mortar between bricks and repair as required • Check the caulking and weatherproof conditions around windows, doors, skylights, and repair as required
Heating	• Check the fuel oil and water level of the boiler every day • Keep the boiler room clean and tidy

	• Drain the water in the boiler once a week • Clean or replace the oil filter of the boiler once a month or when fuel is obtained during the heating season • Drain the heating riser every year before the heating season begins • Recalibrate the thermostat every year (heating timer) • Check whether the low water level stop valve is operating normally
Security and Fire Safety	• Immediately replace the burned-out bulb • Check smoke detectors and replace batteries every year • Check and confirm that all valves and meters are marked with marks for easy identification in emergencies, and keep all keys on the same purpose convenient • Understand the location of all "service interruptions" in the basement of the building: heat, water, gas, electricity, etc. • Check and maintain the safety of the front and rear door locks • Ensure that vacant apartments are not allowed to enter; regular inspections • Repair cracks in path and sidewalks • Check the curtains once a year, repair or replace if necessary • Check fire extinguishers every six months • Check the condition of the escape route and perform maintenance or repairs as required • Keep fire exits and staircase corridors unblocked
Energy Conservation Guidelines	• The following guidelines are designed to help you understand how to save energy and reduce fuel costs. • The guidelines start with simple, inexpensive but effective steps that you can and should take immediately.

Maintenance & Repair Committee Responsibilities

In the process of building maintenance, it is necessary to maintain the beauty and robustness of the building according to the value of the building, which requires a lot of responsibilities. The most important duties we can talk about are:

(1) Formulate building maintenance and repair policies and submit them to the tenants' association.

(2) Collect information about building maintenance needs through surveys of apartments and public areas and by conducting annual inspections of buildings from the roof to the ground.

(3) Work with officials of the tenant association to formulate annual and monthly budgets detailing available maintenance costs.

(4) To compile the list, you can call contractors, technicians, and convenience facilities regularly for bidding and cost estimation, and check their reference materials to confirm their qualifications and reputation.

(5) Develop a "scope of work", clearly state the requirements or expectations of each contract maintenance work, contract the contractor to bid, evaluate and review after receiving the bid, and select qualified contractors to provide advice to officials.
(6) Develop and maintain a schedule of upcoming repairs and ongoing projects, including basic information about each job, such as the scope of work involved, which the contractor is, the payment schedule, and the name of the tenant supervisor assigned to oversee this effort.
(7) Regularly meet with the contractor to review the project progress and supervise the progress and quality of the work until it is completed successfully.
(8) Maintain up-to-date documents containing complete records for all past and current maintenance and repair items.

Performance Requirements of Building Fabric

The requirement to provide an acceptable internal environment is only one of the performance requirements of modern buildings. If maintenance performance indicators are correctly determined, maintenance performance can provide or identify resource parts and controls, problem areas, maintenance contributions, benchmarks, personnel performance, and contributions to the maintenance and overall business goals [37]. The performance level of a building depends on various factors, and the emphasis on these individual performance requirements varies from case to case. However, minimum standards are set by regulations and guidelines, such as building code regulations, which must be met anyway. The increasingly important role of buildings as assets has also affected the way buildings are designed to maximize long-term value and minimize structural and fabric maintenance costs. The performance requirements of the building can be summarized as follows [19]:

(1) Structural stability: To fully satisfy its required functions, the building must be able to withstand the load applied to it without deformation or collapse.
(2) Durability: The long-term performance of the structure and fabric requires that the elements of the building can withstand the changes and hostility of the environment in which they are placed without deterioration. The ability of each part of a building to maintain its integrity and function within a specified period is the basis for the long-term operation of the building.
(3) Thermal insulation: To save energy, internal conditions must be kept within fixed parameters, which indicates that the external fabric of a given building provides acceptable standards of heat resistance.
(4) Exclusion of moisture and protection from the weather: The passage of moisture from the exterior, whether it is groundwater rising due to capillary action, precipitation, or other possible sources, should be blocked by the building envelope. Moisture entering the building may have some adverse effects, such as the decay of timber elements, deterioration of surface finish and decoration, impact on certain processes in the building, and health hazards to occupants.
(5) Acoustic Insulation: During the building construction process, the sound transmission from the outside to the inside or between the internal spaces should be considered. The acceptable sound transmission level of a building will vary greatly depending on the nature of the building and its location.
(6) Flexibility: Especially in industrial and commercial buildings, the ability of buildings to deal with and respond to changing user needs becomes very significant. Therefore, the flexibility required in the future must be considered.

(7) Aesthetics: The issue of building aesthetics is subjective. However, it should be noted that in some cases the importance of a building's aesthetics is negligible, while in other cases it is very important. The degree of the pursuit of aesthetics will have an inevitable impact on the cost of the building.

Standards of Maintenance in Building

Maintenance standards are documents containing technical specifications or other precise standards intended to be used as rules, guidelines, or definitions [15]. If insufficient maintenance is performed, the fabric of the building will first become unsightly, then accepted by the occupants, and finally become dangerous and uninhabitable. The maintenance manager must decide the optimal maintenance level of the work to maintain an acceptable environment in the building he or she cares about. For instance, he or she must decide whether the building should be temporarily repaired and then replaced, or whether it should be replaced immediately. To determine the best course of action, he or she needs to consider the use and condition of the building, the relative cost and effectiveness of different types of repairs, the expected future life of the building, acceptable maintenance standards, and similar matters. The first step is to determine reasonable maintenance standards for various building elements, such as paint, rainwater items, and windows and pats. These are usually divided into two categories:

(1) The small number where standards can be related directly to cost.

For instance, the roof should not degrade before a leak occurs, as this will lead to higher maintenance costs in the future.

(2) The majority where maintenance costs do not increase appreciably as the condition deteriorates.

For example, despite the appearance deterioration, the cost of repainting interior wall surfaces after 7 years is almost higher than that after 5 years. Therefore, discussions with management and residents are needed to agree on appropriate standards. After establishing a reasonable standard, it is necessary to estimate the deterioration rate of each element so that the change of its state is related to its life age. This proportion is influenced by many factors such as aspect ratio, age, and location. The maintenance manager should supplement the published data with information about element history. The next step is to determine the maintenance strategy to be implemented for each component and the methods and materials to be used. The maintenance cost of each component can be estimated over 20 or 30 years. During this period, most parts will need to be replaced or repaired, and the average annual maintenance cost can be calculated. Finally, by adding the average annual cost of each element, the average annual cost of implementing a maintenance strategy can be evaluated. If the available resources can cover the total cost, the maintenance manager can make a work plan, but if the resources are insufficient, a lower fabric maintenance standard consistent with the available funds must be established [38].

Economic and Social Significance of Buildings Maintenance

Building maintenance mainly affects three aspects of our life. First of all, it is related to the safety and health of persons and property. Secondly, it is related to the economy. From the perspective of a small-scale economy, it is the economy of a town; from the perspective of a large-scale economy, it is the economy of the whole country. Finally, it affects society and the environment to a certain extent. Hence, the main economic and social significance that buildings maintenance has including [39-40]:

(a) Dilapidated and unhealthy buildings reduce the quality of life and in some ways contribute to certain anti-social values. For example, unfinished abandoned buildings are still sanctuaries for criminals and social villains.
(b) As mentioned earlier, maintenance can prevent decay and failure thereby extending the physical life of the building and thereby delaying replacement costs and preventing new construction.
(c) The appearance, quality, and general physical conditions of buildings usually reflect the pride or indifference of the public, the prosperity level of the area, social values, and behavior.
(d) The appearance and location of certain buildings and infrastructure in the vicinity of streets increases or improves the beauty of the environment. Therefore, any action aimed at maintaining this structure will usually attract public attention and sympathy.

Research Approach

This chapter deals with the various methods or sources of data used in obtaining materials and information needed by the researcher for writing the project to obtain and achieve meaningful, accurate, and correct results in carrying out the research work.

METHODS OF DATA COLLECTION

The surveys are carried out in shops, hospitals, malls, offices, hotels, and schools. All data were collected through two kinds of sources, primary and secondary sources.

(a) Primary source

The major instrument used in collecting data comprised of the questionnaire and oral interview. The oral interview was used in a situation where the respondent was observed incapable of comprehending the ground intents of the questions. In addition, where it was suspected that using an oral interview would facilitate the respondents where he might have deliberately or accidentally avoided any question in the questionnaire.

(b) Secondary source

The secondary source of data collected through a literature review of books, articles, and papers related to the study carried out by the researcher within the area of the study. The questionnaire and interviews containing expository questions and are directed to the people doing maintenance in the different establishments, other people in charge of building maintenance, and different people with knowledge about building maintenance. All necessary questionnaires were distributed randomly either personally or via email amongst the selected professionals and a total of 95 questionnaires were submitted and 81 usable responses were received within the scheduled period as shown in table 3 below. The response rate of 85.26%, which is likely to be representative and acceptable.

Table 3 Types of commercial buildings response rate in percentage

Types of commercial buildings	Number of Questionnaires		Percentage Returned (%)
	Sent	Returned	
Hotels	9	7	77.78
Hospitals	15	12	80.00
Shops	29	25	86.21
Offices	22	21	95.45
Schools	16	13	81.25
Malls	4	3	75.00
Total	**95**	**81**	**85.26**

Methods of Data Analysis

This involved processing, editing, coding, classification, and tabulation of all data collected so that it can be analyzed. Data were analyzed to identify, describe and examine the roles of maintenance operations in the performance of buildings. The data set after coding was posted to a worksheet for data cleaning to remove errors. Data collected from questionnaire surveys were analyzed using the Statistical Package for Social Scientists (SPSS) and excel spreadsheets for a proper look at the level of maintenance attention that commercial buildings within Rwanda receive, develop ideas to the role of building maintenance to ensure building performance, and show the role of maintenance and repair policy in the performance of building in Rwanda, while the Relative Importance Index (RII) used to rank the primary source and causes that lead to the deterioration of commercial buildings. In addition, the results found were presented in different methods like charts, tables, and pies. This chapter also clarifies the ways that both maintained and non-maintained buildings perform and how comfortable and safe the occupants are. The Relative Index Analysis (RIA) for each variable is calculated by using the formula as follows: "Very important" equals 5 points, "Important" equals 4 points, "Medium important" equals 3 points, "Low important" equals 2 points, and "Not important" equals 0 points. Relative Importance Index (RII) was used for each category and calculated as follows:

$$\textbf{RII (\%)} = \frac{\boldsymbol{RIA}}{\boldsymbol{N}}$$

Where: $\boldsymbol{RIA} = 100X1 + 75X2 + 50X3 + 25X4 + 0X5$, and

$\boldsymbol{N} = X1 + X2 + X3 + X4 + X5$

RIA: Relative Index Analysis
RII: Relative Importance Index
X1: Number of respondents answering very important
X2: Number of respondents answering important
X3: Number of respondents answering medium important
X4: Number of respondents answering low important
X5: Number of respondents answering not important
N: Total number of respondents

DISCUSSION AND IMPLICATIONS

The study was conducted with the use of a questionnaire containing expository questions; it was directed to the people doing maintenance in hotels, hospitals, offices, shops, schools and malls, and other people in charge of building maintenance, and different people with knowledge about building maintenance. The research findings are interpreted according to the aims and objectives of the study that were appropriate for the establishment of the abstract and conclusion.

Level of Maintenance Operations

The questionnaire shows how the buildings are inspected periodically to ensure the building performance. According to the responses of respondents, the inspection is categorized in the following way: Weekly with 24%, monthly with 32%, 3months with 24%, 6months with 16%, 1year with 4%, 2years with 0%, and above two years with 0% as shown in figure 1 below. Inspection of buildings helps to ensure preventive maintenance to provide the satisfaction of building occupants. Building inspection increases the performance of a building aesthetically. As commercial buildings are used for business purposes, the building inspections help to increase maintenance of the building that leads to the increase of production.

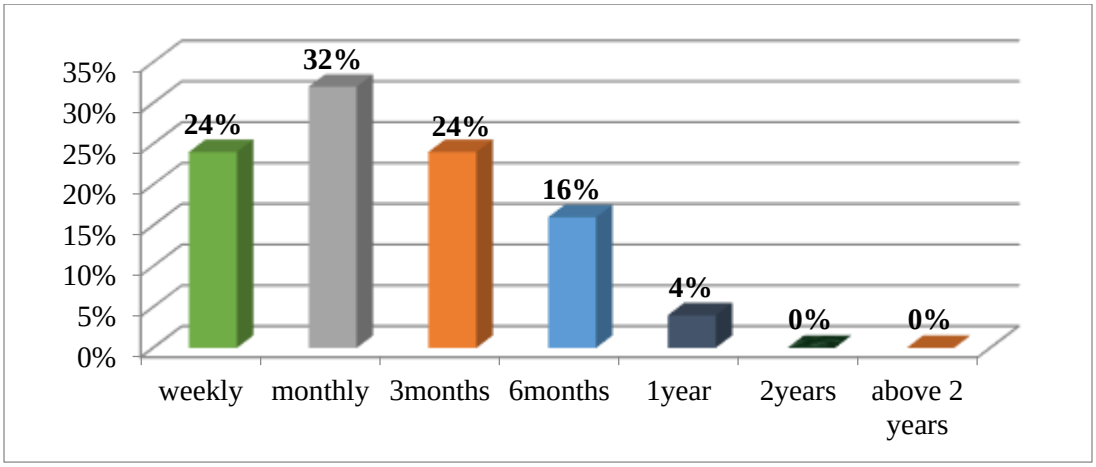

Figure 1: Building maintenance inspections periodically

Causes that Lead to Deterioration of Commercial Buildings

The deterioration of buildings mainly depends on the type of building and the maintenance time. Table 4 below lists and ranks all the causes for the deterioration of commercial buildings in the construction industry in Rwanda. In addition to the different information provided by the respondents, the 5 main sources and causes are as follows: Human (RII=80.56%), Chemical (RII=77.47%), Atmospheric (RII=68.83%), Structural (RII=59.26%), and Moisture (RII=57.41%).

Human cause leads to the deterioration of commercial buildings due to failure to clean and carry out routine maintenance, ignorance of the causes of deterioration and decay, inadequate planning

for proper maintenance, and failure to raise awareness of maintenance needs of all people using the buildings and adopting negative attitudes require urgent measures.

Chemical cause leads to the deterioration of commercial buildings due to the interaction of certain cleaning agents with materials and/or components leading to decomposition, softening, or discoloration, and the interaction of certain dissimilar materials in close contact with each other in a corrosive environment.

Atmospheric cause leads to the deterioration of commercial buildings due to reaction of structure, exterior fabrics, finishes, and cladding with atmospheric elements (for example, wind, rain, sunshine, frost, and snow in cold weather, air pollution, and the reaction of building to the penetration of the above atmospheric elements).

Structural cause leads to the deterioration of commercial buildings due to reaction of structural elements to precipitation, moisture, shrinkage, and thermal movement, the reaction of structural elements to changes in load patterns, the natural aging of structural elements, the response to corrosive elements, and deterioration due to the lack of inspection and maintenance.

Moisture cause leads to the deterioration of commercial buildings due to penetration of the external fabric of cladding, or the moisture generated through ground-floor constructions, which may create suitable conditions for the growth and invasion of fungi, while excessive moisture in the internal atmosphere may lead to excessive condensation and corrosion, irrigation and faculty plumbing.

Table 4 Primary source and causes that lead to the deterioration of commercial buildings

The primary source and causes that lead to the deterioration of commercial buildings	N	RIA	RII (%)	Rank
Human	81	6525	80.56	1
Chemical	81	6275	77.47	2
Atmospheric	81	5575	68.83	3
Structural	81	4800	59.26	4
Moisture	81	4650	57.41	5
Fire	81	4050	50.00	6
Faulty Design	81	3650	45.06	7
Faulty Construction	81	3375	41.67	8
Faulty Materials	81	2750	33.95	9
Faulty Components	81	2550	31.48	10
Faulty Systems	81	2275	28.09	11
Cleaning	81	2175	26.85	12

Concept of Building Maintenance

Kigali commercial buildings are maintained using different concepts; these concepts include planned maintenance, unplanned maintenance, condition-based maintenance, and corrective maintenance or all of the above at once. Generally, the purpose of maintenance is to ensure longevity, reduce costs and improve value. Figure 2 below shows how commercial buildings in

Kigali city are maintained using these concepts. Planned maintenance prevents problems that can happen predictably within the life of a building, such as cleaning gutters or painting. According to the respondents, the research shows that the planned maintenance concept is used at 40%, unplanned at 24%, collective at 16%, condition-based at 8%, and 12% for the use of all of the concepts together. Hence, in Kigali commercial buildings, planned maintenance is most commonly used at a high level than other concepts while condition-based maintenance is at a low level used.

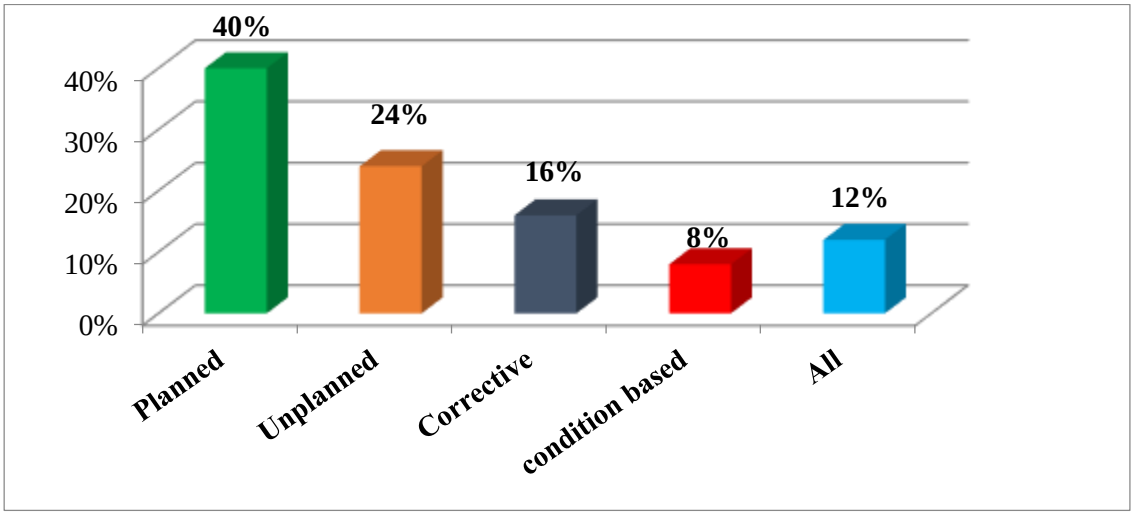

Figure 2: Commercial buildings are maintained using different concepts

Building Performance

The level of performance of buildings depends upon several factors, and the emphasis which is placed upon these individual performance requirements varies from situation to situation. The increasing role of the building as an asset has also affected how buildings have been designed to maximize the long-term value and minimize the maintenance costs of the structure and fabric. According to figure 3 below, the responses showing that 72% of respondents agree that building maintenance affects building performance, 20% disagree and 8% don't know about this. As maintenance is done to restore the condition of the building, this means that building performance is affected also. The research also shows that the clients take care of the building appearance; aesthetics is one of the indicators of building performance. Building maintenance operations in Kigali commercial buildings use different concepts to ensure the performance of buildings and to increase the production of the business assets.

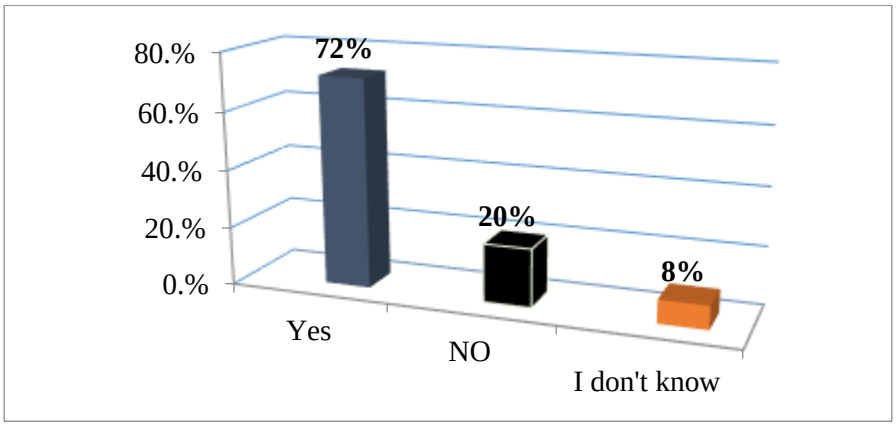

Figure 3: Building maintenance to ensure building performance

General Recommendations

Series of investigations carried out by the researcher on the maintenance of buildings in Rwanda points to the fact that maintenance activities within Rwanda are at a low ebb and as such many buildings are in a state of disrepair. It was also observed that adequate attention is not given to maintenance in most commercial buildings. Even where some attention is given, maintenance activities are left in the hands of an administrator who possess little or no knowledge of maintenance works in general. This leads to little or nothing being done as and when due. These are recommendations to the commercials buildings owner's and government for understanding and analyzing the roles of maintenance operations in the performance of building in Rwanda. Especially Kigali commercial buildings need a high level of maintenance to fulfill the requirements of buildings to ensure their performance. If the following recommendations are adopted, these will solve the problems of maintenance in Rwanda; the recommendations are the followings:

(a) The building owners should maintain their properties at regular intervals including keeping maintenance records.
(b) Maintenance professionals should be incorporated in the design team to advise other professional colleagues on the maintenance implication of their design alternatives and alternative methods of construction for easy maintenance.
(c) All professionals in the built environment should diversify. Every one of them should not be competing in project production. They should take all maintenance works as an aspect of the construction industry to be able to carry out effectively and efficiently the teaming maintenance work requirement in Rwanda. Quality workmanship and effective supervision at every stage of project production should be optimal to effect quality project production and subsequent minimal maintenance requirement.
(d) Every facility and property should have a well-detailed maintenance plan, program, and schedule to aid in the effective maintenance operation. Property owners should bear in mind the need for these maintenance activities and as such should map out a percentage of the initial cost of the property for subsequent maintenance cost in the life span of the property. Building owners

should also map out days in their busy life to effectively 'house-keep' their property and they should embark carefulness in the use of the property to reduce the rate of the defect and subsequent re-occurrence maintenance cost.
(e) The building inspections should be done too regularly to restore the destroyed element of a building to ensure the health and safety of building users for the performance of the building. The government should provide a building maintenance policy, to prevent some accidents that can happen in buildings with a lack of maintenance.

CONCLUSION

From the beginning of the buildings at the inception stage of construction up to the period of residence stage, the entire buildings need maintenance as well conducting the inspection process during in use or occupation. The maintenance of commercial buildings in Kigali city requires attention at the highest level. This attention is of the basic importance of which the objective must be to keep buildings to an acceptable standard to make them functional and reliable. It was seen during the research process that the level of maintenance activities in Kigali city is inadequate. Additional, the building may fail due to several sources and causes, such as human, chemical, atmospheric, structural, moisture, fire, faulty design, faulty construction, faulty materials, faulty system, faulty systems, and cleaning. Cutting costs to maximize profit by contractors through the use of sub-standard materials causes defects in the long run. Lack of effective planning and scheduling also leads re-occurrence of faults due to defects. Carelessness and recklessness of the users of the property are also a direct effect of defects and subsequent maintenance work which will affect the performance of a building. The even-busy attitude of property owners and residents due to the bustling and hustling of everyday life is also a cause of neglect especially the house-keeping aspect of maintenance and thus has led to a low maintenance attitude and subsequent run-down appearance of the building. Building maintenance has been found as one of the ways to improve the performance of commercial buildings in Kigali, this has come out as a result of protecting both building life and building function. Generally, building occupants' safety and comfort are based on how the building is maintained, and this characterized the better serviceability of the building rather than unmaintained.

References

[1] Mohammadi, Amir; Tavakolan, Mehdi; Khosravi, Yahya (2018). *Factors influencing safety performance on construction projects: A review. Safety Science, 109(), 382 397.*doi:10.1016/j.ssci.2018.06.017
[2] Al-Humaidi, H.M., Tan, F.H., 2010. Construction safety in Kuwait. J. Perform. Constr. Facil 24 (1), 70–77.
[3] Fang, D., Wu, H., 2013. Development of a Safety Culture Interaction (SCI) model for construction projects. Saf. Sci. 57, 138–149.

[4] Fang, D., Wu, C., Wu, H., 2015. Impact of the supervisor on worker safety behavior in construction projects. J. Manage. Eng. 31 (6), 04015001.
[5] Ikpe, E., Hammon, F., Oloke, D., 2012. Cost-benefit analysis for accident prevention in construction projects. J. Constr. Eng. Manage. 138 (8), 991–998.
[6] Mohseni, P.H., Farshad, A.A., Mirkazemi, R., Orak, R.J., 2015. Assessment of the living and workplace health and safety conditions of site-resident construction workers in Tehran. Iran. Int. J. Occup. Saf. Ergon. 21 (4), 568–573.
[7] Wanberg, J., Harper, C., Hallowell, M.R., Rajendran, S., 2013. Relationship between construction safety and quality performance. J. Constr. Eng. Manage. 139 (10), 04013003.
[8] Madureira, S., Flores-Cloren, I., Brito, J.D. and Pereira, C. (2017), "Maintenance planning of facades in current buildings", Construction and Building Materials, Vol. 147 No. 2017, pp. 790-802, doi: 10.1016/j.conbuildmat.2017.04.195.
[9] Ismail, Zul-Atfi (2020). Maintenance management practices for green building projects: towards hybrid BIM system. Smart and Sustainable Built Environment, ahead-of-print (ahead-of-print), –.doi:10.1108/SASBE-03-2019-0029
[10] Michael, M. (2000). Defining And Rating Commercial Building Performance. *A White Paper*, 1.
[11] Government of canada, M. (2008). *heritage building maintenance manual.* Manitoba: Winnipeg.
[12] Minne, Elizabeth; Crittenden, John C. (2015). *Impact of maintenance on life cycle impact and cost assessment for residential flooring options. The International Journal of Life Cycle Assessment, 20(1), 36–45.* doi:10.1007/s11367-014-0809-z
[13] Cotgrave, M. r. (2005). *The technology of refurbishment and maintenance.* Hampshire: Palgrave macmillan.
[14] Wellington, R. (2010). *Scope of Building Maintenance 2nd edition.* Queensland: Department of Housing and Public Works.
[15] Housing, M. O. (2011). *Draft national building maintenance policy.* Nairobi.

[16] Arditi, D., Nawakorawit, M., Designing building for maintenance: Designer's perspective, Journal of Architectural Engineering, vol. 5, no. 4, 1999, p. 107-116.
[17] Hou Yin Lee, H., Scott, D., Overview of maintenance strategy, acceptable maintenance standard and resources from a building maintenance operation perspective, Journal of Building Appraisal, vol. 4, 2009, p. 269–278.
[18] Minarovičová, Katarína; Prušková, K.; Vochozka, M.; Juhásová Šenitková, I.; Fariborz, H.; Váchal, J.; Kulhánek, F.; Juhás, P.; Mareček, J.; Oláh, J.; Flimel, M.; Melcher, J.; Šilarová, S. (2019). *Environmental aspect of maintenance of buildings with ETICS. MATEC Web of Conferences, 279(), 03005–.* doi:10.1051/matecconf/201927903005.

[19] Cotgave, M. r. (2002). *construction technology2: industrial and commecial building.* liverpool: Macmillan Palgrave.
[20] Love, P.E., Niedzweicki, M., Bullen, P.A. and Edwards, D.J. (2012), "Achieving the green building council of Australia's world leadership rating in an office building in Perth", Journal of Construction Engineering Management, Vol. 138 No. 5, pp. 652-660, doi: 10.1061/(ASCE)CO. 1943-7862.0000461.
[21] Ismail, Z. (2019), "Improving maintenance management practices on green building projects", Management of Environmental Quality: An International Journal, Vol. 31 No. 4, pp. 1-15, doi: 10.1108/MEQ-05-2019-0093.
[22] Darko, A., Zhang, C. and Chan, A.P.C. (2017), "Drivers for green building: a review of empirical studies", Habitat International, Vol. 60 No. 2017, pp. 34-49, doi: 10.1016/j.habitatint.2016.12.007.
[23] Aktas, B. and Ozorhon, B. (2015), "Green building certification process of existing buildings in developing countries: cases from Turkey", Journal of Management in Engineering, Vol. 31 No. 6, pp. 1-9, doi: 10.1061/ (ASCE) ME.1943-5479.0000358.
[24] Djokoto, S.D., Dadzie, J. and Ohemeng-Ababio, E. (2014), "Barriers to sustainable construction in the Ghanaian construction industry: consultants' perspectives", Journal of Sustainable Development, Vol. 7 No. 1, pp. 134-143, doi: 10.5539/jsd.v7n1p134.
[25] Zhao, D.X., He, B.J., Johnson, C. and Mou, B. (2015), "Social problems of green buildings: from the humanistic needs to social acceptance", Renewable and Sustainable Energy Reviews, Vol. 51 No. 2015, pp. 1594-1609, doi: 10.1016/j.rser.2015.07.072.
[26] Gan, X., Zuo, J., Ye, K., Skitmore, M. and Xiong, B. (2015), "Why sustainable construction? Why not? An owner's perspective", Habitat International, Vol. 47 No. 2015, pp. 61-68, doi: 10.1016/j. habitatint.2015.01.005.
[27] Shi, Q., Zuo, J., Huang, R., Huang, J. and Pullen, S. (2013), "Identifying the critical factors for green construction–an empirical study in China", Habitat International, Vol. 40 No. 2013, pp. 1-8, doi: 10.1016/j.habitatint.2013.01.003.
[28] Ines, F.C., Jorge, de B., A systematic approach for maintenance budgeting of buildings facades based on predictive and preventive strategies, Construction and Building Materials, vol. 24, no. 9, 2010, p. 1718-1829.
[29] Al-Khatam, J.A., Building maintenance cost, Master of engineering report, College of Environmental Design, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia, June 2003, p. 1-66.
[30] McKone, K.E., Schroeder, R.G., Cua, K.O., The impact of total productive maintenance practice on manufacturing performance, Journal of Operations Management, vol. 19, 2001, p. 39–58.
[31] Pintelon, L., Srinivas, K.P., Vereecke, A., Evaluating the effectiveness of maintenance strategies, Journal of Quality in Maintenance Engineering, vol. 12, no. 1, 2006, p. 7-20.

[32] Md Azree Othuman Mydin (2015), Significance of building maintenance management system towards sustainable development: A review, Journal of Engineering Studies and Research Vol. 21 No. 1, pp. 58-65, doi: 10.29081/jesr.v21i1.41.
[33] Arditi, D., Nawakorawit, M., Issues in building maintenance: Property manager's perspective, Journal of Architectural Engineering, vol. 5, no. 4, 1999, p. 117-132.
[34] Mohd-Noor, N., Hamid, M.Y., Abdul-Ghani, A.A., Haron, S.N., Building maintenance budget determination: An exploration study in the Malaysia government practices, Procedia Engineering, vol. 20, 2011, p. 435-444.
[35] Olanrewaju, A.L., Mohd, F.K., Arazi, I., Building Maintenance management in a Malaysia University Campuses: A case study, Department of Civil Engineering, Universiti Teknologi PETRONAS, 2010, p. 76-89.
[36] Zainal, A.A., Model proces generik pengurusan penyelenggaraan bangunan sekolah, Universiti Teknologi Malaysia, PHD Thesis, 2007.
[37] Myeda, N.E., Kamaruzzaman, S.N., Pitt, M., Measuring the performance of office building maintenance management in Malaysia, Journal of Facilities Management, vol. 9, no. 3, 2011, p. 181-199.
[38] H.Seeley, I. (1987). *building maintenance.* Nottingham: Palgrave.
[39] Chibuike, A. A. (2011). Impact of Maintenance of Buildings and Infrastructural Facilities to the National Economy. Owerri.
[40] Md Azree Othuman Mydin (2017), Significance of building maintenance management on life-span of buildings, Journal of Robotica & Management vol. 22, no. 1, 2011, p. 40-44.