ADDIS ABABA UNIVERSITY

ETHIOPIAN INSTITUTE OF ARCHITECTURE, BUILDING CONSTRUCTION, AND CITY DEVELOPMENT

Developing Built-Asset Maintenance Maturity Rating Model for Public University Buildings in Ethiopia

By

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The undersigned have examined the thesis entitled **'Developing Built Asset Maintenance Maturity Rating Model for Public University Buildings in Ethiopia'** presented by **Zewdu Seblework** , a candidate for the degree of Master of Science**,** and hereby certify that it is worthy of acceptance.

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ABSTRACT

In Ethiopia, a significant amount of funds is invested in mega projects like dams, highways, railways, airports, power plants, public buildings, etc. These investments are showing unprecedented expansion which, by some estimates, has shown a 9-fold growth of the GDP of the construction sector. However, once these projects, be it mega or otherwise, are completed and ownership is transferred, the post-construction phase of asset management is noticeably neglected, if not ignored totally. And this national reality is witnessed in the building facilities of public universities in the country. In this research paper, a modest attempt is made to examine the building maintenance practice of the nation, factors affecting proper maintenance management, and challenges faced. A thorough investigation of the current situation of building facilities of public universities in Addis Ababa is made. Along with that significant focus is made to develop a viable maturity rating model for building maintenance management of public universities in Ethiopia. A multi-case study was conducted on the three public universities in Addis Ababa. The research approach of this study is both deductive and inductive research. Both quantitative and qualitative data are collected from primary and secondary data sources by document analysis, observation, and semi-structured interviews of the FM office and project office representatives of each public university. All the semi-structured interviews, document analysis, and observation data were analyzed using the thematic and statistical analysis method. The three main objectives of this study are effectively addressed. When it comes to identifying factors that influence the proper practice of building maintenance management in public universities in Ethiopia, the main factors were grouped under seven categories and five critical factors. Finally, a built asset maturity rating model is proposed based on the weights calculated by DEMATEL, MCDM analysis weights that can be used as a self-assessment tool by public universities in Ethiopia.

Keywords: Facility Management, Built Asset, Maintenance, Maturity Rating Model, DEMATEL

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ABBREVIATIONS

AACRA	Addis Ababa City Roads Authority
AEC	Architecture, Engineering, and Construction
AMMM	Asset Management Maturity model
ANP	Analytical network process
CAD	Computer-aided design
CMM	Capability Maturity Model
CMMS	Computerized maintenance management system
DEMATEL	Decision making trial and evaluation laboratory
DTS	Developmental transition stage
ECA	Economic Commission for Africa
EFQM	European Foundation for Quality Management Excellence
ERA	Ethiopian Roads Authority
GDP	Gross Domestic Product
GIS	Geographical information systems
GTP	Growth and Transformation Plan
FM	Facility Management
FTS	Formative transition stage
I3F	Integrated Feeder Factors Framework
IFMA	International Facility Management Association
IFMIS	Integrated financial management information system
IFS	Initial formative stage
IS	Information Systems
ISO	International Organization for Standardization

KM	Knowledge Management
LCE	life-cycle cost engineering
MCDM	Multi-criteria decision-making
PCMM	Public Commissioning Maturity Model
PM	Project Management
P2M2	Project Management Process Maturity Model
P3M3	Portfolio, Programme, and Project Management Maturity Model
QMMG	Quality management maturity grid
R&M	Renovation and Maintenance
SCM	Supply Chain Management

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CHAPER ONE: INTRODUCTION

1.1. Background of the study

A substantial financial investment is spent annually in Ethiopia for new infrastructure development projects like buildings, dams, highways, railways, and hydroelectric power. National accounts data in the African Statistical Yearbook, Economic Commission for Africa (2019) shows that the construction industry's Gross Domestic Product (GDP) grew from 1,302M USD in 2010 to 11,362.35M USD in 2018, which is a 9-fold growth. In the past decade, the industry's annual growth rate was also remarkable, with figures as high as 38.7% in 2013 (African Statistical yearbook, 2019). Thus, the expansion in the size of the construction industry is most notable.

A few years back, globally, more focus was given to the earlier life cycles of a construction project management phase, design & construction. This is mainly because more attention was given to initial capital investments (Flanagan and Jewell, 2005). However, when a total life-cycle cost of a project is considered, the design & construction cost during the project implementation phase is not more than 20% of the full life-cycle cost (WLC). The remaining 50-80% of the cost is spent during the facility management and/or operation & maintenance phase (Flanagan and Jewell, 2005; Heaton et al., 2019). This implies that the traditional project-product management neglects the post-construction stage of an asset management concept. Thus, thinking about keeping structures in their original state as much as the means and resources allow, considering the life-cycle cost, and getting the best service in its useful life is an approach that aligns with a core principle of asset management.

In current practice, once a project is completed and the product is transferred to the owner, the product management lacks the application of appropriate principles and procedures in a similar manner that is conducted during the project development phase by the owner/organization/client. This has caused constructed facilities in Ethiopia to be managed and utilized unprofessionally. Maintenance is the most important aspect of asset management. According to British Standards Institution (BS 3811: 1984), maintenance is defined as "the combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function''. Chanter & Swallow (1996) define maintenance as "work undertaken to keep, restore or improve every facility, i.e., every part of the building, its services and surrounds to a currently acceptable standard and sustain the utility and value of the facility'. In the context of the current development of many infrastructures in Ethiopia, it is crucial time for this concept of maintenance to be incorporated early in project management so that the best value for the money spent can be achieved.

Although there is a massive investment in the construction industry as part of the nation's ten years road map, and there are advanced methods, best practices, policies, and standards in maintenance management across the globe, however limited studies address the issues of maintenance management in Ethiopia, and there are several questions that are left unanswered. These include: What is the building maintenance management practice in the nation? What are the factors that affect proper maintenance management practice and their challenges? What kind of maturity rating model can improve the existing maintenance management practices to an advanced level? Thus, this study answer one of this research question by developing a viable maturity rating model for building maintenance management for public universities in Ethiopia.

Based on previous unpublished master's thesis works, maintenance management seems to be an ignored sector in the Ethiopian Construction Industry, facing multiple challenges for several reasons. For instance, Nibret (2015) identified the following seven key challenges in managing public university building facilities: lack of building operation and maintenance policy; unavailability of professional facility managers; unavailability of organized Facility and Maintenance Management department under public organizations; poor planning of facility management; unavailability of training for building maintenance staffs; lack of regular building condition survey; and inaccessibility and inability to use technologies like computerized maintenance system to simplify building facility management.

In addition, Sahelu (2015) identified corrective maintenance as the only type of maintenance used in Addis Ababa's public hospitals. Even the practice of corrective maintenance was found to be ineffective. The study tried to justify the main reasons for such poor practice: attitude of users and misuse of facilities; lack of discernible maintenance culture; inadequate training; use of poor-quality components and materials by the maintenance department.

From these studies, one can understand that there is a great demand for the development of a maturity rating model that has the potential to minimize the existing challenges of facility and maintenance management practice in Ethiopia. The model can help to identify current practice, determine strengths & weaknesses, analyze the gap, capture the level of awareness and understanding, and pinpoint stakeholders' needs, which paves the way to design a policy framework.

The Ministry of Urban and Construction Development (MUCD) of Ethiopia acknowledges the existing challenges of the construction industry and prepared a policy document to optimize the role of participants and stakeholders through the process; technology; institutional enhancement, and appropriate human resource development as one of its primary objectives of the policy (MoUDC, 2012). According to Zakaria et al. (2018), strict legislation on sustainability policy set by government and organizations are vital measures or indicators in creating a sustainable facility and maintenance management. Thus, these processes must consider the entire useful life of a built environment.

Maintenance management integrates multiple disciplines to influence the efficiency and productivity of economies of societies, communities, and organizations and how individuals interact within the built environment. Facility and Maintenance Management affects the health, well-being, and quality of life in the world's societies and populations through the services it manages and delivers (ISO, 2018). While Facility and Maintenance Management has such a broad impact, recognizing its principles, policies, and practices at a global level is low; the practice in the case of a developing country like Ethiopia is even at a much lower level.

Moreover, prior studies indicate a lack of system that helps the built environment be safe, productive, and convenient to end-users in the Ethiopian construction industry (Nibret, 2015; Takele, 2017; Nuru, 2020). Hence, this study attempts to design a maintenance maturity model that could be used as an input for asset owners, public property managers, and private building owners to improve the performance of the Facility and Maintenance Management sector based on best practices and benchmarks. This research will also develop a maturity model that is tailored to the practices of maintenance management by taking public universities in the country as case studies. This model can be used as a tool for improvement as it can explain the aspects and criteria that can be improved by universities in a stepwise manner and does not become a burden. The model can also be used for other institutions and/or government organizations by making a few adaptations/modifications to meet their needs.

1.2. Problem statement

"Another flaw in the human character is that everybody wants to build, and nobody wants to do maintenance" (Kurt Vonnegut, Jr.). According to Thaheem and De Marco (2014), developing countries risk incurring more significant losses to avoid smaller ones. A good example is the under-performance of routine maintenance operations, which eventually leads to serviceability problems. Correspondingly, proper and timely maintenance helps achieve longer economic life, resulting in lower depreciation costs and thus higher profitability. Inadequate maintenance has become one of the most significant issues organizations face in developing countries. Thaheem and De Marco (2014) argue that maintenance is seen as an unimportant activity in most developing countries and is not given high priority for many reasons. One of the important reasons is the inconsistency of planning and development policies, mainly influenced and manipulated by short-term political goals, rise in housing demand due to increasing urbanization, and near-constant upheaval in economic conditions. These developing countries then witness speedy and hasty construction with a lower level of planning, poor design, low quality, poor execution, and lack of management precision, resulting in higher maintenance and operations costs. Inefficient and unproductive selection and utilization of construction materials in the early stages later triggers wasteful maintenance actions: environmental and economic sufferings from constant construction & reconstruction works and overspending of money, which could otherwise be used for social causes that can harm the sustainability of the environment (Thaheem and De Marco, 2014).

Maintenance and facility management in the context of Ethiopia is poorly practiced. According to (Nibret, 2015),there is almost very limited or no finance/budget allocation. No Facility Management (FM) Policy is formulated to keep public buildings facilities regularly maintained to provide the optimal function to occupants and end-users. This has caused public building facility owners and service seekers to perform the tasks under full-service capacity. Sahelu (2015) has also identified lack of maintenance policy as a cause of poor maintenance practice in Ethiopia. The study recommends for further research on the process of building maintenance management for various types of buildings in Addis Ababa, focusing on factors causing poor maintenance and delivering new, improved processes. In addition, setting up organizational structures, policies, and quality standards is encouraged to improve the management of building maintenance practices. Furthermore, according to (Nuru, 2020), there is no well-developed system for performing preventative maintenance or a set schedule for performing corrective maintenance.

Takele (2017) studied public university building maintenance management practices in Ethiopia by taking two cases: Adama Science and Technology University (ASTU) and Addis Ababa University (AAU). The study found that there was no clear, well-defined, and documented departmental maintenance policy; no condition standards were set for the universities buildings, and therefore no clear performance indicators were set from the outset to gauge the effectiveness of building maintenance strategies; no maintenance management manual was available, lack of database to record information regarding building history and its maintenance of the building and other facilities, and there was no established condition assessment system in the maintenance departments that would accurately establish maintenance needs of buildings for universities. The study suggested that further studies are needed to develop a maintenance policy, MMS (Maintenance Management System) & checklist to develop a maintenance condition standard assessment of buildings.

There has been a substantial amount of money spent on infrastructure development in higher education. In the last two decades alone, 34 new universities and the expansion of existing ones in different parts of the country were built. In 2002, the total numbers of public universities were only 2. Currently, existing colleges are being upgraded to university levels, and new universities are being developed, bringing the total number of institutions to more than 45 (37 are new universities established since 2005). However, there is still a lack of an organized maintenance system. Unavailability of policy, regulation, proclamation, or framework and maintenance management system to keep public building facilities at their optimal operational level results in unnecessary operation and maintenance costs and extreme renovations. Improper management of facilities operation and maintenance of buildings leads to inefficiency and poor productivity of workers; negative impacts on occupants such as disruption of the teaching-learning process and overall economic development were identified as a research gap in the Ethiopian Context. As a result, this research aims to develop input for a policy framework based on benchmarks and best practices and a maturity model to improve public universities' facility and maisntenance practices and address present gaps.

According to studies in Ethiopia, most of the research shows that there is essentially no organized system for maintenance management. The critical gap discovered by past research in the country is that while most found no policy or structure for maintenance management practices, none looked into why. Why don't we have a policy, a well-organized system, and a set of standards? Maintenance management is a topic that necessitates thorough investigation.

1.3. Research Aim and Objective

The study aims to assess the current level of maintenance practice and develop a maintenance maturity/rating model that can serve as an input in shifting current maintenance practices of buildings to improved level.

1.3.1 Specific Objectives

The specific objectives of this study are listed as follows:

- To assess current practices of maintenance management by taking public university building facilities in Ethiopia as case studies
- To explore factors that influence the practice of building maintenance management
- To develop a maintenance maturity rating model that can help shift current maintenance practices into improved levels

1.4. Research questions

- What is the maintenance management practices of public university building facilities in Ethiopia?
- What are the factors that affect the maintenance management practice of building facilities in Ethiopia?
- What type of maintenance management maturity model can be used to shift the existing level of maintenance management practice to an advanced level?

1.5. Significance of the Study

When a structure is built, it needs to be kept in good condition to provide the designed level of service and meet its intended purpose. This need will be amplified when the built-in environment expands. Proper maintenance management is crucial to delivering standard services and maintaining the sustainability of an investment. As per the researcher's knowledge, though few studies are conducted on building maintenance management, there is a need to further assess the maintenance management practice in Ethiopia. Prior research has found a lack of policy and a well-organized system, but it hasn't explored the "why?". In addition, there are no maturity rating models of maintenance practices in the country, which can help to gradually improve the practice to an advanced level. Thus, the researcher strongly believes that this study will enhance the knowledge in maintenance management, helps to establish policies and systems, and adopt a feasible, tailored, step-by-step guide that incorporates an accepted practice of maintenance management in public universities. Moreover, the output of this study can help other public or private institutions to adopt better maintenance management practices.

1.6. Scope of the Study

This study focuses on appraising the current level of building maintenance management practice and identifying factors that influence building maintenance management practice in public university building facilities in Ethiopia. Eventually, a maintenance management maturity rating model will be developed in the context of Ethiopia.

This study includes participants from public universities in Ethiopia to achieve the first two objectives in a survey to measure the building maintenance management practices. In addition, three public universities out of 5 in Addis Ababa have purposely selected as case studies for tailoring a maturity model to achieve the third objective of the study.

1.7. Limitation of the Study

The main limitation of this research is resources in terms of time and finance. The research problem required more time to conduct an in-depth study and funds for traveling to different regions to identify potential maintenance management experts. In addition, the country's political instability, and the current COVID pandemic has made it difficult to travel .

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

Building maintenance management is a fundamental component of facility management (FM), which integrates many disciplines that affect the efficiency and productivity of societies, communities, and organizations and how people interact with the built environment. FM affects the health, well-being, and quality of life of much of the world's societies and populations through the services it manages and delivers (ISO, 2018). While FM has a broad impact, recognizing its principles and practices has been lacking. Moreover, in the case of developing countries, the sustainable facilities management process and practices are unclear and immature (Zakaria, Hashim, and Ahzahar, 2018) and (Olayinka, 2018).

There is a challenge in getting finance for new facility development (Danie et al., 2017). On the other hand, in developed countries, because of long building life cycles and the low rate of new construction, more and more shift to renovation and maintenance (R&M) of existing buildings is becoming common. According to (Talamo and Bonanomi, 2015), there is a great demand to enhance and improve the productivity and efficiency of facility management in the AEC (Architecture, Engineering, and Construction) /FM domain. This study is intended to assess the current practice of building facility maintenance management of public universities in Addis Ababa, Ethiopia, and develop a maintenance management maturity rating model that may be utilized to improve the current level of practice.

2.2. Construction Process and Asset Life-cycle Delivery

Every asset has a life cycle, and infrastructure is no exception. These cycles cover the asset's entire life cycle, from conception to decommissioning, this includes the planning and design phases, construction (implementation), and service (operation) life phases, which are shown in Figure 2.1 (Rahman and Vanier, 2004).

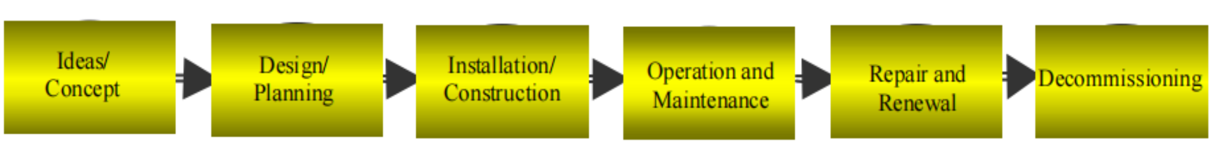


Figure 2- 1: Construction Process and Asset Life-cycle Delivery (Adopted from Rahman and Vanier, 2004)

Organizations are trying to comprehend the implications of the ISO 55000 Asset Management Standard, which is rapidly developing in physical asset management. Each company has its reasons for adopting Asset Management standards and principles. but they ultimately come to the same conclusion: Would investing in an asset management system deliver a long-term competitive advantage? Will companies obtain the required value from their assets if they employ an asset management system to optimize cost, risk, and performance throughout the asset life-cycle?.

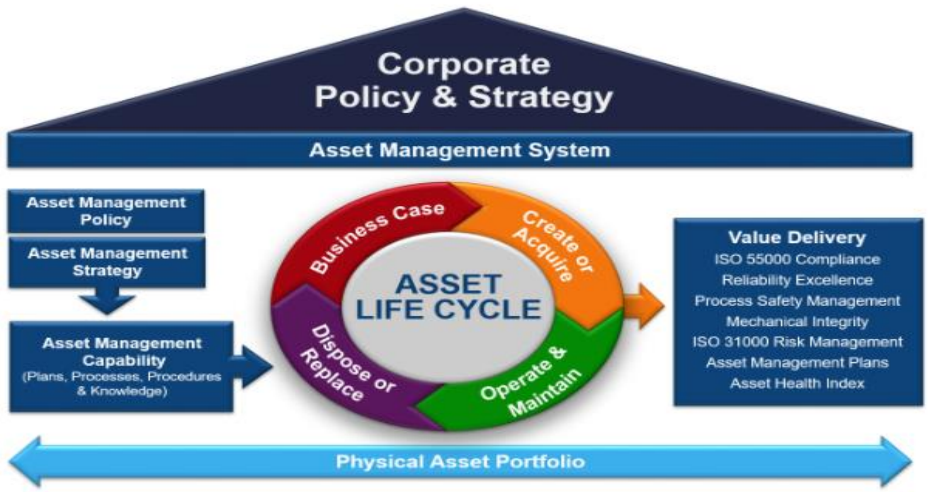


Figure 2- 2: Integrated Framework for Asset Management System

(Source: https://www.lce.com based on ISO55000)

Understanding the essential components of an asset management system is crucial to determining whether deploying it is worthwhile. The Asset Management System Framework (Figure 2), established by the life-cycle cost engineering (LCE), provides the critical links between the elements of an asset management system and the value that the system may generate. Leadership, policy, and strategy are broad factors required for developing the organization's commitment to an effective asset management system, according to ISO 55000. These components outline the governing principles and explain how asset management will help the business achieve its goals and objectives.

2.2.1 Asset Management Fundamentals

According to (ISO55000, 2014), policies, processes, or monitoring actions shall be addressed in a way that helps to achieve the primary objectives of the organization through realizing value from assets. Therefore, the basic concept of asset management includes the following fundamentals:

- **Value**: Assets exist to provide value to the organization and its stakeholders. Value refers to aligning asset management objectives to organizational objectives. A life-cycle management approach is used to realize value from assets and establish a decision-making process.
- **Alignment**: asset management translates the organizational objectives into technical and financial decisions and plans:
  Risk-based, information-driven planning and decision-making processes.
  Integration of the asset management processes with the functional management processes of the organization (HR, Finance, Logistics, etc...)
  The specification, design, and implementation of a supporting asset management system.
- **Leadership**: Value realization is influenced by leadership and workplace culture.
  i. Clearly defined roles, responsibilities, and authorities.
  ii. Ensuring that employees are aware, competent, and empowered.
  iii. Consultation with employees and stakeholders regarding asset management.
- **Assurance:** asset management gives confidence that assets will fulfill their required purposes.

i. Developing and implementing processes that connect the assets' required purposes and performance to the organizational objectives.
ii. Implementing processes for assurance of capability across all life cycle stages.
iii. Implementing processes for monitoring and continual improvement.
iv. Providing the necessary resources and competent personnel to demonstrate assurance by undertaking asset management activities and operating the asset management system.

2.2.2 Public Infrastructure Asset Management in Ethiopia

Organizations, whether commercial or public, are required to provide the highest value in asset management and related services (e.g. education and health sectors). According to the World Bank (2019), the federal government of Ethiopia does not maintain a comprehensive and consolidated register of its fixed assets. Presently, fixed-assets management is decentralized at the budget unit level. It was reported that asset registers maintained by these budget units do not provide information on the age and usage of assets. This report rates the current practice of public asset management at the budget unit level as “D,” with “A” being the best practice.

Though Article 65 of the Federal Government Procurement and Property Administration Proclamation No. 649/2009 dictates all heads of budget units to record the date, description, quantity, and cost of acquisition and indicate the custody and usage of fixed assets, there is, however lack of clear and comprehensive asset management policy at the federal government level. If the policy were correctly implemented, each budget agency would have been required to maintain an asset register for buildings, roads, bridges, dams, irrigation systems, heavy equipment, etc. However, the World Bank (2019) report indicated no records of land, buildings, and subsoil assets. The asset registers at each budget unit do not provide their usage and age information. It should be noted that the federal government has now recently started to use an integrated financial management information system (IFMIS) to record the financial report for fixed and non-fixed assets.

The new Project Management Proclamation 1210 (2020) sets asset registration and post-completion performance evaluation of constructed assets as indicated in articles 14 through 16. Hence, the Management of Public assets and its information record-keeping for further assessing the performances of built assets now become a cross-cutting issue in managing building facility asset Management.

Public infrastructure asset implementing agencies like Ethiopian Roads Authority(ERA) spend 50 Billion ETB annually, Addis Ababa City Roads Authority(AACRA) spend 3.9 to 5.8 Billion ETB annually for the past three consecutive years, Ministry of Science and Higher Education, (MOSHE) spend 20-25 Billion ETB annually for the past three years and Ministry of Health, (MOH) spend 9-15 Billion ETB annually for the past three consecutive years, hence these agencies spend a lot of money on public infrastructure assets (MoF, 2021). Thus, it needs to be assessed to evaluate how the agencies currently acquire, hand over, and manage constructed facility assets after construction, determining their sustainable use. Nevertheless, there is no established standard policy, procedure, and asset management process using cutting-edge technology. Hence, infrastructure asset in Ethiopia in general and that of public infrastructures in particular require proper management and maintenance throughout their entire life cycle to get the best value for the resource invested (MoF, 2021). Whereas Experience from other countries show that there is a public agency which manages public built asset in centralized manner. For example, GAEB is Egypt's largest governmental institution in charge of school construction development, operation, and maintenance (Abdelhamid et al., 2015).

2.2.3 Universities in Ethiopia

2.2.3.1 Public University Establishment & Expansion

It is strongly believed that higher education in Ethiopia is based on the traditional church education system of the Ethiopian Orthodox Church. The Church has been training priests and spiritual leaders in its disciplines for more than 1,700 years, as Bishaw & Melesse (2017) argued. In Ethiopia, modern education ‘in a university setting’ is only around 70 years old. In the context of facility asset management in public universities in Ethiopia, the university's highest management bodies, including but not limited to the Ministry of Education, the university Board of Directors, and University Management at a strategic level, must set strategic directions and targets related to university-built facility assets.

Table 2- 1: Public University Establishment and Timeline in Ethiopia

Period	Political System	Number of Universities	Features
Pre-Modern	Absolute Monarchy	-	Dominated by Orthodox Church education
1950-1974	Emperor Haile Selassie	1	Different University Colleges in different parts of the country
1974-1991	Dergue Regime	2 Universities & Colleges	Emphasis on Marxism and Leninism philosophy
1991-2005	EPRDF	8	Upgrading 6 colleges to university levels
2005/06-2010/11	ESDP III	21	Development of 13 new universities

2010/11-2014/15	ESDP IV	33	Development of 11 new universities
2015/16-2019/20	ESDP V	47	Development of 12 new universities and upgrading of two university colleges

Ethiopia's universities are currently more than double what was before 2005, regardless of overall assets or financial investment. In recent years, university enrollment growth has accelerated to meet the rising demand for higher education. According to national data, the country had only two universities before 2005, but after the addition of 40 new universities and the upgrading of existing colleges to university level, the total number of public universities has reached close to 50 in 2020. Ethiopian universities are divided into generations based on their founding year, namely 1st generation, 2nd generation, 3rd generation, and 4th generation. Eight (8) universities are classified as first-generation, thirteen (13) as the second generation, and the remaining eleven (11) and twelve (12) universities are classified as the third generation and fourth generation universities, respectively.

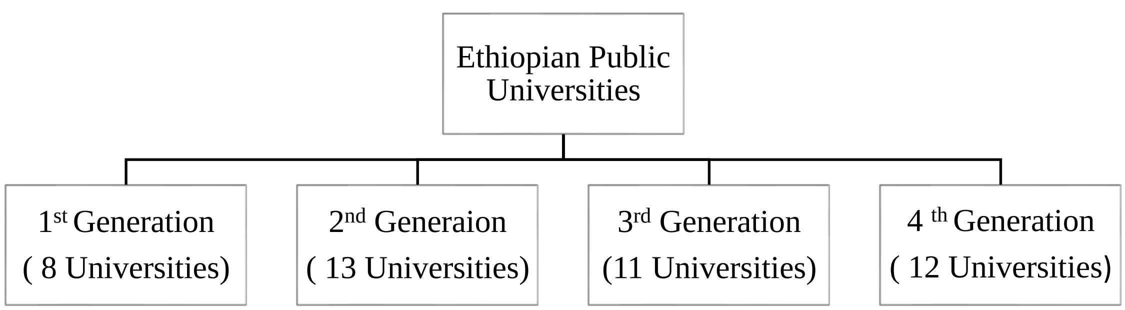


Figure 2- 3: University Generation based on year of establishment **(ESDP III -VI)**

Construction within a university includes new construction, Maintenance, Renovation, and Expansion of Student Dormitory, Library Buildings, Lecture Halls, Classroom Buildings, Office Buildings, Student Cafeteria and Laboratories, and Assembly Halls, Staff Residence. Facility project briefing, design, construction, and post-occupancy processes are all involved in university construction projects (RIBA, 2020).

2.2.3.2 The leadership of Public Universities in Ethiopia

According to Kim(2020), university facilities are classified into four types: basic education facilities, support facilities, research facilities, and associated facilities. To achieve the core teaching and learning objectives, public universities in Ethiopia require substantial facilities, which frequently include buildings that are integrated with the process, technology, and people who have intricately linked relationships to one another in the university, so higher learning institutions require an efficient and effective facility. The 2003 Higher education proclamation of Ethiopia identified three major bodies with authorities for the management of public universities: the Board to act as the head of the general administration accountable to the Ministry; the **Senate** which is accountable to the head of the University; and **University President** who is considered as CEO's of the university.

Proclamation 650 (2009) gave similar responsibility for the leadership of public universities in Ethiopia. The responsibility of university property is given to the university leadership in accordance with the proclamation and other applicable laws as indicated in 8(4) and 17.2 (e) of the 2009 proclamation. It also gives direction to university leadership to prepare and establish institutional plan, budget, and organizational structure of the university article 8(4), (2009). Moreover, the proclamation also sets directions to access information and establish efficient system for statistical data collection and information exchange 27(1), (2009).

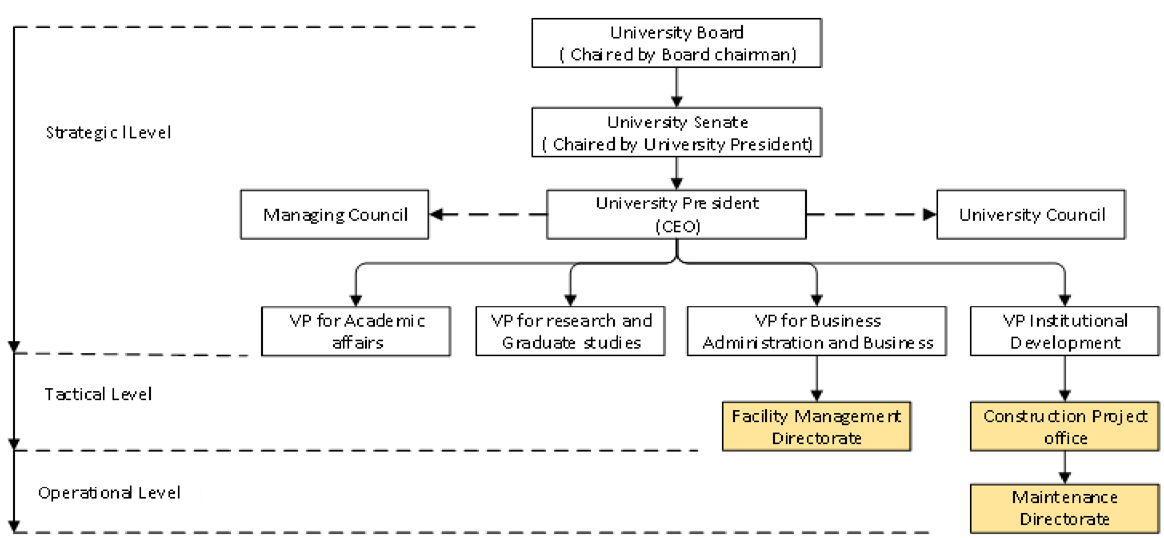


Figure 2- 4: Typical Public University Organizational Structure in Ethiopia

The two new bodies included in the governance structure are the managing council and the university council; both assume an advisory role to the president. Managing Council is chaired by the President and is constituted of vice presidents, the officer for student affairs, and others appointed by the president. It is given authority to advise the president on strategic issues and other cases that the president believes require collective information and serve as a forum for monitoring, coordinating, and evaluating institutional operations. The president also chairs the University Council. It includes the core members of the managing council, all deans, directors, members of the Senate standing committee, the chief librarian, the registrar, other key academic officers, service department heads, an appropriate number of academic staff, and student representatives with right gender mix (Article 57.1).

2.3. Facility Management

2.3.1. Definitions of Facility Management

Different scholars and Facility Management Associations have defined Facilities Management (FM) differently. The diversified definitions of FM are shown in Table 2 based on the review of different litterateurs.

Table 2- 2: Definitions of FM

Association	Definition
IFMA (2020)	FM is a profession that encompasses multiple disciplines to ensure functionality, comfort, safety, and efficiency of the built environment by integrating people, place, process, and technology.
ISO 41001:2018	FM integrates multiple disciplines to influence the efficiency and productivity of economies of societies, communities, and organizations and how individuals interact with the built environment.
BIFM (2018)	FM is the integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of the client's primary activities.

Association	Definition
FMAA (2015)	FM is the practice of integrating an organization's people and business processes with its physical infrastructure to improve the company's performance.
HKIFM (2021)	FM is how an organization integrates its people, work process, and physical assets to serve its strategic objectives. As a discipline, FM is the science and art of managing this integrative process from operational to strategic levels to promote organizations' competitiveness.
GEFMA (2013)	FM is defined as the analysis and optimization of all cost-related processes relating to building, construction of another facility, or organization performance that are not associated with the organization's principal activity.
SAFMA (2017)	FM is an enabler of sustainable enterprise performance through the whole life management of productive workplaces and effective business support services.
Scholarly Definition of FM	
Abdullah et al. (2013)	FM is multi-disciplinary services and activities that have integration between people, place, process, and technology.
Fadahunsi et al. (2019)	FM is an interdisciplinary feature of a company that coordinates room, infrastructure, individuals, and organization.
Potkany et al. (2015)	FM is a term that is intimately correlated to building management. More broadly, FM should be seen as more than just conventional building management related to day-to-day building operations; it should also include long-term planning and a focus on its users.
Mohanta & Das (2017)	FM is a multifaceted, complex process that supports the management and maintenance of a building and its services, but a lack of updated information often challenges it.

Due to the cultural differences across countries and the numerous temporal dimensions in which scholars have focused their attention, different meanings of FM have developed over the years but still have a shared vision and mission. Based on this fact, the researcher adopt the following FM definition: FM is the Science and Art of managing the integrated process from operational to strategic levels to ensure the functionality, comfort, safety, and efficiency of the Built Environment by integrating People, Place, Process, and Technology.

2.3.2. Basics of FM

The international association of facility management, IFMA, defined FM as “a profession that encompasses multiple disciplines to ensure functionality, comfort, safety, and efficiency of the built environment by integrating people, place, process and technology”(Iso, 2018). Moreover, Facility management is a term that is closely associated with building management. More broadly, facility management should not only be understood as general building management connected with everyday building operations, but it should also include long term planning and focus on the facility users (Potkany, Vetrakova, and Babiakova, 2015)

The concept of facility management (FM) is a combination of non-core organization services focusing mainly on maintaining buildings (Zakaria, Hashim, and Ahzahar, 2018). According to (Brooks, 2015), Facility Management (FM) is an integrated approach for an organization to operate, maintain, improve and adapt its buildings and infrastructures in such a way that the primary objectives of the organization, occupants, owners, and facility managers are supported. FM comprises various areas, but facility maintenance management (FMM) constitutes most of its assignment, 85% (Lavy and Jawadekar, 2014) of the total costs incurred by FM activities. According to Flanagan and Jewell, this figure is a little lower - 80% (Flanagan and Jewell, 2008)

2.3.3. Roles and responsibilities of FM

The roles and responsibilities of FM service providers depend highly on the nature of the organization they give services (Eric Teicholz, 2004). Whereas in the international association of facilities management (IFMA), Facility managers are essential because they make sure the places in which people work, play, learn and live are safe, comfortable, productive, and sustainable. The international association of facilities management (IFMA) also categorized the roles of FM as follows:

- Impacting operational efficiencies
- Supporting productivity of facilities and personnel
- Managing risks to facilities and personnel
- Mitigating environmental impact
- Promoting sustainable tactics for long-term cost management
- Leveraging technological solutions

- Reducing or overcoming the effects of natural disasters
- Guaranteeing compliance
- Leveraging security

2.3.4. Importance of FM

The physical workplace has an important impact on the performance and productivity of people, as stated (Eric Teicholz, 2004). Once an organization occupies any facility to implement its core business services and processes, facilities management must support the core business and ensure continuity (Habib BU JAWDEH, 2013). For instance, the core business of an educational organization is to deliver education within a given scope. Different facilities support this primary goal of the premise to facilitate the educational process. Hence the need for facility management is unavoidable.

Project stakeholders, especially owners, are focused on the initial construction costs. However, the subsequent operation and maintenance costs during facility management of a building over the life of the building could amount to many times more than its initial construction cost (which includes the cost of design and construction) (Becerik-Gerber *et al.*, 2012).

Life-cycle management of infrastructure is essential for all public sector assets. Public sector asset includes but is not limited to transport, water, buildings, education, commercial, and health facilities. Emphasis should be placed on ensuring that public capital assets are safeguarded and maintained during the life-cycle of physical assets to provide the required level of service for present and future customers in the most cost-effective way (Giglio, Friar, and Crittenden, 2018).

2.3.5. Knowledge Domains of FM

FM Competence is required to organize all of the organization's functions (IFMA, 2015). So, the FM domains of knowledge are Project Management, Leadership & Strategy, Operations & Maintenance, Finance & Business, Sustainability, Communications, Occupancy & Human Factors, Performance & Quality, Facility Information Management & Technology Management, Real Estate Management, and finally Risk Management (IFMA, 2015). To work effectively, facilities management should integrate the knowledge of both facilities and management. Concerns about support services for operations and activities should be motivated by the appropriate, relevant, and adequate facility and management knowledge.

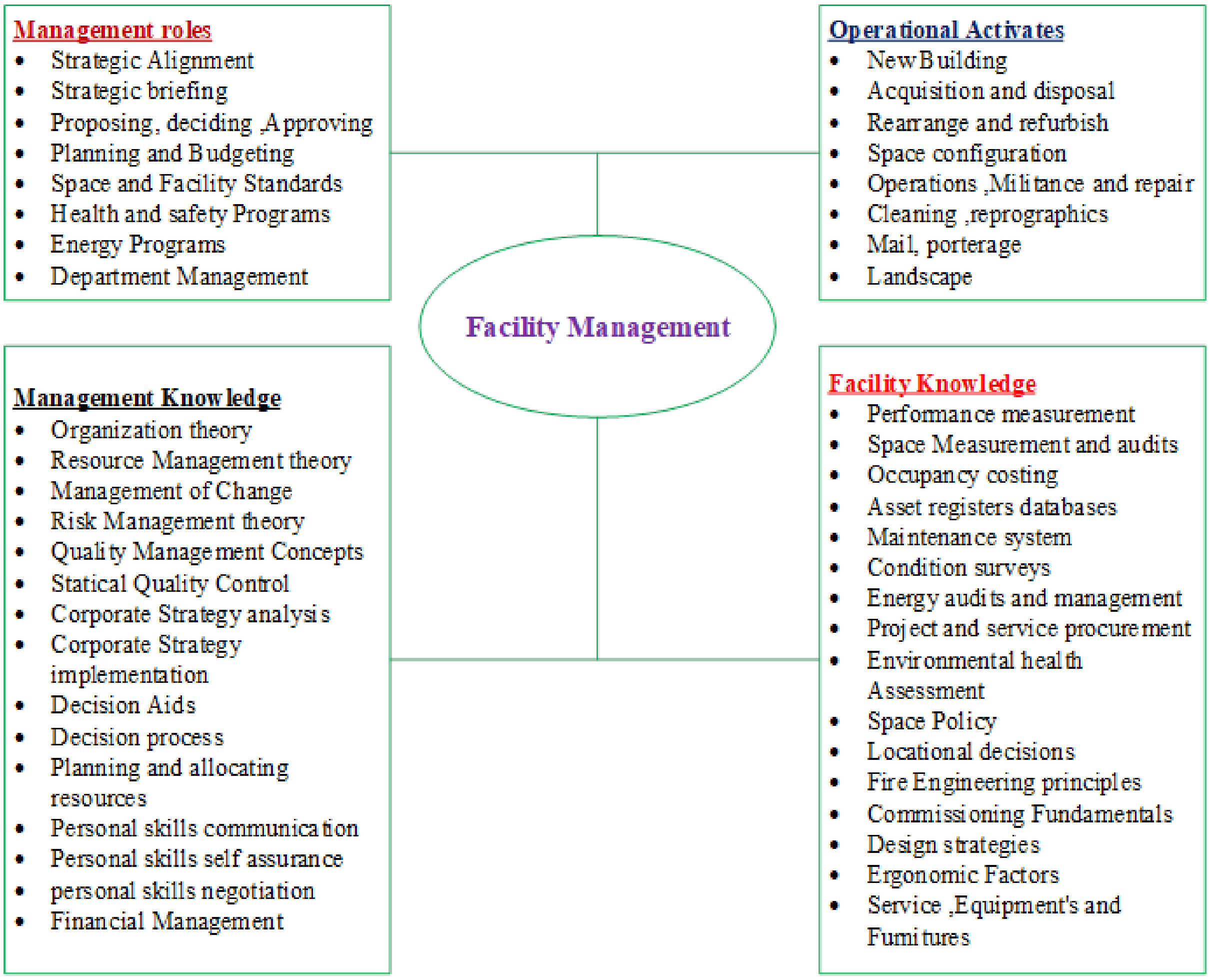


Figure 2- 5: FM Knowledge Domain (Source: Kincaid,1994)

FM is an integrated process that covers a wide variety of tasks going beyond the performance of operation and maintenance of the buildings and business service. It can be considered an entire process that operates at three levels: strategic, where critical planning decisions are made; tactical, where analysis and design processes occur; and operational, where implementation and day-to-day running of facilities processes are handled. A key element for effectively managing the maintenance of the assets is to have continuous and reliable information about the asset inventory, condition, and performance. This information is the most valuable to FM decision-makers.

2.3.6. The FM principles and Theories

According to (Eric Teicholz, 2004), the Facility Manager's roles and responsibilities are stated differently by different organizations. For instance, IFMA has identified 41 roles under eight headings. In contrast, Herman Muller Inc., during the 1970s, established the FMI and developed a three-element model of people, place, and process as adapted from (Eric Teicholz, 2004), as shown in Figure 7.

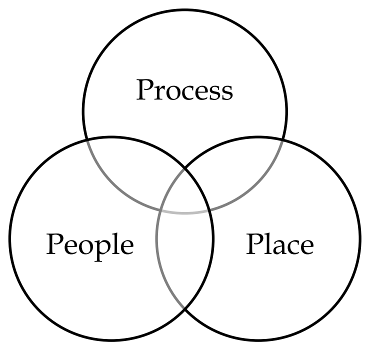


Figure 2- 6: Three-element Model of People, Place, and Process

These three interlocking circles represent the critical role of Facility managers by integrating the people and their workplaces towards a productive, safe, and conducive environment.

2.3.7. Facility Management Practice

The practice of (FM) is the process by which organizations guarantee that their buildings, systems, and services support core activities even while contributing to attaining their strategic goals under stable business conditions. The practice of FM looks to enhance communication, streamline coordination, make choices based on objective facts, and ensure operations are related to the overall strategy and each initiative can be applied to and developed by any organization. Depending on the information mentioned above, FM practices differ in different countries worldwide.

2.3.7.1 International FM Practice

FM services were first provided in the 1950s and 1960s in the USA and were fully developed in the 1970s, while in Europe, FM practices started to develop in the 1980s (Nielsen, 2012). The United Kingdom was the first country in Europe where FM practices began to grow. The United

Kingdom was recognized as Europe's most crucial FM market, followed by Germany and France (Sari, 2018).

The Development of FM formed two different schools: American and British. In the USA, the FM is focused on workplace efficiency and management of the facilities. Compared to the British approach, the American FM pays more attention to the technical issues and installations.

The United Kingdom, the United States, the Nordic European countries, and the Netherlands are thought to be leading international developments in FM (Nielsen, 2012). Italy is one of the European countries experiencing a delay in FM practices compared to other countries in the area. Such a delay could be caused by an abnormality in the Italian economic structure, which is heavily skewed toward small and medium-sized businesses (Sari, 2018).

The FM practices in Asia and Africa are still considered newcomers in the industry compared to those in Europe and the USA. As the door to Asia and the meeting point of western and Asian culture, Hong Kong has become one of the leading countries of FM in Asia. FM in Hong Kong has begun in 1994 under the local IFMA (Isa *et al.*, 2016) and (Maliene, Alexander and Lepkova, 2008).

FM practice in developed countries such as the United States and Europe significantly differs from that of developing countries such as Asia and Africa in terms of service quality, the number of facilities management standards that exist, and the number of research studies that have been published. However, the lack of financial support in Asian countries and some European countries, and Australia has become a bender. Moreover, implementing integrated facilities is also a challenge (Sari, 2018). Table 2. 3 summarizes FM practices in different countries.

Table 2- 3: Summary of FM Practices in Different Countries

Country	FM practices
USA	In USA FM practice, FM is concerned with workplace efficiency, facility management, and a greater emphasis on technical issues and installations
	FM practice in the USA is more process-oriented, with a focus on planning, coordinating operations, and the physical workplace is the primary target
UK	The practice of FM in the United Kingdom is recognized as the pioneer in Europe, followed by Germany and France (Maliene, Alexander, and Lepkova, 2014). The UK FM practice considers people's emotions and views, which is critical in creating high productivity and, as a result, efficiency in the workplace (Kamarazaly, 2014)
Germany	Germany's FM practice is intermediate on the integrated FM but has FM national standards. Many improvements in quality, transparency, and collaboration have still to be made (Maliene, Alexander, and Lepkova, 2014). Professional associations are established and contribute positively to the development of FM. However, their position and size are still not the same as in the UK or Netherlands(Sari, 2018).
France	French FM practice mainly focuses on real estate service provision, but it lacks an integrated concept of FM, and the facilities managers' profession is not recognized as autonomous (Maliene, Alexander, and Lepkova, 2014).
Italy	The Italian FM practice is concerned with maintaining and managing urban and real estate properties; additionally, the sector is characterized by innovation and vitality and covers various specialties (Maliene, Alexander, and Lepkova, 2014).
Norway	Among the Scandinavian countries, Norway has the minor developed FM practice. Service quality is much more crucial for many Norwegian companies than in an unfavorable economy(Sari, 2018). There are internal managerial sub-divisions throughout each company and, in many cases, service-delivery sub-divisions. On the other hand, the country has its FM national standard (Maliene, Alexander, and Lepkova, 2014).
Finland	The Finnish FM market is still in its infancy. Local companies used to purchase operational services from outside vendors, and some large corporations also bought management services. Total FM transactions have been completed with the largest FM service providers (Maliene, Alexander, and Lepkova, 2014).
Netherlands	FM Practice in the Netherlands has been well developed. Recently a standard has been developed covering the classification of facility costs and the definition of facility-related terms (Maliene, Alexander, and Lepkova, 2014).
Hong Kong	As the door to Asia and the meeting point of western and Asian culture, Hong Kong has become one of the leading countries of FM practices in Asia. The FM practices in Hong Kong began in 1994 under the local IFMA (Maliene, Alexander, and Lepkova, 2014) and (Isa *et al.*, 2016). This organization supports and organizes any research related to the field of FM in the Country by organizing an annual conference to share knowledge between the researcher and FM practitioners in the Country(Sari, 2018).

Singapore	In Singapore FM industry is already implementing integrative facility management services with proactive maintenance despite the traditional one. By implementing bold care, the building can perform more optimally as well as save more energy (Sari, 2018)
Malaysia	FM practice in the developing countries of Asia, such as Thailand, Korea, and Malaysia, is still considered new and at the level of infancy (Maliene, Alexander, and Lepkova, 2014). Malaysia FM practices are generally done by the outsourcing partner, the international FM company; no local facilities management company is found in Malaysia. However, the development of FM practices and research in this country shows a growing interest, thus giving a positive insight into the future development of the FM industry in this country. Most of the practice of FM in Malaysia at present is undertaken by real estate firms as property consultants (Sari, 2018).

To summarize the international practice, FM has a long history in the United States and Western European countries. The type of activities that originated in the United States in the middle of the 20th century and Europe around 1980 has weathered various evolution stages. FM today differs dramatically from the scenario it faced at its beginning. However, FM in Asia and Africa is still in its infancy. Following the development of new technologies, complex construction, and telecommunications and electronic commerce expansion, FM has widened beyond traditional services such as real estate and property management, financial management, market analysis, and building maintenance. Currently, facilities are viewed as strategic business resources.

2.3.7.2 FM Practice in Ethiopia

The responsibility for the whole life cycle management of public buildings is given to the public authority that uses the property for planning, acquisitions, maintenance, and disposal (FPPA, 2009, Article 24). However, public bodies involved in managing public buildings have not organized building Maintenance policy that obliges the proper management of public facilities. On the other hand, international organizations operating in Ethiopia have better practices in facility management in general and building maintenance practices in particular. The international organizations include but are not limited to international livestock research institutes (ILRI), African Union (AU), United Nations (UN) organizations, including the economic commission of Africa (ECA), embassies, and international hotels. However, all these international organizations could not represent the actual maintenance practices of the local context in Ethiopia.

Ethiopian FM practice has numerous challenges, including lack of policy or standards, lack of skilled workforce in the Public University buildings, lack of Integrated FM, and inefficient FM planning (Belaynesh Nibret, 2015). In addition, Sahelu (2015) stated that poor maintenance management and deficiency of skilled workforce were also evident in the public hospital building maintenance management. Furthermore, a computerized maintenance system is required to make managing building facilities easier (Nibret, 2015). Federal Housing Corporation's FM practice faces several difficulties relating to proper operation, maintenance, risk, sustainability concepts, emergency management, and integrated facility information management (Nuru, 2020).

In general, Ethiopia is still considered a greenhorn in the FM industry compared to other countries, particularly developed ones. Currently, FM has expanded far beyond the realms of real estate management and the tradition of building maintenance to the level where facilities are considered strategic business resources and have developed into integrated facilities management services. So far, there are not enough studies to identify problems in building facility management practice in Ethiopia. However, the increase in FM practices and research in the country suggests a growing interest in this area, signaling the start of the country's future facilities management development.

2.4 Building Maintenance

Building maintenance management is a fundamental component of facility management (FM). BS 3811:1984 defined Maintenance as a combination of any actions carried out to retain an item or restore it to an acceptable condition. The term acceptable condition seems to be more subjective and needs further explanation. According to British Standards Institution (1993), maintenance is defined as “The Combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function.” Chanter & Swallow defines maintenance as “Work is undertaken to keep, restore or improve every facility, i.e., every part of the building, its services and surrounds to a currently acceptable standard and to sustain the utility and value of the facility” (Chanter and Swallow, 2007) according to Al-Zubaidi the prime aim of building maintenance is to preserve a building in its initial effective state, as far as practicable, so that it serves its purpose effectively (Al-Zubaidi, 1997).

According to Stanford (2010), building maintenance aims to prevent or at least reduce the degradation or deterioration of the quality of service provided by each building over its design service life. This definition doesn't include any improvements resulting from increased expectations beyond what the building was initially designed to provide. Each structure and the individual component of the building has a finite service life. Replacement or major renovation is required (Stanford, 2010). On the other hand, Seeley (1987) defined maintenance as ‘work undertaken to keep, restore or improve every part of a building, its services, and surroundings, to a currently acceptable standard, and sustain the building's utility and value of the building.’

According to European standard (Straub, 2012), maintenance is defined as the combination of all technical, administrative, and managerial actions during the life cycle of an item intended to retain it or restore it to a state in which it can perform the required function (function or a combination of functions of an item which are considered necessary to provide a given service).

2.4.1 Nature of Maintenance

According to (Seeley, 1987), Building Maintenance comprises three separate main components- servicing, rectification, and replacement.

Servicing is a cleaning operation undertaken at regular intervals of varying frequency and is sometimes termed day-to-day maintenance.

Rectification work usually occurs early in the life of a building. It arises from shortcomings in the design, inherent faults in or unsuitability of components, damage of goods in transit or installation, and incorrect assembly.

Replacement is inevitable because service conditions cause materials to decay at different rates. Much replacement work stems not so much from the physical breakdown of the materials or elements as from deterioration of appearance.

Maintenance objectives are highly related to the economy (providing high performance with as low a cost as possible). The objectives of conducting building maintenance, according to Alner & Fellows, 1990 as cited in (Horner, El-Haram, and Munns, 1997), are:

- Ensure that the buildings and their associated services are in good condition.
- To maintain the value of the buildings as physical assets.
- To maintain the buildings to have good qualities to use and meet all requirements.

(Kans, 2008) described the maintenance objectives at a tactical level and a strategic level. At the tactical level, the goals are; to optimize schedules and inventories and carry out the prioritized activities to reach effective utilization. While at the strategic level, maintenance objectives are to achieve cost efficiency and reach general production goals, such as reliability, safety, etc.

Seeley (1987) described the primary aim of maintenance as to preserve a building in its initial state, as far as practicable, so that it effectively serves its purpose. Some of the primary purposes of maintaining facilities are:

- Retaining the value of the investment.
- Maintaining the building in a condition in which it continues to fulfill its function; and
- Presenting a good appearance(Seeley, 1987).

Similarly, Herbert (2010) states the goal of maintenance is to prevent or at least reduce the degradation or deterioration of the quality of services provided by each building component over its design service life. He further states that Maintenance is not a process of improvement that may be required to meet increased expectations for performances beyond which the component was originally designed to provide, as illustrated below.

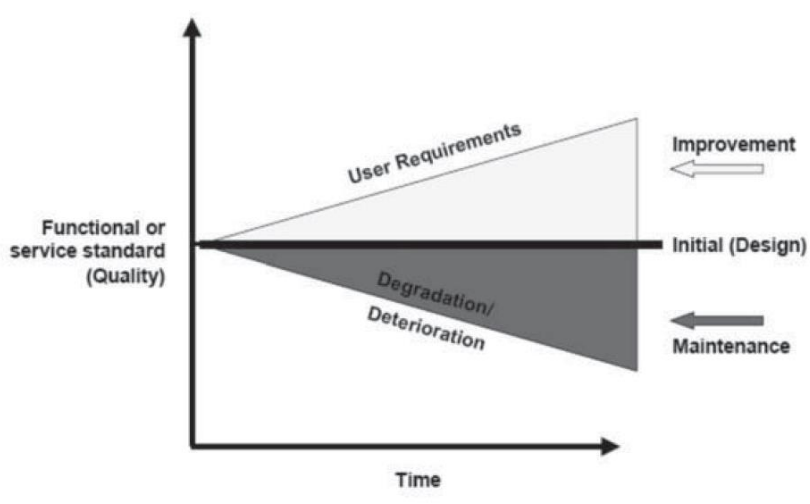


Figure 2- 7: Functionality/ quality vs. Time (Herbert, 2010)

The existence of obsolescence was also recognized by the Chartered Institute of Building (1990) which proposed an alternative definition of maintenance and refurbishment as "work undertaken to keep, restore, or improve every facility, its services and surrounds to a currently acceptable standard and to sustain the utility and value of the facility."

Sharp (2007), on the other hand, described four maintenance cycles that occur until the point at which a building fails to satisfy the occupier's demands and a significant refurbishment is required. Even after refurbishment, some residual obsolescence remains, and this grows over repeated refurbishment cycles until the obsolescence gap is too significant for an organization to bear. At this point, the organization either re-locates, the building is demolished and re-built, or the installation is refurbished beyond its original purpose, and a change of use occurs.

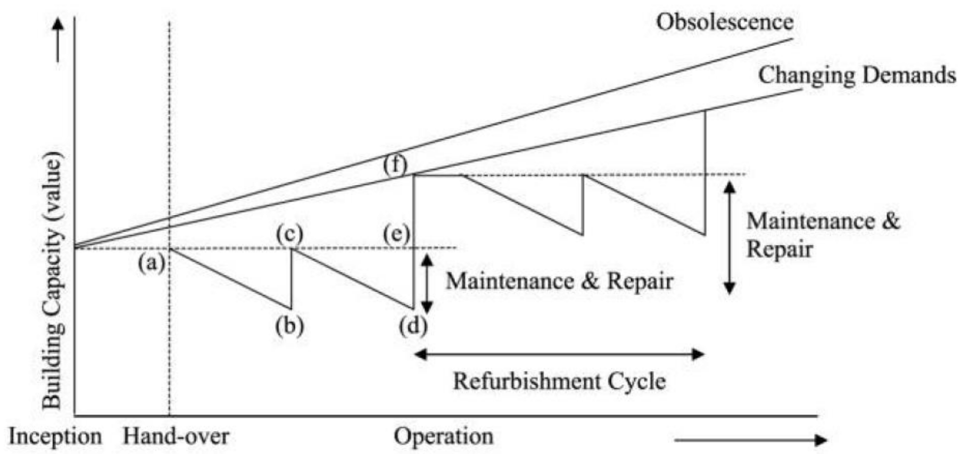


Figure 2- 8: Building Maintenance & Refurbishment Cycles

2.4.2 Strategy and Policy

2.4.2.1 Maintenance Strategy

Atkin and Brooks (2015) stated the importance of a Building Maintenance strategy "A well-defined maintenance strategy will support the organization's business objectives; whereas a poorly defined strategy, or none at all, could have significant adverse on safety, legal and commercial consequences" (Brooks, 2015). The authors also relate the importance of maintenance in fulfilling the environmental and social responsibility commitments and target its dependence on a clear maintenance strategy. The strategy needs to be dynamic to accommodate the evolving needs of business objectives.

Maintenance strategy should be prepared in a way that can meet current and future needs by considering the facility's capacity to deliver the service demanded from it.

- It must be reviewed annually to ensure that it meets the business' objectives
- It must consider the total cost of ownership (Life-cycle costing approach)
- It should be an integral part of the facility management strategy.

Building maintenance objectives, benefits, and policies (standards) are the three primary considerations in developing a maintenance strategy. On the other hand, chanter and Swallow (2007) stated the three essential elements for formulating a maintenance policy as maintenance strategies, defining maintenance standards, and allocation of maintenance resources. Maintenance activities could not be planned and implemented successfully without understanding these elements.

2.4.2.2 Building Maintenance Policy

Policies give standards for decision-making, but they also allow for a certain flexibility. They show the "why" behind a specific action. A policy is a set of general rules and regulations that serve as the framework for making day-to-day decisions.

A maintenance policy should be developed to support the preparation of operational plans in line with the maintenance strategy. The policy should outline the scope and actions to be taken to meet business objectives and how those relate to goals defined in the facility management strategy to maintenance (Brooks, 2015)

As stated in (Lee and Scott, 2009), Alner and Fellows (1990) summarize that safety is the primary concern for planning maintenance strategy to ensure building and associated services are in safe condition, fit for use, and comply with the law and all statutory requirements. Maintenance work is carried out to maintain the value of the physical assets of the building stocks and quality. A maintenance policy is a tool for maintenance personnel to plan their appropriate maintenance strategies (Lee and Scott, 2009). The maintenance policy consists of five major components, and different maintenance strategies are developed from these components. Maintenance policies of most organizations have to be tailored to their resources and needs (Seeley, 1987).

The five major components:

a. The length of time for maintaining for their present use.
b. The life requirements of the buildings and their fittings and services.
c. The standard to which the building and its services are to be maintained.
d. The reaction time required between defects occurring and a repair being carried out.
e. The legal and statutory requirements shall also be considered.

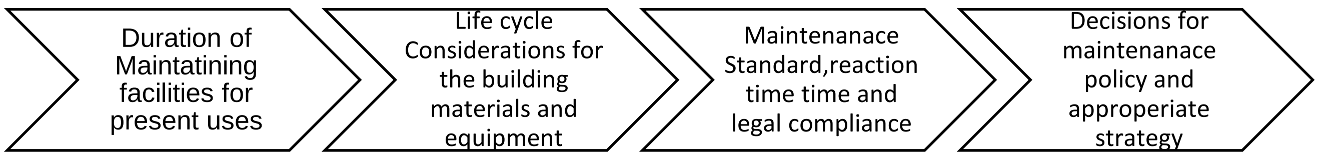


Figure 2- 9: Sequence for Developing Maintenance Policy and Strategy (Lee and Scott, 2009)

2.4.2.3 Acceptable Maintenance Standard in Building Facilities

Organizations have different interpretations of the acceptable maintenance standard, which may be higher or lower than the original design standard (Lee and Scott, 2009). Then, D.S.S. (1996) has a similar opinion that the maintenance standard is a fundamental element of the maintenance process, and the building regulations influence its health, safety, and uses.

Lee and Scott (2009) suggested that acceptable maintenance standards can be influenced by:

(1) Building regulations, health/safety, and uses: This is related to building regulation, safety rules, and user requirements which determine the acceptable Maintenance standard.

(2) Available Maintenance resources: The allocation of Maintenance resources is different among different organizations, and hence the resources allocated to the maintenance activities also define the acceptable Maintenance standard. Organizations with adequate maintenance resources have a higher maintenance standard than the original standard. On the contrary, organizations with limited or even inadequate maintenance resources encounter difficulties bringing a building facility to the initial prototype but just meeting statutory requirements.

(3) Maintenance Policy and strategy: The Maintenance policy and procedure guided by the organization's objective set the type of maintenance and maintenance frequency. The standard of maintenance defines the acceptable standard/condition of Maintenance.

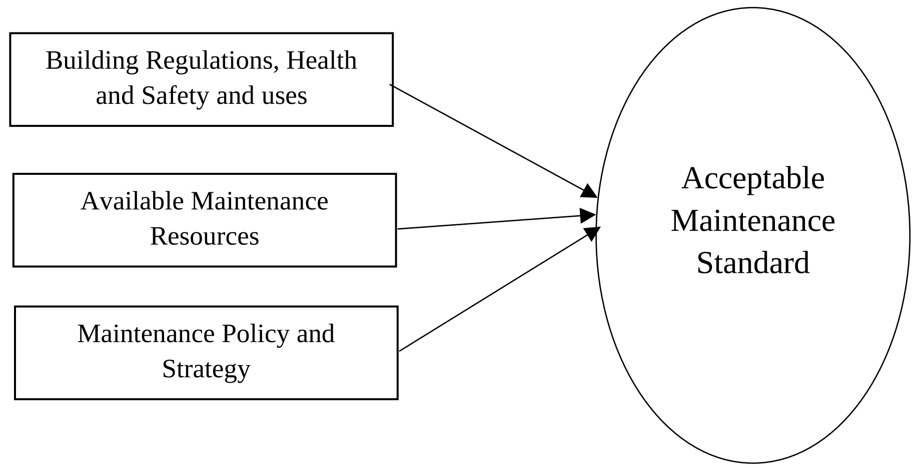


Figure 2- 10: Determinants of the Acceptability of Building Maintenance Standards

2.4.3 Classification of Building Maintenance

British Standard 3811 classified building maintenance as follows:

1. Planned Maintenance: The maintenance is organized and carried out with forethought, control, and the use of records to a predetermined plan.
2. Unplanned Maintenance: The maintenance is carried out to no predetermined plan.
3. Preventive Maintenance: Maintenance is carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the performance degradation of an item.
4. Corrective Maintenance: The maintenance carried out after a failure has occurred and intended to restore an item to a state where it can perform its required function.
5. Emergency Maintenance: The maintenance necessary to put in hand immediately to avoid serious consequences. This is sometimes referred to as day-to-day maintenance, resulting from such incidents as gas leaks and gale damage.
6. Condition-based Maintenance: The preventive maintenance initiated as a result of knowledge of the condition of an item from routine or continuous monitoring.

7. Scheduled Maintenance: The preventive maintenance is carried out at a predetermined interval of time, number of operations, mileage, etc.

Figure 3 below illustrates the type of maintenance categorized by means of terms and definitions as stated (BS 3811: 1984).

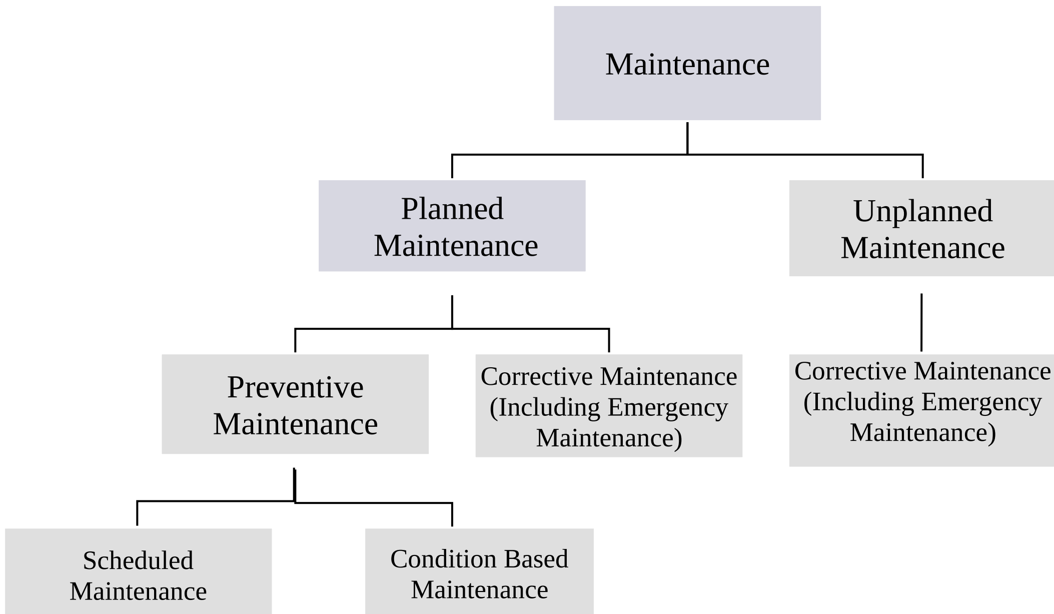


Figure 2- 11: Classification of Maintenance (Adapted from BS3811:1984)

2.4.4 Building Maintenance Process

Maintenance management is composed of a cyclic process that involves a set of inter-related activities as defined in Brooks (2015), figure 13, for effective implementation of facility maintenance practices.

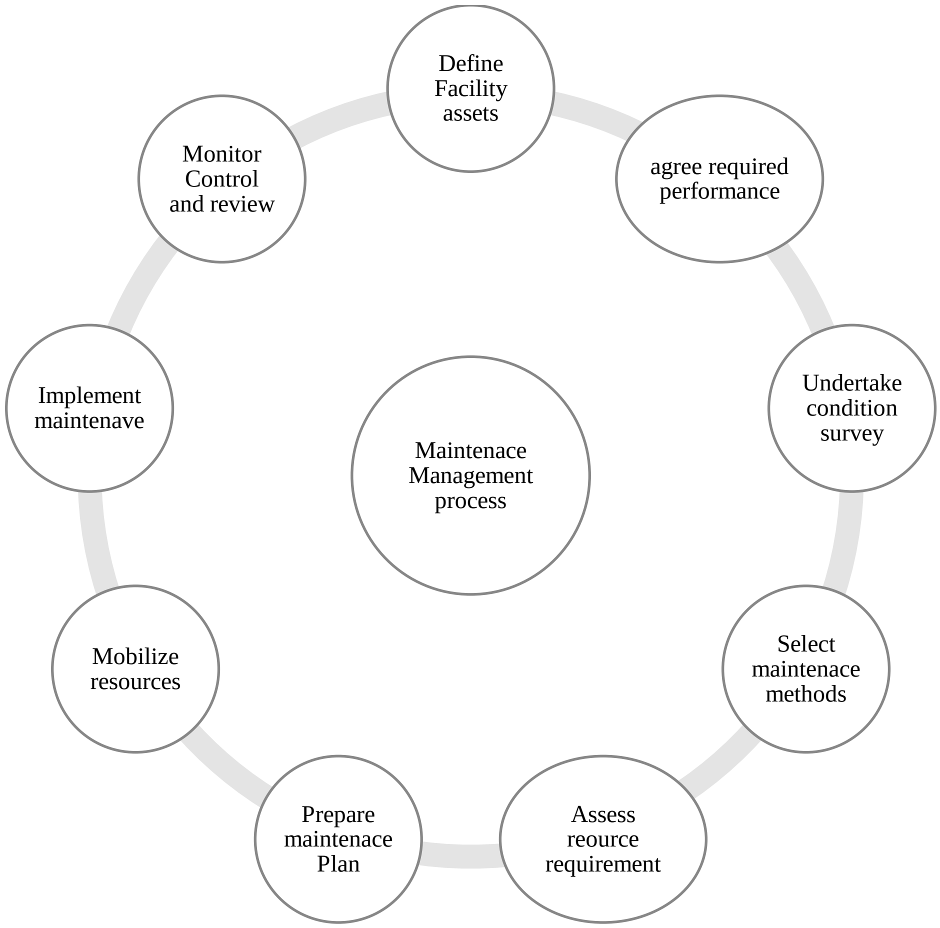


Figure 2- 12: Maintenance Management process, adapted from (Brooks, 2015)

According to (Dennis *et al.*, 2017), maintenance management defects are usually improper planning of works, inefficient record system (data), and failure to identify the potential defect causes and specify the correct remedial work. The use of paper-based forms in reporting defects is rudimentary and haphazard. Information like a daily report is unreliable, and not all the pieces are implemented. Therefore, it’s challenging to assess remedial works' decision-making due to a lack of proper maintenance planning. The resource management defect is related to poor craft. The technicians involved in maintenance management should be trained with technical skills to complete tasks efficiently. The technician’s competencies will ensure the quality of maintenance management provided.

2.4.5 Maintenance Organization

The department, segment, or unit within an organization that is responsible for the management of buildings and engineering services is known as the maintenance organization. The department's size and scope are determined by the size, complexity, type, and geographic location of the buildings and the size and nature of the organization to which they belong. The size is also dependent on the procurement method that the parent organization chooses to execute maintenance of its buildings. For example, an organization that decides to outsource a more significant part of the maintenance work will have a more minor maintenance department than choosing to do its major maintenance work in-house.

The relevance of an organization's structure on productivity and customer satisfaction has been described by organizational theory. Several studies have demonstrated that the structure and operation of an organization have a substantial impact on its output, which in turn influences the settings in which it operates (Mandal, Venta, and El-Houbi, 2008)

The maintenance department must have enough built-in flexibility to handle any work because of the demand. Maintenance is, strictly speaking, a business and a significant one. As a result, by incorporating it as a strategic business unit, the organization will be strengthened. As a result, the department should be viewed as an entrepreneurship-led institution rather than an engineering-led one to be creative, inventive, and competitive. The maintenance organization's Mission Statement, underlying purposes, and values should aim to promote user happiness and productivity (Olanrewaju and Abdul-Aziz, 2015)

More significantly, the structure of the maintenance department reflects the emphasis that the parent company places on the buildings' performance in achieving the firm's business goals. The type and qualities of the employees and resources within the maintenance department are more critical and place a higher value on its buildings. For example, in the hotel industry, building performance is viewed as a direct source of revenue and profit. Universities will very probably be unable to function without operational buildings. Even a virtual university must have a certain number of facilities to function. As a result, political, social, cultural, and economic pressures drive the requirement for good building performance. Inadequate building performance results from poor service delivery due to a lack of a well-designed maintenance department.

Budget allocations are another important factor in determining the organization of the maintenance department. And it is frequently dependent on government profits. Many universities outsource their "non-core services," as they are known. Non-core services are those that a company considers do not directly contribute to its corporate business objectives or are a necessary evil that must be endured regardless of the expense (Olanrewaju and Abdul-Aziz, 2015).

However, major companies, such as universities, with numerous facilities in their portfolio, will almost certainly require a separate maintenance group, especially given the importance of maintenance to their corporate operations. Even though a building solely supports the university's objective, it is practically unavoidable since a university cannot run without functional structures. It is deserving of greater attention than the academic institutions are now giving it. Its standing should be upgraded to a human resource because a university cannot function without functional buildings. As a result, to get the most value for money, the maintenance department must be inextricably tied to the university's corporate goal and vision. This reflects a favorable policy (Swallow, 2007), acknowledging buildings as capital items.

2.5 Factors Influencing the Practice of Building Maintenance Management

This section presents a systematic examination of literature and the critical factors that influence the proper practice of Building Maintenance in various functional buildings. Different scholars have identified the crucial determining factors that can impact the course of Building Maintenance management from multiple contexts and perspectives for various functional buildings, focusing on developing countries. For instance (Buys & Nkado,2006; Islam et al., 2019; Talib et al., 2014; Dahal & Dahal,2020; Zillante, 2007; Faremi, 2009; Uguwu et al., 2018; Ogunmakinde, 2015; Mkilania, 201) have identified the diverse factors that influence the successful implementation of Maintenance practices in the context of both developed and developing countries. Hossanain et al. (2013) and Jandali & Sweis (2018), on the other hand, identified and grouped these characteristics into seven influential groups listed below: Statutory requirements, design phase, construction phase, maintenance department, maintenance budget, maintenance group operations, and community perception about maintenance industry. Furthermore, the critical factors that influence the practice of building facilities maintenance management reviewed from the literature are summarized below.

Table 2- 4: Summary of reviewed Literature on critical factors from corresponding studies

Author	Building Function	Study area	Number of factors	Methods used	Country	Critical factors	Related studies
Dahal & Dahal, (2020)	Public Buildings	Building Maintenance	9	Descriptive statistics	Nepal	Insufficiency of Maintenance budget	(Talib et al., 2014;Zillante, 2007;Faremi, 2009;Besiktepe et al., 2020;Ismail, 2014)
						Lack of Maintenance productivity standards and specification	(Ofori. I.. Duodu, 2015;Jandali & Sweis, 2018;Parida & Kumar, 2009)
						Workmanship Quality during construction	(Islam et al., 2019;Akinsola et al., 2012;Zillante, 2007;Faremi, 2009)
Islam et al. (2019)	Buildings	FM cost Performance	16	Descriptive statistics	Malaysia	Design Error	(Ofori. I.. Duodu, 2015;Ajetomobi & Olanrewaju, 2015; Breesam & Jawad, 2021)
						Construction quality	(Ajetomobi & Olanrewaju, 2015; Breesam & Jawad, 2021; Ajetomobi & Olanrewaju,2015; Dahal &Dahal,2020)
						Awareness towards Maintenance	(Talib et al., 2014; Ofori. I.. Duodu, 2015; Buys & Nkado, 2006)
Jandali& Sweis (2018)	Hospital Buildings	Maintenance Management	70	Descriptive statistics & EFA	Jordan	Construction material selection & specification	(Mkilania, 2016;Faremi, 2009;Buys,2006; Ajetomobi & Olanrewaju, 2015)
						Consideration of Life cycle costing analysis	(Hassanain et al., 2013;Buys & Nikkado,2006)
						Involvement of FM expert during design	(Islam et al., 2019;Zillante, 2007;Buys & Nkado, 2006;Ajetomobi & Olanrewaju, 2015;Meng, 2013)
						Quality of defect rectification in facilities	(Talib et al., 2014;Hassanain et al., 2013;Faremi, 2009)
Mkilania (2016)	Public Sector	Maintenance practice	13	Descriptive statistics	Tanzania	Maintenance Standard, Policy & strategy	(Besiktepe et al., 2020;Blessing et al., 2015;Odediran 2015)
						Lack of Maintenance plan and program	(Islam et al., 2019;Zillante, 2007;Buys & Nkado, 2006)
						Lack of effective Maintenance culture	(Akinsola et al., 2012; Zillante, 2007; Faremi, 2009; Blessing et al., 2015)
Ofori (2015)	Public Buildings	Building Maintenance	15	Descriptive statistics	Ghana	Misuse of facilities due to attitude of users	(Zillante, 2007;Faremi, 2009;Ajetomobi & Olanrewaju, 2015)
						Availability of specialized Maintenance contractors	(Jandali & Sweis, 2018;Breesam & Jawad, 2021; Tan et al ,2014;Chua et al,2014)
						Delay in using the building after completion	(Jandali & Sweis, 2018;Ofori. I.. Duodu, 2015;Odediran,2015)

Author	Building Function	Study area	Number of factors	Methods used	Country	Critical factors	Related studies
Talib (2014)	Public Buildings	Building Maintenance	10	Descriptive statistics	Malaysia	Lack of preventive maintenance method	(Talib et al., 2014;Jandali & Sweis, 2018;Blessing et al., 2015; Dahal & Dahal)
						Availability of skilled Maintenance staff	(Islam et al., 2019;Akinsola et al., 2012;Zillante, 2007;Ogungbile & Oke, 2015;Ismail, 2014)
						The concern is given to future maintenance by the internal team	(Ofori. I.. Duodu, 2015;Faremi, 2009;Jandali &Sweis,2018)
Hassanain et al. (2013)	Hospital Buildings	Maintenance Cost performance	33	Descriptive statistics	Saudi Arabia	Method of awarding maintenance contracts	(Hassanain et al., 2013;Jandali & Sweis, 2018;Buys & Nkado, 2006)
						Coordination between construction and maintenance team	(Islam et al., 2019;Jandali & Sweis,2018)
						Accuracy in forecasting maintenance expenditure	(Jandali & Sweis, 2018;Shamkhi & Al-Hajj, 2014)
						Lack of training for Maintenance personnel	(Islam et al., 2019;Zillante, 2007;Ogungbile & Oke, 2015;Blessing et al., 2015)
Faremi (2012)	Banking	Maintenance management	13	Descriptive statistics	Nigeria	Maintenance work quality by the internal staff	(Talib et al., 2014;Ofori. I.. Duodu, 2015;Jandali &Sweis,2018)
						Quality and availability of replacement parts &components	(Talib et al., 2014;Zillante, 2007;Blessing et al., 2015;Dahal Dahal,2020)
Akinsola (2012)	Tertiary Institutional Buildings	Facility Maintenance management	16	Inferential Statistics	Nigeria	Accuracy in forecasting maintenance expenditure	(Jandali & Sweis, 2018;Hassanain et al., 2013)
						Design Efficiency	(Rashidul Islam et.al,2021; Ramly, 2007;Jandali &Sweis,2018)
						Experience as a Design professional	(Awol et al., 2016; Meng, 2013)
Zillante (2007)	Public Hospital Buildings	Maintenance management	22	Descriptive statistics	Nigeria	Misuse of facilities due to attitude of users	(Ajetomobi & Olanrewaju, 2015; Blessing et al., 2015; Odediran et al, 2015)
						Difficulty in the procurement of spare parts and components	(Jandali & Sweis, 2018;Faremi, 2009)
(Buys & Nkado, 2006)	Tertiary education	Maintenance management	25	Descriptive statistics	South Africa	Communication and collaboration skills	(Talib et al., 2014,Islam et al., 2019)
						Lack of Maintenance Manual	(Ogungbile & Oke, 2015; Islam et al,2019)
						Maintenance data recording, storage & as-built documentation	(Jandali & Sweis, 2018;Hassanain et al., 2013;Islam et al., 2019;Mkilania, 2016)

2.6 Overview of Maturity Model

Maturity models came into the scene based on Crosby's (1979) Quality Management Maturity Grid, which established a model based on five incremental stages of maturity for quality management in an organization. (Fryer, Ogden, and Anthony, 2013) proposed five maturity stages based on (Bessant et al., 2001) to develop continuous improvement skills, allowing firms to plan and grow the quality of organizational processes by developing a strategy to increase their ongoing improvement abilities. The ISO 9004:2009 (2009) standard includes a quality management maturity model.

The organization aspires to be the best in maintenance management. Using the maintenance management method solely, even over a lengthy period, is insufficient for achieving excellence. Maturity Models, which are formed of phases that reflect the various maturities, best define the foundation for reaching excellence in maintenance management. The idea of maturity is intimately related to the possibility of success or failure. Immature organizations are characterized by improvisation in management without establishing the vital connections between the various knowledge areas.

A maturity model is a conceptual framework made up of constituent pieces that define the maturity of the area of interest. In certain situations, it also explains the processes that the organization will need to develop to achieve the desired future.

Another definition presents maturity as the development of systems and processes that are repetitive by nature, setting a high probability that each one of them is successful. However, repetitive processes and systems are not by themselves a guarantee of success. They only increase its likelihood. Developing maturity is a continuous process. Improvements in maturity depend on a concentrated effort to create, improve and foster communication between executives and professionals. To achieve the outlined strategic objectives, organizations use maturity scales to measure results and the level or degree of maturity that the organization finds itself regarding project management practices (Talita Ferreira de Souza, 2015).

A maturity model is a technique for evaluating the effectiveness of work performed in an organization and determining the competencies they need to learn next to improve their performance. It is also a way to assess how well an organization manages its business processes. There are numerous primary process categories and maturity degrees (Meng, Sun, & Jones, 2011). In essence, maturity refers to how efficiently a firm or system performs in terms of self-improvement.

The maturity model can assist businesses in determining their current competencies and capabilities, as well as the processes necessary to advance to the next level. Maturity curves or scales are split into five or six levels, each with abilities. There are a variety of maturity models to choose from. The following subsections show descriptions of some of the most popular maturity models.

2.6.2 Types of Maturity measurement

There is a significant body of literature on maturity models and their use in various sectors. For Instance, Project Management (PM), Knowledge Management (KM), Information Systems (IS), and Supply Chain Management (SCM) knowledge areas all use maturity models (Banyani and Then, 2010) to assess the current level of maturity and plan for improved performances.

2.6.2.1. Capability Maturity Model (CMM)

The Capability Maturity Model Integration (CMMI) project was developed in 1986 by SEI to integrate the various CMM models. CMMI, which sought to improve software development processes, was published in 1993, focusing on the fields of systems and software engineering. Capability maturity model is the first maturity model to be developed. The model was developed by the software Engineering Institute at Carnegie Mellon University. The model was initially developed for use in the improvement of software development processes. This model has served as a basis for developing several maturity models in different fields, including project management. Unlike Project Management maturity models, this model assesses the entire software development process, including the PM and technical parts of software development. The CMM model has five maturity levels beginning from the initial stage (level 1) to the most matured level of optimization (Level-5). Each maturity level has key processes areas (KPA) that identify it. In addition, the model has a prioritized improvement path to achieve a higher-level capability.

However, as the model is descriptive, it does not tell an organization how to improve. Instead, it describes essential attributes expected to characterize an organization at a particular maturity level. The following are characterizations of the five maturity levels (Paulk, 1993).

- Level 1- Initial: The software process is ad hoc and occasionally even chaotic. Few processes are defined, and success depends on individual effort.
- Level 2- Repeatable: Basic project management processes are established to track cost, schedule, and functionality. The necessary process discipline is to repeat earlier successes on projects with similar applications.
- Level 3- Defined: The software process for both management and engineering activities is documented, standardized, and integrated into a standard software process for the organization. All projects use an approved, tailored version of the organization's standard software process for developing and maintaining software.
- Level 4- Managed: Detailed software process and product quality measures are collected. Both the software process and products are quantitatively understood and controlled.
- Level 5- Optimizing: Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies

2.6.2.2. Project Management Process Maturity Model $(PM)^2$

The Project Management Process Maturity Model, shortly $(PM)^2$, is one of the pioneer PM maturity models developed. The model was developed by (Kwak and Ibbs, 2002); it covers nine project management knowledge areas and the five stages of the project life cycle and discusses the critical processes of each scale in those stages.

The $(PM)^2$ model, like the CMM model, has five levels of maturity with a slight difference in its use of terminologies. This model also has five levels starting from Ad-hoc (Level 1), planned (level 2), Managed at project level (level 3), Managed at a corporate level (Level 4), and to the most matured continuous matured (level 5). To give some insight into the description of maturity level, key project management processes and their Organizational characteristics of levels 1 and 5 are given below.

- Level 1 Basic PM process: No PM process or practices are consistently available. Its Major organizational characteristics are functionally isolated and lack of senior management support.

- Level 5 contentious learning where PM processes are continuously improved while its major organizational characteristic is Project driven organization, dynamic energetic with continuous improvement of PM processes and practices (Kwark and William, 2002).

2.6.2.3. Asset Management Maturity model, AMMM (IAM)

Asset Management maturity is the extent to which the capabilities, performance, and ongoing assurance of an organization are fit for purpose to meet its stakeholders' current and future needs, including the ability of an organization to foresee and respond to its operating context. Organizations that demonstrate Asset Management maturity should be able to anticipate and respond to both the changing business environment and changing stakeholder needs in a manner that retains alignment of the various activities within the organization.

The institute of asset management (IAM) AMMM model has six perspectives or dimensions of evaluation and six maturity levels like other maturity models. The measurements for each level include:

- Asset Strategy and delivery
- Documentation, controls, and review
- Systems, integration, and information management
- Communication and participation
- Structure, capability, and authority
- Competency and training

The six maturity levels and their description are as follows:

- Level 0-Innocent - The organization has not recognized the need for this requirement, and there is no evidence of commitment to putting it in place
- Level-1 Aware - The organization has identified the need for this requirement, and there is evidence of intent to progress it.
- Level-2 Developing - The organization has identified the means of systematically and consistently achieving the requirements and can demonstrate that these are being progressed with credible and resourced plans.
- Level-3 Competent - The organization can demonstrate that it systematically and consistently achieves relevant requirements set out in ISO 55001.

- Level-4 Optimizing - The organization can demonstrate that it is systematically and consistently optimizing its Asset Management practice in line with the organization's objectives and operating context.
- Level-5 Excellent - The organization can demonstrate that it employs the leading practices and achieves maximum value from managing its assets according to its objectives and operating context.

2.6.2.4. Portfolio, Programme and Project Management Maturity Model' (P3M3)

The P3M3 seeks to give an assessment and measurement score for portfolio, program, and project-related activities that contribute to a successful project outcome within process areas. The P3M3 levels show how important process areas can be organized hierarchically to form a capability progression that an organization can use to set goals and plan its improvement journey. The levels facilitate organizational transitions from an immature state to becoming a mature and capable organization with an objective basis for judging quality and solving Programme and project issues.

P3M3 assessments can be used across an organization to assess portfolio, program, and project management operations. The model comprises three models that can be evaluated independently or collectively: Project management, Program Administration, and Portfolio management. P3M3 assesses the maturity and performance of each model from seven distinct viewpoints that exist across the three models and are evaluated at all five maturity levels. The evaluation perspectives for each level against the perspectives are as presented in Table 4 (P3M3, 2015).

- Organizational governance
- Management control
- Benefits management
- Risk management
- Stakeholder management
- Finance management
- Resource management

As with the Software engineering Institute (SEI's) Capability Maturity Model, P3M3 version 3 (2015) is described by a five-level maturity framework. These levels constitute the structural components that comprise P3M3.

- Level 1 – Awareness of the process
- Level 2 – Repeatable process
- Level 3 – Defined process
- Level 4 – Managed process
- Level 5 – Optimized process

Table 2- 5: P3M3 Evaluation Perspectives and Levels Source: P3M3 (2015)

2.6.2.5. The EFQM model

Maturity	Portfolio	Program	Project
Level 1 – Awareness of the process	Does the organization's board recognize programs and projects and run an informal list of its investments in programs and projects? (There may be no formal tracking and documenting of the process.)	Does the organization recognize programs and run them differently from projects? (Programmes may be run informally with no standard process or tracking system.)	Does the organization recognize projects and run them differently from its ongoing business? (Projects may be run informally with no standard process or tracking system.)
Level 2 – Repeatable process	Does the organization ensure that each program and project in its various portfolios are run with its processes and procedures to a minimum specified standard? (There may be little consistency or coordination between portfolios.)	Does the organization ensure that each program is run with its processes and procedures to a minimum specified standard? (There may be little consistency or coordination between programs.)	Does the organization ensure that each project is run with its processes and procedures to a minimum specified standard? (There may be little consistency or coordination between projects.)
Level 3 – Defined process	Does the organization have its own centrally controlled portfolio processes, and can individual initiatives flex within these?	Does the organization have its own centrally controlled program processes, and can individual programs flex within these processes to suit the program?	Does the organization have its own centrally controlled project processes and can individually project flex within these processes to suit the project?
Level 4 – Managed process	Does the organization obtain and retain specific management metrics on its whole portfolio of programs and projects to predict future performance? Does the organization assess its capacity to manage programs and projects and prioritize them accordingly?	Does the organization obtain and retain specific measurements on its program management performance and run a quality management organization to predict future program outcomes better?	Does the organization obtain and retain specific measurements on its project management performance and run a quality management organization to predict future performance better?
Level 5 – Optimized process	Does the organization run continual process improvement with proactive problem and technology management for the portfolio to improve its ability to predict performance over time and optimize processes?	Does the organization run continual process improvement with proactive problem and technology management for the program to improve its ability to predict performance over time and optimize processes?	Does the organization run continual process improvement with proactive problem and technology management for projects to improve its ability to predict performance over time and optimize processes?

The European Foundation for Quality Management Excellence (EFQM) model is a framework that enables people to recognize the cause-and-effect relationships that exist in an organization's actions and outcomes. The European Foundation for Quality Management model was created in 1991 as a quality management system. "Enablers" and "Results" are the two criteria in the EFQM model. Leadership, People, Strategy, Partnerships and Resources, and Processes, Products, and Services are the Enablers; criteria, whereas People Results, Customer Results, Society Results, and Business Results are the results categories.

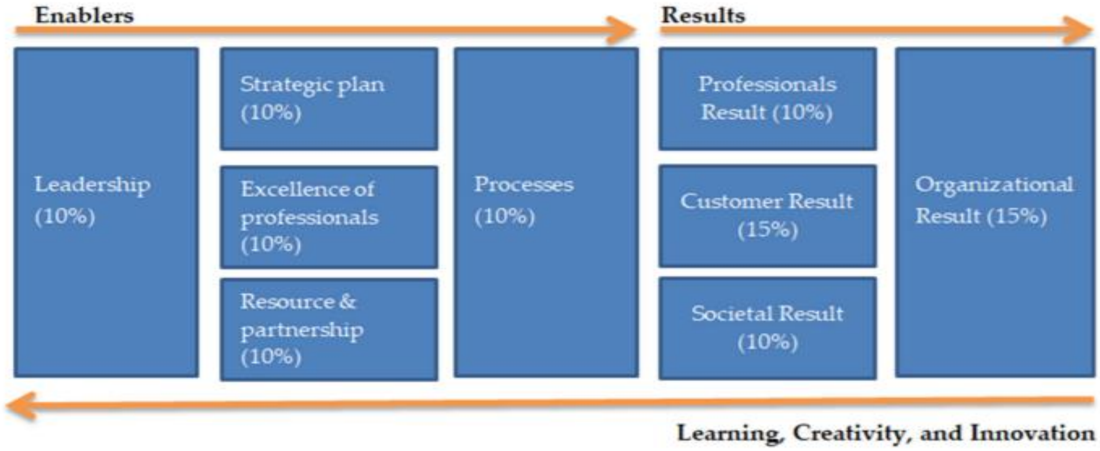


Figure 2- 13: The EFQM Model: Enablers and Results

The diagram above shows the dynamic nature of the model. If the Enablers are effectively implemented, the organizations will reach the desired Results (EFQM, 2021). The arrows emphasize always learning and continuously improving the Enablers to achieve the expected results. Organizations can perform a self-assessment based on those EFQM criteria above to achieve excellent performances. Each criterion implies the need for an organization to change and actions to improve its capabilities (EFQM, 2021).

The model's dynamic nature is depicted in the diagram above. The companies will achieve the required Results if the Enablers are executed successfully (EFQM, 2021). The arrows indicate the importance of continuing to learn and improving the Enablers to reach the desired outcomes. Organizations can conduct a self-assessment based on the EFQM criteria above to attain excellent performance. Each criterion implies that an organization must change and that measures must be taken to improve capabilities (EFQM, 2021).

The EFQM Model Direction/ Perspective of evaluations

1. Purpose, Vision & Strategy

An outstanding organization is defined by a Purpose that inspires, an aspirational Vision, and a Strategy that delivers.

2. Organizational Culture & Leadership

Organizational Culture is the specific collection of values & norms shared by people and groups within an organization that influence, over time, the way they behave with each other and with Key Stakeholders outside the organization.

Organization Leadership relates to the organization rather than any individual or team that provides direction from the top. It is about the organization acting as a leader within its ecosystem, recognized by others as a role model, rather than from the traditional perspective of a top team managing the organization

3. Engaging Stakeholders

The Purpose, Vision & Strategy of an organization is linked to identifying and understanding Stakeholder needs within its unique ecosystem.

There is a clear linkage between how an organization executes its Engaging Stakeholders strategy (Criterion 3) and the perceptions of its performance by those Stakeholder Groups (Criterion 6) that it serves.

4. Creating Sustainable Value

An outstanding organization recognizes that Creating Sustainable Value is vital for its long-term success and financial strength

5. Driving Performance & Transformation

Now and in the future, an organization needs to meet the following two important requirements at the same time to become and remain successful.

On the one side, it needs to continue successfully managing the delivery of its current business operations. (“Driving Performance.”)

On the other side, there are constant changes inside and outside the organization that need to be managed in parallel to remain successful. (“Driving Transformation.”).

6. Stakeholder Perceptions

This Criterion concentrates on results based on feedback from Key Stakeholders about their personal experiences of dealing with the organization and their perceptions.

7. Strategic & Operational Performance

This Criterion concentrates on results linked to the organization's performance in the ability to fulfill its Purpose, deliver the Strategy and Create Sustainable Value and its fitness for the future.

2.6.2.6. The SPICE-FM Process Maturity Model

The SPICE framework for step-by-step process improvement was built utilizing experiences gathered in the information technology sector, and it depends explicitly on the CMM (Paulk et al., 1995; Amaratugna et al., 2002). The Structured Process Improvement for Construction Enterprises model (SPICE) has already been used to assess FM process capabilities in the UK. The SPICE FM model is mainly concerned with management processes. Its premise is that if management processes are executed successfully, they will impact the performance of the core processes (Amaratunga, Sarshar, and Baldry, 2002). The model is composed of five progressively developing levels used to measure the performances of current process maturity and plan for improved versions in construction and FM businesses.

Level One- Initial

Level one is the basic entry-level of the model. This level has no key process, and it has little focus on the process irrespective of the organization's size. The processing capability of level one organizations is unpredictable, as the process is constantly changed or modified as the work progresses. Performance depends on the capability of individuals rather than that of the organizations

Level Two-Planned and Tracked

There is a degree of project predictability at this level, and the organization has established policies and procedures for managing the major project-based processes. The major objective of this level is to focus on an effective management process within the construction project. This allows organizations to repeat the successful practices of earlier projects as an effective process can be characterized as practiced, documented, enforced, trained, evaluated, and improved.

Level Three- Well Defined

At this level, both management and engineering activities are documented, standardized, and integrated throughout the organization rather than differing from project to project. Employees in any organization can easily refer to this standard process. All projects use approved, tailored versions of the organization's standard processes, which consider each project's unique characteristics.

Level Four-Quantitatively Controlled

At this level, organizations can set goals for the product, process, and supply chain relationships. As part of an organizational measurement program, productivity and quality are measured from important construction process activities across all projects. This forms the basis of an objective for measuring the product, process, and degree of customer satisfaction. Organizations gain control of projects by narrowing variations in process performances so that they can fall within acceptable boundaries.

Level Five-Continuously Improving

At this level, the entire supply chain focuses on continuous process improvement. Level five -an organization can identify and strengthen the process before any problem emerges and collaboratively. Data on the effectiveness of the process is used to perform the most beneficial analysis of any new technologies and proposed changes in the organization's process. Innovations that exploit best practices in business management are identified and adopted throughout the organization. There is also a capability to transfer identified best practices throughout the organization.

Process Enablers

The SPICE-FM maturity rating model has process enablers identified as per-conditions for implementing process improvements and focusing on the results from a key process. This forward-looking approach indicates process capability before a process takes place. They provide detailed features that a key process must possess to yield successful results. Process enablers are applied across all the key processes. SPICE process enablers are described as follows:

Commitment: this ensures that the organizations take to ensure that the process is established and will endure. It typically involves establishing organizational policies. Some processes require organizational sponsors or leaders' commitment to performing, ensuring that leadership positions are created and filled and relevant organizational policy statements exist.

Ability: These preconditions must exist to implement the process completely and generally involves adequate resourcing of appropriate organizational structure and training.

Verification: This verifies that the activities are performed in compliance with the agreed process and emphasizes the need for independent external management and quality assurance.

Evaluation: this describes the basic internal process evaluation and reviews used to control and improve the process. During the early stages of maturity, this translates into efforts by the team to improve their existing processes.

Activities: this describes the activities, roles, and procedures necessary to implement the process. It typicality involves establishing plans and procedures, performing the work, tracking it, and taking corrective action as necessary.

2.6.2.7. Facility Management Maturity Model (I3F)

Assessing the maturity of facility management at the micro level (organization) and Macro level (industry, country) level is a key start to assessing facility management capability. The assessment of facility management maturity at the industry level has been made based on the integrated feeder factors framework (I3F), which are the key factors essential for the maturity of the facility management industry that has been identified by (Banyani and Then, 2015).

The term "feeder factors" deduces its meaning from the conception that each factor contributes toward the development of the FM industry and at the same time gives to and receives contributions from the other factors. The contribution depends on the feeder factors' dominant progression and integration level as assessed using the "feeder factors progression and integration matrices." The dominant progression is assessed based on the feeder factors progression matrices. These matrices contain 22 feeder factors ranging from lower to higher levels. On the other hand, the dominant integration level is assessed based on the four integration criteria, i.e., coordination, trust, interdependence, and influence, within the integration matrix. The maturity level of the FM industry within a country depends on the assessed dominant progression and integration levels (Banyani and Then, 2015).

The model involves five levels and six dimensions or perspectives of evaluation

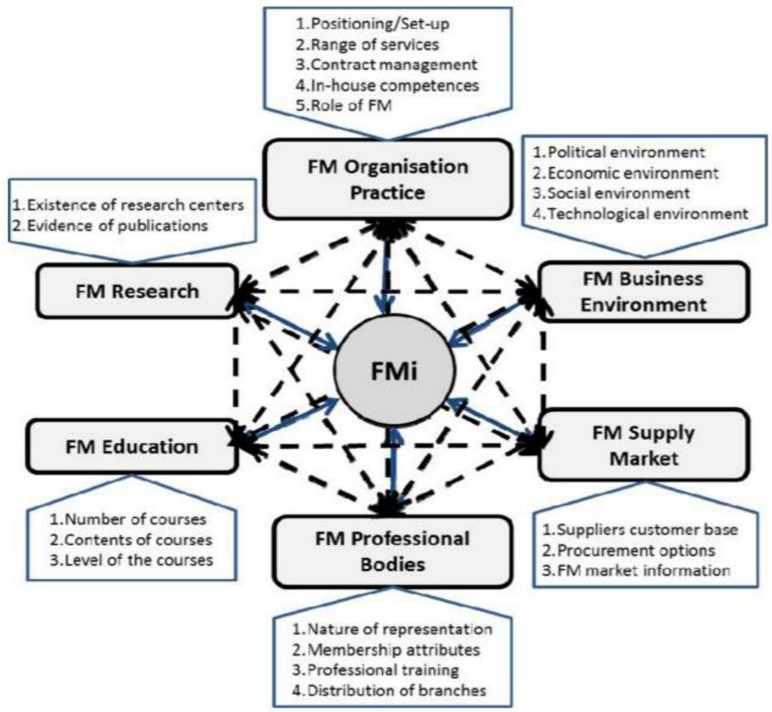


Figure 2- 14: Integrated Feeder Factor Framework (I3F)

- Initial formative level (IFS): defines the progression and integration levels at Level I
- Formative transition stage (FTS): signifies the dominant progression and integration at level II
- Developmental transition stage (DTS): indicates that the dominant progression and integration at level III

Full mature stage (FMS): fully developed industry showing that the assessment of progression and integration is at Level IV

2.6.2.8. The Public Commissioning Maturity Model (PCMM)

Volker developed the Public Commissioning Maturity Model (PCMM) in 2014. This model was used to analyze public organizations' capabilities regarding construction customers' responsibilities in successfully commissioning projects (Volker, 2014).

This maturity model consists of 10 aspects divided into several sub aspects and five levels of maturity. These ten aspects include 1. Organizational strategy and policy; 2. Cultural aspects and leadership; 3. people and learning organizations; 4. Decision making and portfolios; 5. Stakeholders management; 6. public role; 7. General rules of play; 8. Interactions with supply market; 9. Managing projects and assignments; and 10. Creativity and flexibility.

In this maturity model, the five levels are similar in many ways to that of the CMM model, which includes: "Ad Hoc" is the lowest maturity level, followed by "Repeatable," "Defined," "Managed," and "Optimized," which is the highest. These levels are comparable to the CMM levels in most ways. As in the several areas mentioned in the above sections, maintenance maturity models have also emerged. Some of these models are discussed below.

2.6.3 Maintenance Management Maturity Models

In the field of quality, Antil (1991) suggested a model that has been driven by and heavily based on Crosby's (1979) maturity model. Fernandez et al. (2003) used this model to determine where organizations stand in maintenance to build and implement a computerized maintenance management system (CMMS) that meets their demands. According to the concept, maintenance progresses from a mostly reactive state in the early stages to a preventive and predictive state later. It includes some areas of maintenance management, such as problem-solving methodologies, a software tool to support the management of maintenance activities, and concerns linked to posture in maintaining companies' equipment, with its four classes of evaluation.

Wireman (1992) also developed a maturity model for maintenance management that follows the structure of Crosby's quality model and transforms terminology connected with quality to terms associated with maintenance in certain circumstances. The classes include topics such as the organization's maintenance posture, maintenance resources, maintenance organization, improvement initiatives, and system information and qualification. The maintenance resources class adopts goals that determine the percentage of resources wasted to define each maturity stage. In applying the model to various organizations and activity areas, defining stages by fixed goals may result in inaccessible stages and unequal difficulty in reaching the same level in various companies. When it comes to how well a given task is conducted, the class associated with worker qualification uses intangible issues. Importantly, the model combines two crucial aspects of maintenance: maintenance information and improvement actions, into a single category.

Cholasuke et al. (2004) conducted a pilot survey in the United Kingdom to determine the characteristics or critical ingredients for successful maintenance management. The respondent's businesses were grouped into four maturity levels based on the survey results, which were determined by a combination of two criteria: appropriate maintenance procedures and the advantages derived from maintenance. In addition, each factor was classified into three maturity levels, which included: maintenance effectiveness, which was defined by using targets for the overall equipment effectiveness (OEE) indicator to define the groups; policy and organization, which was defined by the hierarchical structure of the area; planning and scheduling activity, which was defined by using an overtime level limit to define each group; and continuous improvement, which was defined by using targets for the overall equipment effectiveness (OEE) indicator to define the groups. Evaluating the types of maintenance management approaches used to create the groups, such as reliability-centered maintenance and, total productive maintenance (TPM); spare parts management, highlighting the use of the Pareto diagram to control inventory requirements at the excellence level.

Campbell and Reyes-Picknell (2006) proposed a framework based on the Pyramid of Excellence concept, which was defined with the help of a survey. Some maturity levels, such as the material management class, are specified using indicators and goals. Applying approaches like the balanced scorecard and reliability-centered maintenance is an important consideration for defining the highest stages of maturity. The model has a management support class that refers to how a management system is used. Still, there is no explicit reference to using a computer system to support maintenance management. Although human resources are referenced, qualification and training are not. Some topics, such as preventative and condition-based maintenance, team autonomy, and operator participation, are considered in multiple classes.

The previously mentioned maintenance maturity models are over ten years old and do not consider the most recent maintenance management improvements.

Chemweno et al. (2015) established a general framework known as the asset maintenance maturity model (AMMM), which consists of a structured guide to analyze and improve asset management maturity through three phases: performance evaluation, continuous improvement, bench-marking, and standardization. The AMMM is based on a quantitative analysis that comprises a weighted performance assessment score for bench-marking and a risk assessment to help enhance activities. Based on the score value, five levels of maturity are identified. The authors argue that the improvement process focuses on defining a better maintenance strategy for a specific failure and identifying failure risks. The most difficult aspect of applying this methodology is manipulating and understanding the mathematical formulation of the weighted performance evaluation score to determine the maturity level. This model can be used to assess maturity levels. Still, it cannot be used to identify or assist in identifying actions that must be taken to attain the greatest level.

Oliveira and Lopes (2020) proposed a model based on an extensive literature review on Maintenance maturity assessment. The progressive maturity levels for each of the identified factors include: (Organizational culture, Maintenance policy, Performance management, Failure analysis, Planning and programming of preventive Maintenance activities, CMMS, Spare parts inventory management, Standardization, and document control, Human Resource Management, and Result Management (Maintenance Cost and quality) form the model. The developed model was tested for its effectiveness in the Maintenance areas of three companies as a case study. The result indicated the direction for future improvements in the three companies. The self-assessment tool provided some knowledge on behaviors or practices that enable a world-class result. The authors included potential gaps for each factor. The desired states were defined focusing on behaviors rather than indicator values or adopted methodologies, which helps identify improvement actions that lead to better performance.

A summary of the published works on maintenance maturity assessment is shown in Table 5 more comprehensively.

Table 2- 6: Summary of Maintenance Maturity Assessment Models

No.	Maturity Levels/stages	Evaluation Dimensions/perspectives	Contributors
1	• Uncertainty • Awakening • Enlightenment • Wisdom • Certainty	• Management understanding and Attitude • Problem handling • Company maintenance posture • CMMS	Antil (1991)
2	• Uncertainty • Awakening • Enlightenment • Wisdom • Certainty	• Corporate/plant management attitude • Maintenance organization status • Percentage (%) of maintenance resources wasted • Maintenance problem solving • Maintenance workers, qualification, and training • Maintenance information and improvement actions • Summation of company maintenance position	Wireman (1992
	• Innocence • Understanding • Excellence	• Maintenance effectiveness (output) • Policy deployment and organization • Maintenance approach Task planning and scheduling • Information management and CMMs • Contracting out maintenance • Continuous improvement • Financial aspects • Human resource management • Spare part management	Cholasuke et al. (2004)
4	• Innocence • Awareness • Understanding • Competence • Excellence	• Strategy • People • Work management • Materials management • Basic care • Performance management • Support systems • Asset reliability • Teamwork • Processes	Campbell and Reyes-Picknell,2006
5	• Level 1 • Level 2	• People and environment • Functional technical aspects	Chemweno et al. (2015)

	• Level 3 • Level 4 • Level 5	• Plant Design Life • Support • Maintenance Budget	
6	• Level 1 • Level 2 • Level 3 • Level 4 • Level 5	• Organizational culture • Maintenance policy • Performance management • Failure analysis • Planning and programming of preventive Maintenance activities • CMMS • Spare parts inventory management • Standardization and document control • Human Resource Management • Result Management (Maintenance Cost and quality)	(Oliveira and Lopes, 2020)
7		• Customer • Maintenance Policy and Strategy • Maintenance Organization • Information and Knowledge management • Maintenance controlling • Materials Management • Partnership • Maintenance Staff	Winter, C-P. and Fabry, C. (2012)
8	• Ad-hoc • Repeatable • Standard • Managed • Optimized	• Information management • Internal coordination • External coordination • Market approach • Risk management • Processes and roles • Culture and leadership • Overall progress	L. Volker et al. (2013)

Maintenance Maturity levels and Dimensions: Compiled from different litterateurs

In summary, this study's maintenance maturity rating model will be based on the building Maintenance process and departmental organization perspectives as an evaluation dimension to adapt one or two models from the above-discussed models. The new maintenance management maturity model to be developed in this research will also be based on the focus group discussion results, which involve professionals from academia, industry practitioners, university FM, and Maintenance managers.

One of the ways to address the challenges in building maintenance and FM is to improve the outcome of the decision-making process with a structured and systematic approach. Since building maintenance decisions are complex with conflicting criteria, an MCDM approach may effectively address these challenges in the process of building the maturity rating model.

The application of multiple criteria decisions making (MCDM) enables decision-makers to create their own set of essential criteria/dimensions for evaluating the maturity of building maintenance management for a built asset.

The present study employed twelve main maturity dimensions in which 51 (fifty-one) indicators are used to measure built asset maturity level (Table 2-1). The description for each dimension is written in the subsequent section.

Table 2- 7 (Built asset maturity dimensions with their descriptions)

	Dimensions /Perspective	Indicators (KPIs)	Descriptions	References
D1	**Maintenance Policy and Strategy**	Availability of Built Asset management strategy and planning (D11)	a long-term optimized approach to managing the built assets, derived from, and consistent with, the organizational strategic plan and the asset management policy.	(Maletič *et al.*, 2020),(Omar, Ibrahim and Omar, 2017),(Oliveira,2020),(PAS5,2008) and (ISO55000)
		Availability of built Asset management policy (D12)	Built asset Policy is a set of common rules and regulations that serve as the foundation for built asset maintenance decision making.	(Maletič *et al.*, 2020), (Seeley,1987),(Omar, Ibrahim, and Omar, 2017), (ISO55000,2014),(Brooks,2015), (Olarewanju,2015)
		Alignment of Built Asset management objectives with Corporate objectives (D13)	Refers to the alignment of built asset maintenance objectives with corporate business objectives of the organization	(Seeley,1987), (Maletič et al., 2020)
		Built asset maintenance task planning and scheduling (D14))	It involves analyzing the current condition of the building, anticipating future requirements, and bringing the past to focus.	(Omar, Ibrahim and Omar, 2017), (Olarewanju,2015),Cholasuke et al (2004
		Availability of defined built asset Maintenance approach/s (D15)	The balance of maintenance approach for each class of building asset between corrective (when it failed), preventive (maintain regularly), predictive (maintain before it failed), and proactive(maintain the root causes as against the symptoms)	(Hirsch, Anderson, and Melo, 2013), (Olarewanju,2015),(Oliveira,2020),Cholasuke et al (2004)
D2	**Human Resource Management**	Competency of in house maintenance staff (D21)	The ability of staff to apply knowledge and skills to achieve intended results/Knowledge and competencies; development of employee competency	(Maletič *et al.*, 2020), (ISO55000,2014)
		Training programs to maintenance staff (D22)	Availability of good quality training programs in different trades for the maintenance staff	Overachieve,2019), (Olarewanju,2015); Misnanb and Mariah Awanga,2012
		Motivation and inspired teamwork of maintenance staff (D23)	Availability of a conducive and supportive environment that facilitates inspiration and teamwork among maintenance staff	(Olarewanju,2015),Cholasuke et al. (2004)
D3	**Technical and Functional Appropriateness**	Building asset Capacity (D31)	The physical capacity of the built asset to support the level of current and future service activity	(Queensland government, 2017)
		Building asset Functionality (D32)	The suitability and flexibility of the building asset for current and future service delivery.	(Queensland government, 2017)
		Building asset Location (D33)	The physical location of the building asset, relative to current and future demand for services. In dynamic demographics and infrastructure planning, this indicator is an important consideration.	(Queensland government, 2017) and (Olarewanju,2015)

		Building asset Condition (D34)	The physical condition of the building asset appropriate for current and future service activity	(Queensland government, 2017), Deniz Besiktepe et.al (2020),Johnson and Wyatt, Yau, 2012 1999, Ali, Kamaruzzaman,Sulaiman, & Peng,2010
		Technical practicality of Building asset (D35)	The time to complete, reliability to function, regulation and bureaucracy, and site accessibility of built asset to maintenance	Deniz Besiktepe et.al (2020), Kim, Sunitiyoso, & Medal (2019)
D4	**Maintenance Organization**	Organization of Maintenance department (D41)	Delegation of duties, roles, and responsibilities to all maintenance staff and allocation of resources to tasks	(Olarewanju,2015)
		Alignment of Maintenance with organizational objectives (D42)	The maintenance department is organized in a way to aligns with the strategic business objectives	(Olanrewaju and Abdul-Aziz, 2015)
		The efficiency of the maintenance process and work Instructions (D43)	The maintenance organization's Mission Statement, underlying purposes, and values should promote user happiness and productivity. the integration of the asset management system into the quality management system	Johannes, Koos et al ,2021), (Olanrewaju and Abdul-Aziz, 2015)
		Organizational position of maintenance department (D44)	It refers to the organizational location of the maintenance department as (strategic, tactical, and operational) as one of the important strategic units or departments within the organization	(Olarewanju,2015)
D5	**Maintenance Information Management**	Completeness, accuracy, and validity of built asset data (D51)	Measures the accuracy, completeness, and validity of built asset data	Volker,2013
		Built asset registry and asset history of enhancing asset knowledge (D52)	sound registration of asset data as a basic pillar of built asset management	Volker,2013
		Use of Maintenance information management system (as-built documentation) (D53)	Existence of a defined maintenance information management system such as CMMS, CAFM, and BIM-FM) used to store, transfer and retrieve built asset information	Volker,2013,Cholasuke et al (2004), (Queensland, 2017)
		Use of data Capturing Technologies from exiting built asset(D54)	Collecting data from existing built assets using technologies (laser scanners, drones, sensors, and detectors) as input for information modeling	Volker,2013,Cholasuke et al (2004), (Queensland, 2017)
D6	**Building Design Life**	Evaluation of capital expenditure requirements (D61)	Organization's investment decision in existing and new fixed assets to maintain or grow the business.	Bevilacqua and Braglia,2000),(Mansfield and Pinder, 2008), (Horenbeek and Pintelon, 2014)
		Modernization plan of the Built asset (D62)	The process of adapting an asset to the forces of technological obsolescence or functional obsolescence by replacing it with a newer asset.	(Mansfield and Pinder, 2008)
		Disposal plan of the built asset (D63)	A plan used by local governments and municipalities to manage their portfolio of a built asset	Campbell and Reyes-Picknell,2006
		Building remaining Life (D64)	An estimate of the building asset's remaining useful or economic life in terms of its future potential to sustain the delivery of services or the costs of ownership and use not being viable.	Flores-Colen, Brito, & Freitas, 2010 (Queensland government, 2017)

D7	**Maintenance Budget/Financial Perspective**	Operating cost (D71)	The annual operating cost of the building asset in the asset portfolio	(Queensland government, 2017)
		Annual Maintenance Cost (D72)	Reflects the maintenance expenditure per built asset square meter. A budget constraint for Maintenance/Major components, minor components, obsolescence/life cycle analysis, new technologies, changes to legislation, day-to-day repairs, voids	(Shohet and Nobili, 2017), Parida and Chattopadhyay, 2007, Reichelt, Melnikas, & Vilutiene, 2008, Cholasuke et al (2004)
		Differed Maintenance Cost (D73)	The estimated cost of all maintenance work that has not been carried out within a financial year	(Queensland, 2017),(Olanrewaju and Abdul-Aziz, 2015)
		Utilization of Maintenance budget (D74)	A measure of efficiency in managing the allocated budget for maintenance activities	Cholasuke et al. (2004)
		Information and Knowledge about maintenance costs (D75)	Availability of Record for maintenance cost	Cholasuke et al. (2004)
D8	**Culture and Leadership**	Awareness of people towards built asset management (D81)	Measures the degree of awareness of the top managers, maintenance staff, and built assets about the importance of built asset maintenance	Misnanb and Mariah Awanga,2012
		Top management Support (D82)	The degree of top management pro-activeness in adopting forward-looking strategies for survival and sustainability of maintenance management	Volker 2013, Khaled Saleh Al-Omoush,2020, Antil (1991)
		The attitude of employees (D83)	The attitude of maintenance staff as a result of varied cultural background	Volker (2013)
		The willingness of people to learn new methodologies and attend training (D84)	The extent to which people have a positive attitude towards the changes	Volker (2013)
		Values and beliefs towards maintenance (D85)	It measures the way of thinking, behavior, perception, and the underlying assumptions of any person or group or society that considers maintenance as an important matter (priority) and practices it in their lives.	Misnanb and Mariah Awanga (2012)
D9	**Maintenance Materials and Spar part Management**	Maintenance Materials Inventory Management (D91)	classification of spare parts and forecasting of demand for planned maintenance tasks	Oliveira (2020)
		Classification of Maintenance stock items (D92)	classification of maintenance items based on relevant characteristics (criticality, value, and logistics)	Oliveira (2020)
		Inventory management policy (D93)	An organization must follow a policy in the management and control of inventory, including safeguarding and disposal of inventory.	Oliveira,2020 (Shin,2018)
D10	**Risk Management**	Risk assessment strategies and objectives (D101)	Risk management as an integrated part of AM strategy	Volker (2013)
		Risk is embedded in all activities to improve performance (D102)	Incorporation of risk management into the built asset management process throughout the whole life-cycle of the built asset	Volker (2013)
		Analysis of building failure, causes & effects to address the risk (D103)	Built asset failure analysis using different methods and techniques	Oliveira,2020 and Flores-Colen, Brito, & Freitas, 2010
		Statutory compliance risk (D104)	The extent of non-compliance: the degree of non-compliance with local Standards, codes, laws, and regulations, which is identified as a result of an audit, discovery, or the introduction of new legislation.	(Queensland government, 2017)
D11		Value for money (D111)	Strategic and operational decisions must be made with commercial awareness	Oliveira,2020

	Performance Management	Maintenance efficiency indicator (D112)	Measures how well your operation achieves its maintenance goals, like reducing downtime or cutting costs.	(Shohet and Nobili, 2017)
		The physical state of the building is measured by the building performance indicator (D113)	Enabler for the evaluation of the overall state of the built asset or asset portfolio, according to the performance of its components and systems	(Shohet and Nobili, 2017),Yau, 2012
		Building Efficiency Index (D114)	A building energy indicator considering building services, occupant comfort, and climate conditions	(Shohet and Nobili, 2017)
		End-user satisfaction (D115)	The level of satisfaction that end-users obtain from the maintenance service	Parida and Chattopadhyay,2007 , Reichelt, Melnikas, & Vilutiene, 2008 and Lin, Ali, & Bin Alias,2015
D12	**Environmental and Social Impact of the Built asset**	Impact of the Built Asset on the environment (D121)	Presence of hazardous materials, site contamination, or consumption of non-renewable resources	Kim, Sunitiyoso, & Medal,2019, (Queensland Government, 2017)
		Environmental Friendliness of the Built asset (D122)	Measures the built asset sustainability and marketing terms referring to goods and services, laws, guidelines, and policies that claim reduced, minimal, or no harm to ecosystems or the environment	Tan et al. (2014) and Tucker et al. (2014)
		The social significance of the built asset(D123)	The significance of the building asset in terms of cultural heritage significance, community attachment, or other government priorities	(Queensland Government,2017)

The maturity Rating Dimension for the present study includes twelve (12) dimensions to capture all requirements and indicators of maintenance management performances. The dimensions include:

1. Maintenance Policy and Strategy

The maintenance policy is usually not defined explicitly in companies such as it is in the quality area (in the quality area due to the certification of the quality management system it is defined clearly). Policy defines intention, direction, and aims. If there no clear policy and is not defined explicitly, there is no clear aim to be pursued by the organization (Oliveira and Lopes, 2020)

Cholasuke et al. (2004), in their research in the British industries, proposed a category of Classification in which the maintenance policy should be derived from the business strategy of the company or the organization's business goal and strategy, a concept that is also held by some other researchers (Olarewanju,2015) and (Pas, 2008), in its assessment work of the state of maintenance in Swedish companies, noted that the lack of connection between the maintenance policy and the company's overall strategy may result in poor performance of the maintenance area. Robson et al. (2013) proposed a model that, from reading the external environment, directs the manufacturing strategy, which, in turn, is connected to and directs the maintenance strategy to derive the maintenance policy. The maintenance policy class of the model considers the role of maintenance perceived by the organization and the way of acting, leading to the achievement of predefined objectives in the area.

2. Human Resource Management

People are the most important maintenance resource; they will manage, plan, supervise and execute all maintenance practices. Many authors agree that effective maintenance of human resource management is one of the factors of a successful maintenance management program (Antony, 2004). This study considered the Competency of in house maintenance staff (Maletič et al., 2020 and ISO55000, 2014), Training programs for maintenance staff (Overachieve, 2019; Olarewanju, 2015; Misnanb and Mariah Awanga, 2012; Wireman, 1992) and Motivation and inspired team work of maintenance staff (Olarewanju, 2015; Cholasuke et al. 2004) as important indicators in measuring the maintenance maturity for human resource management.

3. Technical and Functional Appropriateness

This study tries to measure the technical and functional appropriateness of the built asset maturity dimension with indicators including Building asset Capacity, Building asset Functionality, Building asset Location, Building asset Condition, and Technical practicality of Building asset (Queensland government, 2017; Olarewanju,2015; Deniz Besiktepe et al.,2020; li, Kamaruzzaman, Sulaiman, & Peng,2010), (By, 2001) and (Horenbeek and Pintelon, 2014).

4. Maintenance Organization

In the building maintenance management context, this dimension refers to the organization of planned maintenance activities and the assignment of resources for its implementation. This dimension involves indicators including the organization of the Maintenance department, alignment of Maintenance with organizational objectives (Olanrewaju and Abdul-Aziz, 2015).

The efficiency of the maintenance process and work instructions as stated in (Johannes, Koos, et al., 2021; Olanrewaju and Abdul-Aziz, 2015) and the organizational position of the maintenance department (Olanrewaju and Abdul-Aziz, 2015).

5. Information Management

The successful maintenance practice depends a great deal on effective information management. It is about managing all maintenance-related data, which includes collecting, analyzing, and transforming data into information to provide the report and feedback to the appropriate function (Antony, 2004).

Improving building maintenance operations requires many supportive facilities for both management and technology aspects. How to successfully capture this information in information technology is a research trend at the time of this study. This will help maintenance teams learn from previous experience and trace the full history of a building element and all affected elements by previous maintenance operations.

Geographical information systems (GIS), computer-aided design (CAD) systems, and relational database management systems provide accurate pictures of the extent of an asset management portfolio (By, 2001).

Information management refers to the sound registration of data as a basic pillar of asset management. Complete, accurate, and valid data on assets and processes stored in adequate data systems are vital for measuring and comparing network performances, agreements on service levels, and budget allocation (Volker, 2013).

The completeness, accuracy, and validity of built asset data, built asset registry, and asset history of enhancing asset knowledge, use of Maintenance information management system (as-built documentation), and use of data Capturing Technologies from existing built assets are the most important indicators to measure maintenance maturity for information management.

6. Building Design Life

This maintenance management maturity perspective/dimension ensures the safety and well being of humans. These can be measured in four categories: Modernization plan of the Built asset, ensuring the built asset functions during Building remaining Life (achieving its design life), ensuring built asset and environmental safety, and ensuring cost-effectiveness (Capital replacement modeling, deciding when to disposal plan of the built asset).

7. Maintenance Budget/Financial Perspective

The main objective of maintenance is to achieve the agreed-built asset performance at the minimum maintenance cost (Antony, 2004). The fifinancial control includes controlling the maintenance budget, contractor cost monitoring, and overall labor and material cost control. An organization with excellent maintenance management will have lower variation between maintenance budget and maintenance cost, and the variance of maintenance cost should be investigated.

This study includes the indicators like operating cost (Shohet and Nobili, 2017; Parida and Chattopadhyay, 2007; Reichelt, Melnikas, &Vilutiene, 2008; Cholasuke et al.; 2004), annual Maintenance Cost (Queensland Government, 2017; Olanrewaju and Abdul-Aziz, 2015), differed Maintenance Cost, utilization of Maintenance budget (and information and Knowledge about maintenance cost Cholasuke et al.2004; Antony 2004) as the most important indicators to measure maintenance performance for maintenance budget or financial perspective.

8. Culture and Leadership

Asset management principles were positively received, and people generally supported the overall asset management objectives as sound and logical (Hermans, Volker, and Eisma, 2014). It helped them explain what funds were required to deliver a specific performance and risk level. An asset management training program is now broadly available, and specific courses are provided on reliability-centered maintenance, risk management, systems engineering, and life cycle costing. In some of the maturity models reviewed in this study, culture and leadership were set at the bottom of 'standard.' Although organizational reform and training were warmly accepted, it takes time for these practices to become firmly established. Indicators like awareness of people towards built asset management, top management Support, the attitude of employees, willingness of people to learn new methodologies and attend training, and values and beliefs towards maintenance as the most important indicators to measure culture and leadership in maintenance management (Misnanb & Awanga, 2012; Volker, 2013; Al-Omoush, 2020; Antil, 1991; Volker, 2013)

9. Materials Management

The survey of US plant maintenance performance in 1993 (Kirby, 2000) stated in (Antony, 2004) showed that the second-highest cost of maintenance is the cost of maintenance spare part inventory. Companies can save a significant amount of money through effective spare parts and materials management.

This study measures these dimensions with indicators including Maintenance Materials Inventory Management, Classification of Maintenance stock items, and Inventory management policy as stated in (Oliveira,2020; Antony, 2004; Cholasuke et al., 2004; Campbell and Reyes-Picknell,2006; Oliveira and Lopes, 2020; Chemweno et al.,2015; Horenbeek and Pintelon, 2014).

10. Risk Management

ISO 31000 (2018) defines risk as uncertainty's effect on objectives. Organizations of all types and sizes face external and internal factors and influences that make it uncertain whether they will achieve their objectives. Maintenance management is not different from these scenarios and is subjected to uncertain events and needs risk management.

This study measures risk management based on risk assessment strategies and objectives; the risk is embedded in all activities to improve performance, analysis of building failure, causes & effects to address risk, and statutory compliance risk based on (Volker, 2013; Oliveira and Lopes,2020; Flores-Colen et al., 2010 and Queensland government, 2017).

11. Performance Management

As stated in (Oliveira and Lopes, 2020), maintenance managers need a good track of performance on maintenance operations and results. They need to know the relationship between the input of the maintenance process and the outcome in terms of total contribution to manufacturing performance and strategic business objectives. As already discussed, there is currently a great emphasis on publicly funded infrastructures. According to (Turcker, 2014), organizations achieving value for money and the public sector must find ways of working more efficiently to provide improved services at lower costs. This can be achieved concerning public infrastructure maintenance by identifying repair requirements quickly and fixing them with short time possible.

Much literature shows that several authors emphasize that performance indicators used by the maintenance area should be aligned with organizational goals. Besides supporting the identification of improvement actions, performance indicators guide the behavior of people who seek to influence them. Therefore, good practices can be adopted if the indicators align with the objectives to be achieved and the maintenance policy. This study includes value for money maintenance efficiency indicator (Oliveira and Lopes, 2020), the physical state of the building measured by the building performance indicator (Shohet and Nobili, 2017), building Efficiency Index (Shohet and Nobili, 2017; Yau, 2012) and end-user satisfaction (Shohet and Nobili, 2017) as key performance indicators of built asset maintenance performance management.

12. Environmental and Social Impact of the Built asset

The rating of built asset maturity should also be made taking into consideration its environmental and social Impact on asset-related maintenance activities. This dimension can be evaluated based on the indicators such as; Impact of the Built Asset on the environment (Kim et al., 2019; Queensland government, 2017), environmental Friendliness of the Built asset (Tan et al., 2014; Tucker et al.,2014) and social significance of the built asset (Queensland Government,2017)

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Research Type

A research design is a procedure for collecting, analyzing, interpreting, and reporting data in research studies(Dinesh, 2014). Based on the purpose of the research area, there are three possible forms of research design: exploratory, descriptive, and explanatory(Yin, 2003). Descriptive research systematically describes a situation, problem, phenomenon, service, or program, provides information about, say, the living condition of a community, or describes attitudes towards an issue(Hoang, 2005)and (Kumar, 2011). Explanatory research attempts to clarify why and how there is a relationship between two aspects of a situation or phenomenon. This type of research attempts to explain, for example, why stressful living results in heart attacks; why a fertility decline follows a decline in mortality; or how the home environment affects children's level of academic achievement(Yin, 2003), (Hoang, 2005)and (Kumar, 2011). Also, from the viewpoint of the objectives of a study, it is called exploratory research. This is when a study is undertaken to either explore an area where little is known or investigate the possibilities of undertaking a particular research study. When a study is carried out to determine its feasibility, it is also called a feasibility study or a pilot study(Yin, 2003) and (Kumar, 2011). Hence, this study was conducted by mixing descriptive and explanatory research designs. This is mainly because descriptive study attempts to describe a situation, problem, phenomenon, service, or program systematically or provides information about or describes attitudes towards an issue.

In contrast, explanatory research attempts to clarify why and how there is a relationship between two aspects of a situation or phenomenon. To use the benefits of these different research designs, the study was conducted by both descriptive and explanatory research strategies based on the research objectives. Moreover, the Descriptive research strategy focuses on answering questions relating to "what" than the "why" of the research subject. But explanatory research strategy focuses on explaining the new patterns of phenomena and elaborating on the details of the research questions such as; what, why, and how.

3.2. Research Approach

Research approaches are plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation. There are two basic approaches to research; quantitative and qualitative; quantitative research is based on the measurement of quantity or amount (Kothari, 2004). It applies to phenomena that can be expressed in terms of quantity. Quantitative research enables a researcher to develop a framework within a confined space(Kumar, 2011). On the other hand, qualitative research is concerned with the qualitative phenomenon (Kothari, 2004) using an inductive style(Creswell, 2014). The qualitative approach allows flexibility, openness, and freedom to include any new ideas or exclude any aspect the researcher initially included, but later considered irrelevant (Kumar, 2011).

In general, qualitative research produces findings not arrived at through statistical procedures or other means of quantification. Qualitative data can be collected through interviews, focus groups, observation, or review of documents. On the other hand, quantitative research produces data that can be statistically analyzed and whose results can be expressed numerically. This research is mainly concerned with measuring phenomena in terms of quantity. Hence, this study mixed research approach was conducted based on a set of objectives and research questions.

3.3. Research strategy

There are numerous research strategies developed and used for descriptive, explanatory, and exploratory research. Some of these strategies fall under the deductive approach, while others are used for the inductive approach. Each research strategy has its certain advantages as well as disadvantages. The research strategy selection is based on the research questions and aims, the available time to conduct study, the extent of knowledge, the collection of data, the philosophical underpinning, and other available resources. Furthermore, these strategies are not mutually exclusive and do not ensure the exact answer to the research question. It is necessary to assess their advantages and disadvantages to formulate the best research strategies(Crossan, 2003).

As a result, both case study and survey research strategies are adopted based on the research questions, research objectives, the extent of knowledge, data collection, and philosophical underpinnings in this study.

3.3.1 Survey

Survey research is defined as collecting information from a sample of individuals through their responses to questions. Accordingly, to obtain information from people, it seems obvious that one should either question them face-to-face or conduct telephonic surveys or mail questionnaires (John et al., 2007). Collecting data through questioning is the main method used in what is known as survey research. Survey research is essentially an approach to data collection that involves collecting data from large numbers of respondents. This is the main distinguishing feature of survey research compared to many other types of research design that are primarily concerned with small numbers (Lancaster, 2005). Indeed, surveys are the most widely used method of data collection in business and management research(John et al., 2007). The survey method involves collecting information from a sample of the target population, selected based on systematic and representative sampling methods using a standardized questionnaire administered identically to all the target respondents in the sample population (Fellows and Liu, 2008). Survey research includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection to generalize from a sample to a population. Although it has limitations such as low response rates (for questionnaire surveys) and the risk of bias, this strategy offers the opportunity to explore a broad range of issues such as those envisaged in this research. Questionnaires are among the most widely used and valuable means of data collection. The range and types of questionnaires that can be used, their design, uses, and implementation can vary enormously, both from the point of view, for example, of the structure of the questionnaire, how it is administered, and methods of analysis and interpretation (Lancaster, 2005). The method is also appeared to be one of the commonly used method for assessing the factors that affect the practice of building maintenance management practices.

In this research, the survey research design was adopted for the three objectives in the quantitative phase to provide a quantitative description of survey participants' attitudes or opinions of survey participates s as suggested by (Ankrah, 2007).

3.3.2 Case study

As a research method or strategy, the case study brings us to question the very term "case": after all, what is a case? A case-based approach accords the case a central role in the research process(Welch et al., 2011). The case study strategy uses multiple sources of evidence to investigate a contemporary phenomenon. A particular phenomenon is tested within its real-life context. It is the opposite form the experimental techniques as the research is 123 undertaken within a non-controlled context(De Boer et al., 2014). A case study is a common research strategy involving an empirical investigation of a particular contemporary phenomenon in a real-life context(Robson and Rowe, 2012). A case study strategy is appropriate if a researcher wants to gain insight into the research processes and context. However, it is regarded as one of the challenging strategies in social science research(Yu, 2006). The positive point is that it helps in an in-depth study of the research topic. There are four types of case study strategy i.e., single case (one critical case), multiple cases (more than one case to generalize), holistic case (considering the whole system), and embedded case (study of several logical sub-units) (Crossan, 2003). Hence, based on the above discussion in this study, the case study research strategy was adopted to address the first and third objectives.

3.3.3 DEMATEL Method

Decision-making can be regarded as the cognitive process resulting in the selection of a belief or a course of action among several alternative possibilities. It is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Multi-criteria. Multi-criteria decision making (MCDM) is the process of finding the best alternative from all of the feasible alternatives where all the alternatives can be evaluated according to a number of criteria or attribute(Rajini, 2017). Based on type of decision problem, decision making is divided into two types of single criterion and multi criteria decision making. Based on the number of criteria, MCDM classified into two types namely Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM). MADM techniques partially or completely rank the alternatives: a single most preferred alternative can be identified or a short list of limited number of alternatives can be selected(Gade and Osuri, 2014). The goal of MCDM is to help the decision maker (DM) to make a choice among a finite number of alternatives or to sort or rank a finite set of alternatives in terms of multiple criteria. The widely used MCDM methods are Analytic Hierarchy Process (AHP) (Rajini, 2017). However, in ANP procedures, using average method (equal cluster-weighted) to obtain the weighted supermatrix seems to be irrational because there are different degrees of influence among the criteria. Therefore, we intended to propose an integrated multiple criteria decision making (MCDM) techniques which combined with the decision making trial and evaluation laboratory (DEMATEL)(Zavadskas et al., 2018).

Maturity models are widely used to develop and improve organizational capabilities by assessing maturity, identified as "competency, capability, level of sophistication" (Rosemann and De Bruin, 2005). It would be impractical to include all the dimensions identified from the literature as an equal measurement dimension in the progression model to assess and identify the maintenance management performance measurement dimension. To select the most significant performance measurement dimensions from the literature, the DEMATEL MCDM method is employed by integrating with Fuzzy logic to avoid the vague inter-dependency relationships between criteria by experts.

Decision making trial and evaluation laboratory (DEMATEL) technique was first developed by the Geneva Research Centre of the Battelle Memorial Institute to visualize the structure of complicated causal relationships through matrices or digraphs (Si *et al.*, 2018) and (Chang, Chang, and Wu, 2011). Since then, it has been widely accepted as one of the best tools to solve the cause and effect relationship among the evaluation criteria(Sumrit and Anuntavoranich, 2012). It is an extended method for building and analyzing a structural model for analyzing the influence relation among complex criteria. However, making decisions is very difficult in the fuzzy environment to segment complex factors (Chang, Chang, and Wu, 2011). Hence, many researchers applied the concept of fuzzy sets to the DEMATEL method. A review of the literature reveals several extensions of DEMATEL for dealing with various sources of uncertainty (Asan *et al.*, 2018). A study by (Si *et al.*, 2018) on applying the DEMATEL method considering 346 publications indicates that fuzzy is the second most widely applied method in combination with DEMATEL following the analytical network process (ANP).

Like many other typical multi-criteria decision-making (MCDM) methods, DEMATEL requires decision-makers (DMs) to provide assessments against criteria using assessment scales. The five-level assessment scale was developed by Gabus and Fontela (1973), in which 0 represents no influence, 1 for low influence, 2 for medium influence, 3 for strong influence, and 4 for very strong influence (Abdullah *et al.*, 2019). Moreover, Being first introduced by Zadeh, the fuzzy-based technique has been widely adopted and used in many practices, particularly for decision-making problems and philosophical evaluation issues (Zhou *et al.*, 2018). Fuzzy theory introduces the concept of membership function to deal with different linguistic variables (Chang, Chang, and Wu, 2011). A certain degree of fuzziness exists in people's thoughts, inferences, and perceptions. The theory aims to solve uncertain or fuzzy data in the environment. Unlike traditional Boolean logic, which defines whether or not an element belongs to a crisp set (1 or 0), a fuzzy set defines a degree of belonging by a membership function. The fuzzy set theory is a way of expressing uncertain or imprecise spatial data. Fuzzy set theory deals with sources of uncertainty or imprecision that are vague and non-statistical (Chang, Chang, and Wu, 2011). The fuzzy set theory is closely linked to classical logic, but it is difficult to determine how to assign membership (Chang, Chang, and Wu, 2011). Zadeh proposed the fuzzy set theory and introduced the concept of membership function cited in (Chang, Chang, and Wu, 2011). Hence, in this study Fuzzy -DEMATEL was adopted to address the third specific objective of this research.

3.4. Sampling Techniques

Sampling is one of the most important factors determining a study's accuracy. So, there are several different sampling techniques available, and they can be subdivided into two groups: probability sampling and non-probability sampling. Accordingly(Kumar, 2011) stated that the accuracy of research findings largely depends on how a sample is selected. The basic objective of a sampling design is to minimize, within the limitation of cost, the gap between the values obtained from the sample and those prevalent in a study population. Therefore, Sampling is a procedure to select a sample from an individual or a large group of the population for a certain kind of research purpose(Bhardwaj, 2019).

The population of this study is assumed to be all university building facilities found in Ethiopia. For objectives one and two, the study adopts a systematic random sampling technique for the quantitative approach and purposive sampling for qualitative approaches by which viable data can be obtained from a specific group of people, as argued by (Grisham and Fellows, 2008) and to conduct a content analysis of cases in the qualitative approach (Djamba and Neuman, 2002). In purposive sampling, the members for a sample are selected according to the study's purpose. It is also called purposeful sampling. It is also called judgmental sampling(Bhardwaj, 2019). The purposive sampling method is criticized for its bias and absence of randomization while collecting data. However, this error can be eliminated by choosing an appropriate data source from the most reliable professionals, as stated in (Djamba and Neuman, 2002). Hence, this study focused on achieving the criteria by collecting data from university presidents, vice presidents, professors, facility maintenance managers, and university construction projects coordination officers who are highly involved with university facilities management to acquire reliable and high-quality information. For objective three, focus group discussion will be performed, taking participants from professionals who have high attachment with university project construction (consultants and construction firms), university facility managers, maintenance managers, individuals from the Ministry of Education and academia who are involved in teaching and research activities in Ethiopia. Purposive sampling will be employed to include samples from every group to allow individuals who are highly related to the research objectives.

Purposive sampling is desirable when known characteristics are to be studied intensively (Kothari, 2004) and enables the researcher to select the data source that provides the best information to achieve the study's objectives (Kumar, 2011). However, different sampling methods will be employed to select a participant from each university based on the nature of the specific research objectives, data availability, and access which will be decided later.

3.5. Method of Data Collection

Data collection is collecting information from all the relevant sources to find answers to the research problem, test the hypothesis and evaluate the outcomes. Data collection methods can be divided into two categories: secondary methods of data collection and primary methods of data collection(Kumar, 2011). Moreover, the data collection design planned the method of gathering or collecting the data. There are many types of collecting data. The two types of collecting data are primary and Secondary data(Patel and Patel, 2019).

- **Primary Data:** It gathers by the investigator's direct observation of relevant people, actions, and situations without asking the respondent(Hoang, 2005) and (Darwish et al., 2017). Therefore, Primary data for this study was collected from industry practitioners and different university facility/property managers using surveys, Observations, interviews, and Focus Groups discussions.
- **Secondary Data:** The secondary data can be collected from technical publications such as manuals, handbooks, datasheets, standards, books and journals, official publications of the Central government, state governments, local bodies, private data services, and computer databases (Darwish et al., 2017) and(Patel and Patel, 2019). Therefore, Secondary data for this study was collected from Literature, records, reports, and Databases will be used as a source of secondary data for this research.

3.5.1 Questionnaire

A questionnaire is a predominant instrument for survey-based studies. So, the questionnaire is a series of questions asked to individuals to obtain statistically useful information about a given topic. When properly constructed and responsibly administered, questionnaires become a vital instrument by which statements can be made about specific groups of people or entire populations. They are a valuable method of collecting a wide range of information from many individuals, often referred to as respondents(Roopa and Rani, 2012). Moreover, Survey methodologies, usually using questionnaires, are among the most popular in the social sciences(Young, 2015). Hence , in this study, a questionnaire was used as a research instrument to collect data to achieve the first and the second objectives.

3.5.2 Interview

Interviews are also a major category of collecting data through questioning and are acknowledged as some of the most effective ways of collecting data in social sciences studies (Lancaster, 2005). Face-to-face or telephone interviews are frequently used in business and management research (John et al., 2007). It allows a mass of information to be collected but is very time-consuming, and sample sizes tend to be small. Thus, although one obtains in-depth information, one may question the representativeness of the findings. One of the benefits of using an interview is that there are no strict requirements for a statistical sample in the same way as for a questionnaire-based survey (Flanagan *et al.*, 2005), Cited in (Tadesse,2019). Hence, in this study, the interview was used as a research instrument to collect data to achieve the first objective. Also used to apply and validate the third objective.

3.5.3 Focus Group Discussion

Introduced by a sociologist, Merton, in 1956, the focus group has long been one of the widest research methods (Chan et al., 2012). A Focus group refers to a controlled group discussion that intends to obtain perceptions on specific topics in a defined environment (Leung et al., 2013). A focus group has a group dynamic and brings several benefits to the gathering of data, including a synergistic group effect that stimulates discussion, with each participant reacting to or being inspired by the comments of the others; efficient use of time; actual content generated from the discussion; observation by the mediator/ researcher in a natural setting; and less mediator bias (Liang et al., 2018). It is an experimental technique that involves collecting data through a dynamic and interactive group discussion led by a moderator (the researcher)(Chan et al., 2012). Through focus group discussions, participants' perceptions, feelings, and experiences are interwoven and stimulated to widen the range of opinions on specific topics and avoid individual bias drawbacks(Leung et al., 2013). Hence, focus groups emphasize results originating from the interactive group discussion among representative participants rather than from individuals within a group. Unlike the personal interview, the focus group provides a natural and comfortable atmosphere where the participants can discuss sensitive issues with others who had similar experiences(Chan et al., 2012). Hence, focus groups emphasize results originating from the interactive group discussion among representative participants rather than individuals within a group(Leung et al., 2013).

A focus group comprises target participants with a moderator(s); it can have two (dyad), three (triad), four to six (mini-group), 7–10 (small group), or 11–20 participants (super-group) (Chan et al., 2012). However, a small group is usually adopted for research that seeks to understand participants' deep feelings (Chan et al., 2012).

Table 3. 1: Participants involved in the focus group discussion

S.No	Position	Experience (Year)	Maximum academic achievement	Educational Background	Organization
1	General Manager	15	PhD degree	Civil Engineer	Electro-Mechanical and Academics
2	General Manager	15	Master's Degree	Construction management	Consultant
3	General Manger	20	Master's Degree	Construction management	Contractor
4	Department Manager	23	Master's Degree	Structural Engineering	Consultant
5	Program director	22	Master's Degree	Civil Engineer	Client
6	Department Manager	16	Master's Degree	Construction Management	Client
7	Facility Manager	30	BA Degree	Business Management	University
8	Facility management	13	MSc Degree	Mechanical Engineering	University
9	Lecturer	5	Master's Degree	Construction Management	University
10	Lecturer	13	Master's Degree	Construction Management	Academics
11	Lecturer	18	PhD Candidate	Civil Engineer	Academics and contractor
12	Lecturer	18	Ph.D. Candidate	Architect	Academics and consultant

As recommended by many researchers, for the current study, an optimal mini-to-small group size of 5–10 participants was used to maintain a balance between depth and breadth in the discussion (Chan et al., 2012)(Chan, Leung, and Yu, 2012). Hence, in this study, Focus Group Discussion was used as a research instrument to collect data to achieve the third objective.

3.6. Method of Data Analysis

Data analysis involves separating research components to produce research findings, which must be valid, reliable, and generalizable. Data analysis allows the study of complex things by identifying their basic elements. The first research objective is to assess the current level of building maintenance practice in public universities in Ethiopia. This requires understanding what FM means, how it is developed, and what strategy is required to establish the challenges in context. With this knowledge, a study of a survey process was carried out. So that to address the first objective, both quantitative and qualitative (to some extent) data analysis was conducted. The second research objective is to assess the critical factors affecting the proper practice of building maintenance management. For this research objective, quantitative and qualitative (to some extent) data analysis was conducted. The factors found in the secondary objectives were used as an input for the new model to be developed. The third research question is intended to develop a maturity model based on the extensive literature review on maintenance management maturity models and the finding of the third research objectives to develop measurement dimensions or perspectives to be included as a tool in assessing the level of maintenance management maturity and the evolutionary requirement to advanced levels.

Moreover, in this study, the knowledge gained from the literature was organized to collect relevant data from concerned bodies in the industry and academia using survey and focus group discussions and structured interviews. Based on the findings from the three questions, a tailored maintenance management maturity model and conceptual framework for policy making proposed helps to gradually shift the current practice to the next advanced levels in a planned way. Quantitative data were analyzed using Microsoft excel 2019 and Dematel software.

3.7. Research Framework

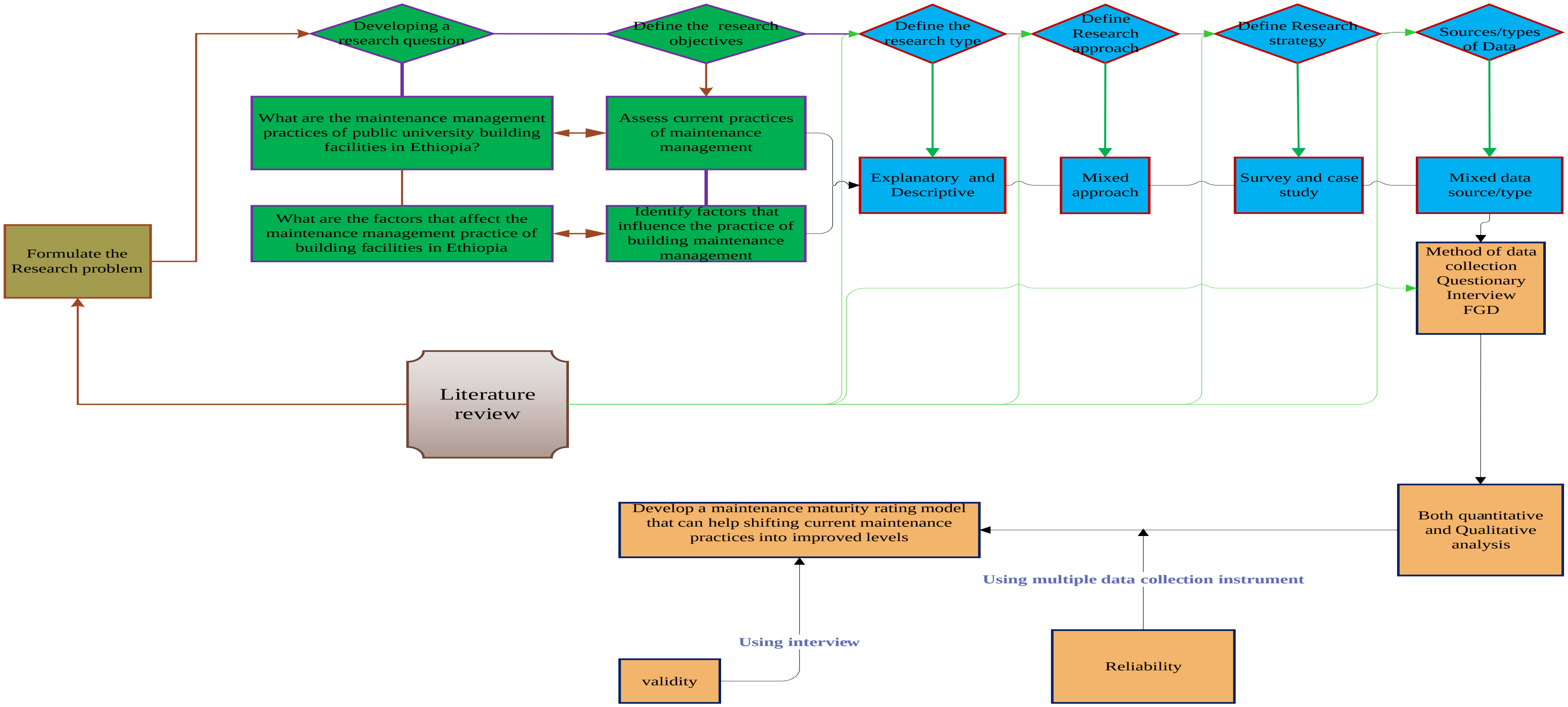


Figure 3- 1: Research Framework

CHAPTER FOUR: RESULT AND DISCUSSION

This section describes the analysis of the three main objectives addressed in this study. The first subsection covers the current maintenance management practices of public university building facilities in Ethiopia. The second part of the analysis explores the factors that influence the practice of building maintenance management. The third part describes developing a building maintenance maturity rating model that can help shift current maintenance practices to improved levels.

4.1. Current practices of maintenance management of public university building facilities in Ethiopia

Reliability: The reliability of the questionnaire was tested using Cronbach's α coefficient. Several studies have confirmed that the value of alpha α is acceptable for internal consistency if it falls between 0.71 and 0.99 (Islam, Nazifa, and Mohamed, 2019) and (Taber, 2018). Conforming to Taber (2018), if the α value is > 0.9, the internal consistency is excellent, and if it is at least > 0.7, the internal consistency is acceptable.

The alpha (α) value is calculated to test the scale's internal consistency. In this study, the α value for the factors influencing the successful practice of facility Maintenance was 0.894, which showed the strong internal consistency of the scale used and suggest reliable data have been obtained.

Data analysis tools. The collected data by the questionnaires were analyzed using the Statistical Package for Social Science (SPSS, version 16).

Validity: Measures used in this research were based on previous studies on similar topics to ensure their content validity. Additionally, the questionnaire was revised and modified by three experts. All the experts have more than ten years of academic and industry experience in the construction industry. The feedback and reflection obtained from the experts were considered, and the necessary adjustment was made. As per the expert recommendation, the improvement strategies was included in the final part of the questionnaire. (Five FM practice improvement strategies were included in the instrument)

Sample Characteristics

In public university administration in Ethiopia, university presidents, vice presidents, and academic staff or professors play a significant role in planning, managing, and using university facilities.

From the respondents' background depicted below in Table 4.1, 50 % of the respondents are lecturers (university professors who may have been active in facility-related activities and had expertise managing maintenance or who may have had difficulty utilizing current facilities as an end-user). 19.1% of the respondents are Vice presidents who are the strategic level (FM managers), (11.8%), Construction project managers involved in the management of university facilities during planning and construction (10.3%) are either FM or Maintenance managers directly involved in FM activities, and students (8%). Moreover; (34.70%) of the respondents have an engineering background by profession. The level of academic achievement and experience would be a metric in an online survey to measure the respondents' capability, skill, and level of knowledge. Regarding their academic qualification, 13.3% were full professors or associates, 36 % have a Ph.D., and 44 % have master's degree. The respondents' work experience in the university is another index to measure their level of knowledge and, hence, the data's reliability. Information regarding their experience shows (Table 1) that about 56% had more than ten years of experience managing or using university facilities.

Out of 207 distributed survey questions to respondents, 76 responses were received, providing a response rate of 36.71 %. Out of 76 respondents, only one response was rejected due to an incomplete response. All questions were fully answered, and there were no ambiguous responses. As stated in (Tan et al., 2014), a 10%–20% response rate is acceptable in a research survey. However, the response rate of this survey is pretty much above the minimum threshold. Table 4.1 presents a detailed background of the respondents' demographic information.

Table 4. 1: Demographic information of respondents

Characteristics	Category	Number of Respondents	% of Response
Role in the University	University Lecturers	34	50.0
	University Vice president	13	19.1
	Construction Project Coordinator	8	11.8
	Facility/Maintenance managers	7	10.3
	Students	6	8.8
Academic qualification	Professor	3	4.0
	Associate Professor	7	9.3
	Assistant Professor	27	36.0
	Lecturers	33	44.0
	Others	5	6.7
Profession	Engineering (Civil, Electrical, and Mechanical)	26	34.7
	Others	49	65.3
Year of Experience in Managing or using University Facility	< 5	6	8
	5-10	15	20
	10-15	42	56
	15-20	9	12
	> 20	3	4

Representativeness of the respondents from Ethiopian public universities

The questionnaire link was sent to presidents, vice presidents, Facility managers, and purposely selected staff from all public universities in Ethiopia. At least one response was collected from 26 universities, accounting for over 50% of the total number of public universities in Ethiopia and representing all universities. As shown in figure 4.1 below, more respondents were obtained from AAU (9), MU (7), and BDU (6), which are representatives from first-generation universities where more senior staffs are found.

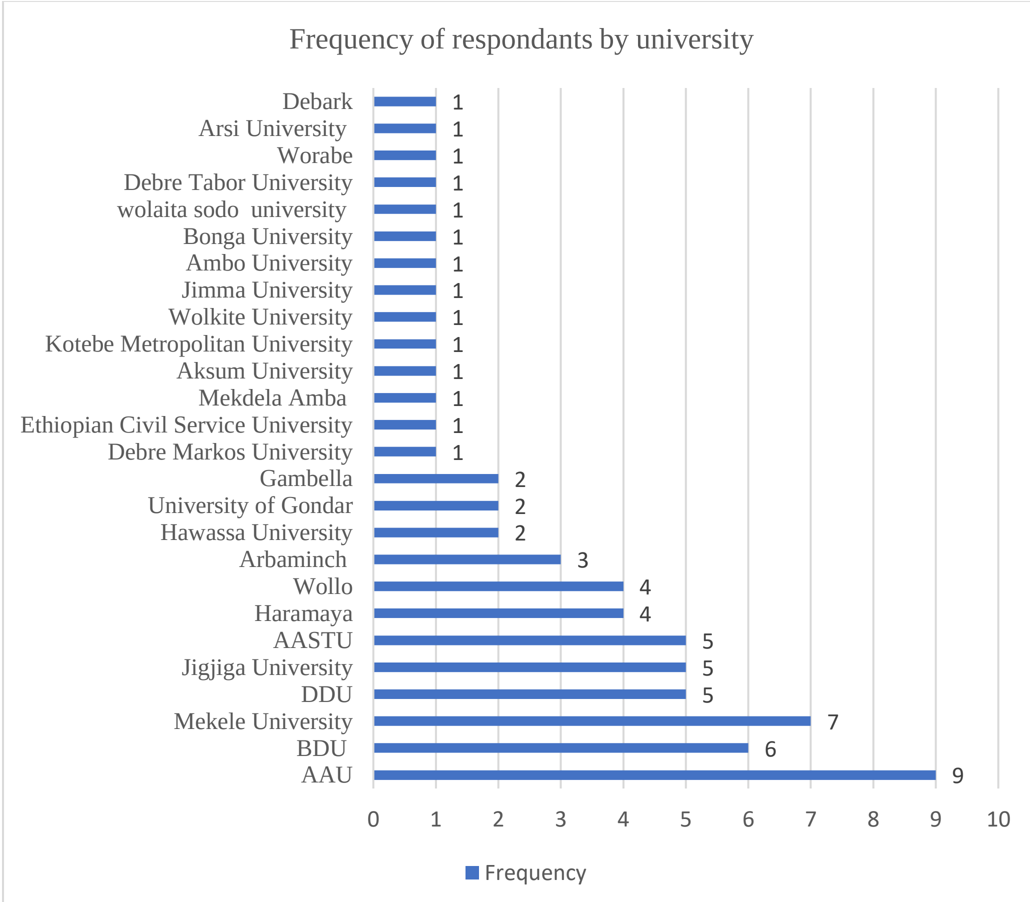


Figure 4. 1 Number of Respondents by their University

Strategic consideration in facilities Maintenance

According to the the analysis, 70.6 % of respondents agreed that the issue of FM is addressed in the main strategic plan of public universities. The reality, however, is very different from the survey's analytical result and the interview results can be used to justify the discrepancy. Respondents were also asked for their thoughts on how the Maintenance Management plan aligns with the university's overall strategic plan. About 62.66 % of the respondents agree that maintenance activity is guided by the university's strategic plan. Furthermore, 86.66 % agree that FM department operations should play an important role in fulfilling the university's core business. Despite this, 73.33 % of respondents reported that there are building defects owing to incorrect maintenance or no maintenance operations done physically on facilities in Ethiopian public universities, as evidenced by the real states of structures on the ground.

Availability of Building Maintenance policy in the university

Only 36% of the respondents believed in the existence of a maintenance policy in the university. The rest, 64% of the respondents, responded that no maintenance policy is applicable for maintenance operations in public universities. Moreover, all the six interviewees also confirmed the lack of policy is one of the key determinants of good maintenance practices. The maintenance policy is usually not defined explicitly in companies such as it is in the quality (Oliveira and Lopes, 2020).

Organizational Management level of Facility management

The management position and capability of the Maintenance department or directorate impact establishing appropriate policy and preparing an integrated plan within the university's main strategies. However, only 22% of maintenance managers are at a strategic level, 50% at the tactical level, and 23% at the operational level, which indicates that less concern is given to building facility management with a limited decision-making capacity, especially at the tactical and operational level. Many authors agree that effective maintenance of human resource management is one of the factors of a successful maintenance management program (Antony, 2004).

Maintenance strategy or approach in use by public universities

For an efficient maintenance Management process, a preventive approach is preferred over corrective maintenance, where corrective maintenance has to complement preventive maintenance. However, 74.65% of the respondents indicated that public universities are practicing only corrective maintenance strategies, resulting in unplanned expenditures for unplanned maintenance activities(Lee and Scott, 2009) and (Brooks, 2015).

Maintenance Procurement strategy in public universities

The procurement strategy is another determinant of proper maintenance practice. Accordingly, the study has tried to identify the maintenance strategy used by most public universities. However, the result indicated the existence of a mixed approach, which is 27 % in-house and 45.97%.

Respondents were requested the availability of FMM information during the operation and maintenance stages of facilities. Accordingly, most of the respondents (78.35%) indicated the difficulty of getting FM-related information for Maintenance operations in public universities in Ethiopia.

Building Defects in public university buildings

The poor practice of building maintenance management can be verified by the number and availability of unrectified building and facilities defects in Ethiopia's asset portfolio of public universities. Respondents were asked to rate how buildings are free from defects and convenient for the core business of universities. Accordingly, 73.33 % of the respondents agree that there are several unrectified building defects indicating poor building maintenance practices in public buildings in Ethiopia.

Facilities or Building components that require frequent maintenance

Respondents were asked to indicate the facilities or building components that require more frequent maintenance. According to tier response Sewerage lines, water supply lines, and fixtures account for 49.33 %, and electrical lines and fixtures account for 30.67 %. Which indicates that service lines' construction quality and maintenance operation made on these components is doubtful. The result is also in compliance with the observation made for selected case university facilities in Addis Ababa as can be seen in figure 4.2 to 4.6.

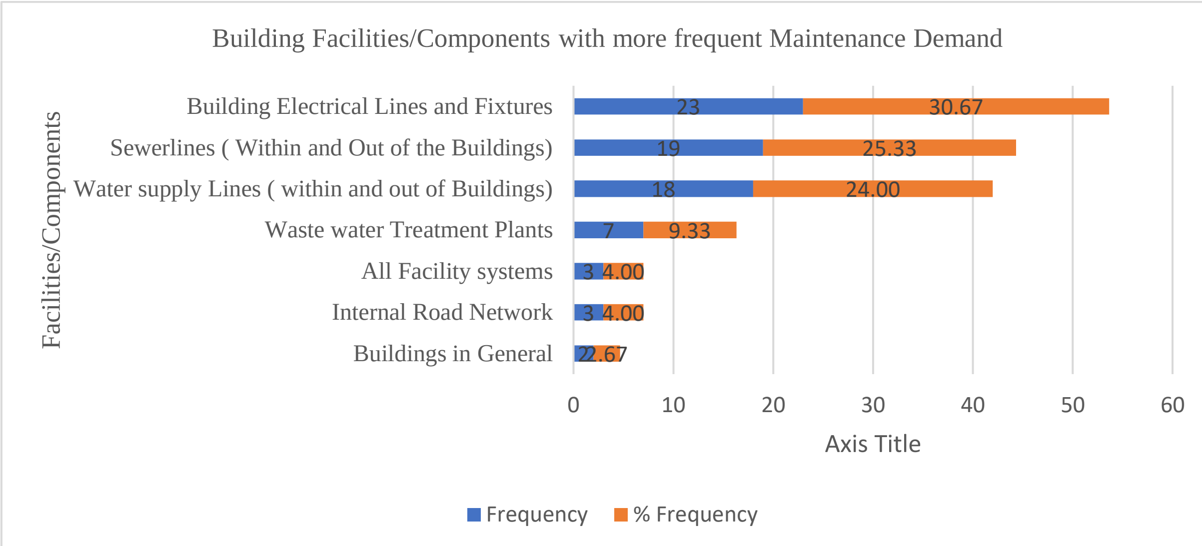


Figure 4.2: Building Facilities/Components with more frequent Maintenance Demand

 Figure 4. 3: Photo showing external electrical installation	 Figure 4.4 photos showing defects due to leakages

Photo taken from case area sites by the author

Figure 4.5: Photo showing defects on the external facade

Figure 4. 6 Photos showing defective/poor electrical connection

Figure 4.7: Photo showing external data and electrical lines

Photo taken from case area sites by the author

Availability of data, documents, and manuals required for maintenance operations

This research has also evaluated the availability of maintenance manuals, drawings, and data needed for maintenance activities. As a result, the analysis of the questionnaire survey, Addis Abeba case studies, and face-to-face interviews showed a key difficulty in the loss of data transferring and information from developer to owner during project handover. According to the results of the questionnaire survey, 78.38 % of respondents agreed that there is a lack of information and an acceptable file management system (the filing system is mostly traditional). This is one of the most pressing issues confronting maintenance departments in Ethiopia's public universities. During the face-to-face interview and site observation, the outcome is validated. Furthermore, in public universities, there is a lack of organized maintenance information management systems. This was also indicated by 72.0% of the respondents affirmation.

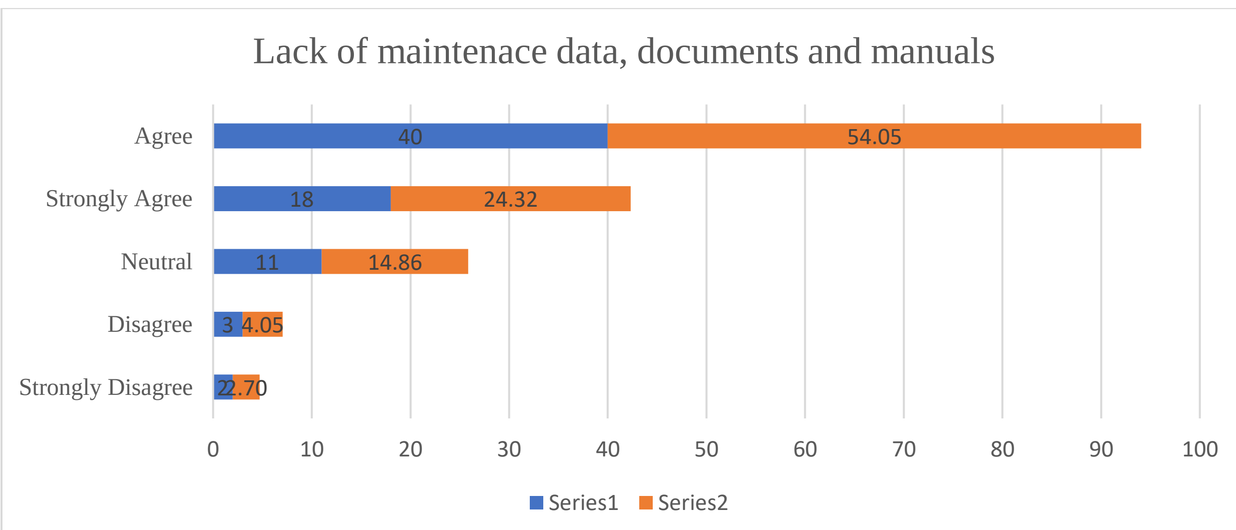


Figure 4. 8: respondent's agreement on the lack of maintenance data, documents, and manuals

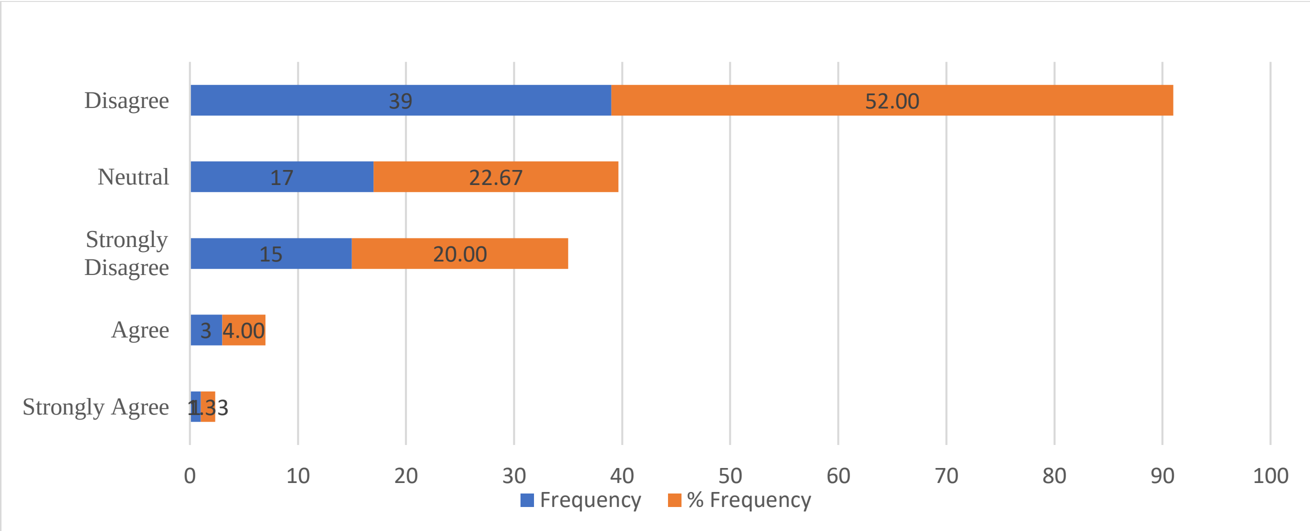


Figure 4.9: agreement of the existence of an organized maintenance information management system

4.2.Critical factors affecting the practice of Building Maintenance Management

This section describes the most critical factors that influence the proper practice of Facilities Maintenance in public universities in Ethiopia. The mean and SD for each factor were calculated, followed by a ranked order analysis using the RII value (equation 1). When two or more factors have the same RII value, the SD values are compared, and the lower SD is considered, the higher rank. If the RII value and SD are both the same, they were assigned to the same rank as argued in Tan et al. (2014) and Islam et al. (2019) for similar studies.

The RII was derived from summarizing the importance of each critical factor that influences the practice of facility maintenance management in public universities of Ethiopia.

$$\mathrm{RII} = \frac{\sum w}{AN} = \frac{5n_5+4n_4+3n_3+2n_2+1n_1}{5N} \qquad \text{Equation 4. 1}$$

Where, W = weighting as assigned on Likert's scale by each respondent in a range from 1 to 5, where 1 = strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = strongly Agree. N =Total number in the sample.

Table 4.2: Critical factors that influence the practice of FMM practices

Serial		Critical Factor	Mean	SD	N	RII	Rank
1	Statutory (SRF)	Lack of building maintenance standards, policy, codes, Strategy and procedure	4.133	0.9772	75	0.827	9
2		The method of awarding maintenance contracts	3.493	0.9778	75	0.699	32
3		Unavailability of Specialized Maintenance contractors	3.880	1.0522	75	0.776	23
4		Unavailability of FM or Maintenance productivity standards and specification	4.093	0.9469	75	0.819	14
5	Design (DRF)	Error in Design	3.733	0.9910	75	0.747	26
6		Construction materials quality, specification and selection	4.120	0.9720	75	0.824	13
7		Failure to consider life cycle costing analysis	4.147	0.8806	75	0.829	8
8		Non-involvement of Maintenance/FM professionals during design phase	3.676	1.1599	75	0.746	27
9		Inefficient Architectural and or/Structural design	3.667	0.9202	75	0.733	28
10		Design Complexity	2.667	0.9910	75	0.533	33
11		Inadequate experience of Design Professionals	3.520	0.9913	75	0.704	30
12	Construction (CRF)	Poor Construction Quality	4.240	0.8194	75	0.848	5
13		Lack of Communication and Collaboration skill	3.987	0.8620	75	0.797	19
14		Faulty/Poor workmanship quality during construction	4.067	0.8751	75	0.813	17
15		Unavailability and/or poor quality of replacement parts & components	3.905	0.9955	75	0.792	20
16		Lack of coordination between construction & maintenance groups	4.173	0.8601	75	0.835	6
17		Inaccuracy of as-Built Drawings	3.773	0.9942	75	0.755	25
18	Maintenance Management (MMDF)	Lack of preventive maintenance method	4.467	0.6844	75	0.893	1
19		Lack of Maintenance Plans & Schedules	4.400	0.6576	75	0.880	2
20		Inadequate training to Maintenance personnel	4.160	0.8227	75	0.832	7
21		Unavailability and lack of skilled and appointed maintenance staff	3.867	1.0569	75	0.773	24
22	Maintenance Budget (MBRF)	Insufficient/ Unavailability of Budget for Maintenance of buildings	3.667	1.1663	75	0.733	29
23		Failure to forecast the accurate maintenance expenditures	4.133	0.9633	75	0.827	10
24		Difficulty in procurement of spare parts/ Procurement rules, regulations	3.947	1.0253	75	0.789	21
25	Maintenance Team Operations (MTOF)	Low concern of future maintenance of existing maintenance team	4.014	0.6971	75	0.825	11
26		Poor maintenance work done by the maintenance unit of the institution	4.068	0.7822	75	0.824	12
27		Poor work rectification done on buildings.	4.067	0.7769	75	0.813	18
28		Lack of Building Maintenance manual	4.093	0.9325	75	0.819	15
29		Lack of as built documentation/Database of maintenance works	4.307	0.8378	75	0.861	3
30	Community Culture, Growth and learning (CCGLF)	Lack of effective Maintenance culture	4.280	0.8631	75	0.856	4
31		Misuse of facilities by occupants /attitude of users	4.093	0.8570	75	0.819	16
32		Delay in occupancy after completion	3.507	1.0827	75	0.701	31
33		Underestimating the impact of FM	3.893	1.1098	75	0.779	22

Note: Bold values highlights the top most Eighteen RII values and ranking, with a mean value >4.0

As indicated in 4.2, the respondents ranked lack of preventive Maintenance method (mean =4.47) as the most critical factor that affect maintenance practices often caused by the absence of appropriate maintenance strategy or approach, which indicated that university maintenance operations are not led by proper strategy. This factor was also the most critical, as confirmed by Talib et al. (2014) and Jendali & Sweiss (2018) in Malaysia and Jordan.

The lack of preventive maintenance methods affects maintenance operations' entire process and practice as the maintenance staff is highly engaged in unplanned day-to-day operations.

The lack of preventive maintenance methods affects maintenance operations' entire process and practice as the maintenance staff are highly engaged in unplanned day-to-day operations.

It can be seen from the data in Table 4.2 that lack of maintenance and schedules is the second most influential factor impacting the practice of facility maintenance management (mean 4.40, RII=0.88). The result indicates that proper maintenance planning and scheduling are identified as non-existent in public universities in Ethiopia, which is in congruence with the findings of previous studies Malaysia (Islam, Nazifa, and Mohamed, 2019), whereby the lack of a maintenance management plan and the schedule was attributed to causing high maintenance budgets which ultimately resulted in high cost of maintenance operations.

The third top-ranked critical factor is the lack of as-built documentation and the unavailability of the database for maintenance activities (mean = 4.47, RII value 0.861), table 4.2. The outdated traditional filing system and lack of maintenance activities are critical challenges (Mkilania, 2016) in public institutes in a similar context.

The community culture, learning, and growth that arise from the community’s learning, cultural background of facility users hinder the proper practice of FMM in public universities. Lack of effective maintenance culture has affected maintenance practices (Mkilania, 2016; Akinsola et al., 2012) and are critical challenge in developing countries like Tanzania and Nigeria.

The survey result shows that poor construction quality is one of the most influencing factors (5th), with an RII of 0.848 (Table 4.2). This value also indicates that how construction stage supervision (Ajetomobi and Olanrewaju, 2015), poor quality components (Ajayi, 2014), and poor craft quality Jandali & sweis (2018) are highly associated with the quality management system used during the construction stage can significantly affect maintenance operations. Moreover, design stage factors such as failure to consider life cycle cost analysis and non-involvement of FM professionals during design and construction stages can attribute to poor construction quality.

Lack of coordination and communication between construction and maintenance groups is ranked in the 6th, (mean= 4.17 & RII=0.835), (Table 4.2) is also considered a more influencing factor in FMM practices of public universities in Ethiopia. This result agree with the findings of Hassanain et al. (2013) in Soudi Arabia and Jandali & Sweis (2018) in Jordan. Efficient use of recent developments in information management, including building information modeling, can improve the coordination and communication gap amongst involved stakeholders in the construction and maintenance stages (Moreno, Olbina, and Issa, 2019).

4.3.Development of Building Maintenance Maturity model

The CMM originates from the quality management maturity grid (QMMG) proposed by Crosby (1980). The grid defines five maturity levels contrasted against several dimensions. As stated in (Chemweno et al. 2015), maturity implies "the evolutionary progress in demonstrating the specific ability or accomplishment of a target from an initial stage to a final desired stage" (Chemweno et al. 2015). Dimensions refer to important process areas the organization emphasizes, e.g., asset performance. A typical maturity model consists of the following steps:

1. maturity levels (e.g., uncertainty, enlightenment, awakening, regression, certainty)
2. dimensions/process areas (e.g., performance standard)
3. Description of elements in each dimension (e.g., the 'performance standard' may be defined by elements, e.g., number of defects).

To identify the maintenance maturity dimensions and indicators under each dimension, the mixed fuzzy DEMATEL method was used. Twelve maintenance dimensions and three to six indicators under each maintenance dimension were identified. This section will present and discuss the result from the fuzzy DEMATEL hybrid method. The method is used to evaluate the cause and effect relationship among maintenance dimensions and indicators through the focus group study to identify building maintenance maturity measurement dimensions and indicators to develop a building maintenance maturity model. For this purpose, the focus group discussion was performed with participants who were requested to provide their expert opinion using the DEMATEL questionnaire. The result of the Fuzzy DEMATEL analysis based on the expert's judgment is presented as follows.

4.3.1. Procedure for Fuzzy DEMATEL Analysis

As described in chapter four, DEMATEL is a commonly used MCDM method to analyze causal relationships, which requires a group of experts judgment in pairwise form (Asan et al., 2018). As the expert's judgments are subjective and have some inaccuracies and vagueness in a real-life situation, a fuzzy set theory that applies fuzzy number is introduced to solve such a problem in decision-making (Uygun, 2016). Therefore, this study applies a fuzzy DEMATEL hybrid method using Triangular Fuzzy Numbers (TFNs) as presented in table 4.4 below.

Table 4. 3: Triangular Fuzzy Numbers Corresponding to each linguistic variable

Linguistic Variable	Influence Score	Triangular fuzzy numbers
No or very low influence	0	(0,0,0.25)
Low influence	1	(0,0.25,0.50)
Medium influence	2	(0.25,0.50,0.75)
High influence	3	(0.50,0.75,1.00)
Very high influence	4	(0.75,1.00,1.00)

In this section, the level of influence of each maintenance dimension and indicator is analyzed and refined using the fuzzy DEMATEL procedures introduced in chapter three. For this purpose, the focus group discussion participants in two groups were requested to provide their professional judgment using the DEMATEL questionnaire as shown in Tables 4.6 and 4.7. For better understanding, the detailed procedure for analyzing experts' opinions using the fuzzy DEMATEL method is presented. For simplicity of analysis, the maintenance dimensions are denoted by Di, where I range from 1 to 12 for each of the maintenance dimensions or perspectives as described in table 4.5 below.

Table 4. 4: Maintenance Dimensions Defined by Maintenance indicators (KPI)

Notation	Maintenance Dimensions /Perspective	Maintenance Dimensions Defined by Indicators (KPIs)
D1	**Maintenance Policy and Strategy**	Availability of Built Asset management strategy and planning (D11)
		Availability of built Asset management policy (D12)
		Alignment of Built Asset management objectives with Corporate objectives (D13)
		Built asset maintenance task planning and scheduling (D14))
		Availability of defined built asset Maintenance approach/s (D15)
D2	**Human Resource Management**	Competency of in house maintenance staff (D21)
		Training programs to maintenance staff (D22)
		Motivation and inspired teamwork of maintenance staff (D23)
D3	**Technical and Functional Appropriateness**	Building asset Capacity (D31)
		Building asset Functionality (D32)
		Building asset Location (D33)
		Building asset Condition (D34)
		Technical practicality of Building asset (D35)
D4	**Maintenance Organization**	Organization of Maintenance department (D41)
		Alignment of Maintenance with organizational objectives (D42)
		The efficiency of the maintenance process and work Instructions (D43)
		Organizational position of maintenance department (D44)
D5	**Maintenance Information Management**	Completeness, accuracy, and validity of built asset data (D51)
		Built asset registry and asset history of enhancing asset knowledge (D52)
		Use of Maintenance information management system (D53)
		Use of data Capturing Technologies from exiting built asset(D54)
D6	**Building Design Life**	Evaluation of capital expenditure requirements (D61)
		Modernization plan of the Built asset (D62)
		Disposal plan of a built asset (D63)
		Building remaining Life (D64)
		Capital replacement decisions (D65)
D7	**Maintenance Budget/Financial Perspective**	Operating cost (D71)
		Annual Maintenance Cost (D72)
		Differed Maintenance Cost (D73)
		Utilization of Maintenance budget (D74)
		Information and Knowledge about maintenance costs (D75)
D8	**Culture and Leadership**	Awareness of people towards built asset management (D81)
		Top management Support (D82)
		An attitude of employees (D83)
		The willingness of people to learn new methodologies and attend training (D84)

		Values and beliefs towards maintenance (D85)
D9	**Maintenance Materials and Spar part Management**	Maintenance Materials Inventory Management (D91)
		Classification of Maintenance stock items (D92)
		Inventory management policy (D93)
D10	**Risk Management**	Risk assessment strategies and objectives (D101)
		Risk is embedded in all activities to minimize asset performance (D102)
		Analysis of building failure, causes & effects to address the risk (D103)
		Statutory compliance risk (D104)
D11	**Performance Management**	Value for money (D111)
		Maintenance efficiency indicator (D112)
		The physical state of the building is measured by the building performance indicator (D113)
		Building Efficiency Index (D114)
		End-user satisfaction (115)
D12	**Environmental and Social Impact of the Built asset**	Impact of the Built Asset on the environment (D121)
		Environmental Friendliness of the Built asset (D122)
		The social significance of the built asset(D123)

Step 1: Evaluate the mutual influences between factors using a fuzzy linguistic scale.

This step must establish a fuzzy linguistic scale based on experts' judgment to assess the causal relationships between the two dimensions and indicators. Accordingly, data from two groups of experts involved in the DEMATEL survey is shown in Tables 4.6 and 4.7, presented in Tables 4.8 and 4.9.

Table 4. 5: Expert group one Judgment based on DEMATEL Questionnaire for maintenance dimensions

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0	3	4	3	4	1	4	3	2	3	2	3
D2	1	0	1	3	2	1	3	2	3	3	4	2
D3	2	1	0	2	3	1	4	0	3	3	4	3
D4	2	3	1	0	3	0	4	3	2	3	3	1
D5	1	2	3	3	0	4	3	1	4	4	4	2
D6	4	4	3	3	3	0	4	2	4	3	3	3
D7	4	3	1	4	3	3	0	3	4	3	4	2
D8	3	3	3	3	3	3	3	0	3	2	3	3
D9	1	1	3	1	3	1	3	1	0	3	3	2
D10	3	3	3	3	3	3	3	2	3	0	3	2
D11	2	4	4	3	4	3	3	3	3	3	0	2
D12	3	2	3	1	3	3	2	3	2	2	2	0

Table 4.6: Expert group two Judgment based on DEMATEL Questionnaire for maintenance dimensions

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0	2	4	2	1	1	4	3	2	3	3	4
D2	2	0	4	4	2	1	2	4	3	3	3	1
D3	1	2	0	1	2	3	3	1	1	4	3	4
D4	1	4	2	0	3	1	4	2	3	2	4	1
D5	2	2	4	3	0	2	3	1	2	3	3	2
D6	1	1	3	3	1	0	3	1	2	1	1	2
D7	1	4	3	3	1	3	0	1	3	2	2	2
D8	3	3	3	3	2	1	2	0	3	3	4	4
D9	1	1	1	3	2	1	3	1	0	2	3	1
D10	4	2	3	2	1	3	3	1	2	0	2	4
D11	2	4	3	3	2	2	4	2	2	3	0	3
D12	4	1	3	2	1	2	3	3	1	3	1	0

Using expected judgment in tables 4.6 and 4.7, the individual direct-influence fuzzy matrix is acquired for each expert group regarding the influence degree among maintenance dimensions (see Tables 4.8 and 4.9 below).

Table 4.7: Individual Direct Influence Fuzzy Matrix (based on Expert group one)

	D1			D2			D3			D4			D5			D6		
D1	0.00	0.00	0.00	0.50	0.75	1.00	0.75	1.00	1.00	0.50	0.75	1.00	0.75	1.00	1.00	0.00	0.25	0.50
D2	0.00	0.25	0.50	0.00	0.00	0.00	0.00	0.25	0.50	0.50	0.75	1.00	0.25	0.50	0.75	0.00	0.25	0.50
D3	0.25	0.50	0.75	0.00	0.25	0.50	0.00	0.00	0.00	0.25	0.50	0.75	0.50	0.75	1.00	0.00	0.25	0.50
D4	0.25	0.50	0.75	0.50	0.75	1.00	0.00	0.25	0.50	0.00	0.00	0.00	0.50	0.75	1.00	0.00	0.00	0.25
D5	0.00	0.25	0.50	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.00	0.00	0.75	1.00	1.00
D6	0.75	1.00	1.00	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.00	0.00
D7	0.75	1.00	1.00	0.50	0.75	1.00	0.00	0.25	0.50	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00
D8	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00
D9	0.00	0.25	0.50	0.00	0.25	0.50	0.50	0.75	1.00	0.00	0.25	0.50	0.50	0.75	1.00	0.00	0.25	0.50
D10	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00
D11	0.25	0.50	0.75	0.75	1.00	1.00	0.75	1.00	1.00	0.50	0.75	1.00	0.75	1.00	1.00	0.50	0.75	1.00
D12	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.00	0.25	0.50	0.50	0.75	1.00	0.50	0.75	1.00

	D7			D8			D9			D10			D11			D12		
D1	0.75	1.00	1.00	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00
D2	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.75	1.00	1.00	0.25	0.50	0.75
D3	0.75	1.00	1.00	0.00	0.00	0.25	0.50	0.75	1.00	0.50	0.75	1.00	0.75	1.00	1.00	0.50	0.75	1.00
D4	0.75	1.00	1.00	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.25	0.50
D5	0.50	0.75	1.00	0.00	0.25	0.50	0.75	1.00	1.00	0.75	1.00	1.00	0.75	1.00	1.00	0.25	0.50	0.75
D6	0.75	1.00	1.00	0.25	0.50	0.75	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00
D7	0.00	0.00	0.00	0.50	0.75	1.00	0.75	1.00	1.00	0.50	0.75	1.00	0.75	1.00	1.00	0.25	0.50	0.75
D8	0.50	0.75	1.00	0.00	0.00	0.00	0.50	0.75	1.00	0.25	0.50	0.75	0.75	1.00	1.00	0.50	0.75	1.00
D9	0.50	0.75	1.00	0.00	0.25	0.50	0.00	0.00	0.00	0.50	0.75	1.00	0.75	1.00	1.00	0.25	0.50	0.75
D10	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.00	0.00	0.00	0.75	1.00	1.00	0.25	0.50	0.75
D11	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.00	0.00	0.25	0.50	0.75
D12	0.25	0.50	0.75	0.50	0.75	1.00	0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.50	0.75	0.00	0.00	0.00

Table 4.8: Individual Direct Influence Fuzzy Matrix (based on Expert Group Two)

	D1			D2			D3			D4			D5			D6		
D1	0.00	0.00	0.00	0.25	0.50	0.75	0.75	1.00	1.00	0.25	0.50	0.75	0.00	0.25	0.50	0.00	0.25	0.50
D2	0.25	0.50	0.75	0.00	0.00	0.00	0.75	1.00	1.00	0.75	1.00	1.00	0.25	0.50	0.75	0.00	0.25	0.50
D3	0.00	0.25	0.50	0.25	0.50	0.75	0.00	0.00	0.00	0.00	0.25	0.50	0.25	0.50	0.75	0.50	0.75	1.00
D4	0.00	0.25	0.50	0.75	1.00	1.00	0.25	0.50	0.75	0.00	0.00	0.00	0.50	0.75	1.00	0.00	0.25	0.50
D5	0.25	0.50	0.75	0.25	0.50	0.75	0.75	1.00	1.00	0.50	0.75	1.00	0.00	0.00	0.00	0.25	0.50	0.75
D6	0.00	0.25	0.50	0.00	0.25	0.50	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.25	0.50	0.00	0.00	0.00
D7	0.00	0.25	0.50	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.25	0.50	0.50	0.75	1.00
D8	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.50	0.75	0.00	0.25	0.50
D9	0.00	0.25	0.50	0.00	0.25	0.50	0.00	0.25	0.50	0.50	0.75	1.00	0.25	0.50	0.75	0.00	0.25	0.50
D10	0.75	1.00	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.25	0.50	0.75	0.00	0.25	0.50	0.50	0.75	1.00
D11	0.25	0.50	0.75	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.50	0.75	0.25	0.50	0.75
D12	0.75	1.00	1.00	0.00	0.25	0.50	0.50	0.75	1.00	0.25	0.50	0.75	0.00	0.25	0.50	0.25	0.50	0.75

	D7			D8			D9			D10			D11			D12		
D1	0.75	1.00	1.00	0.50	0.75	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.75	1.00	1.00
D2	0.25	0.50	0.75	0.75	1.00	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.25	0.50
D3	0.50	0.75	1.00	0.00	0.25	0.50	0.00	0.25	0.50	0.75	1.00	1.00	0.50	0.75	1.00	0.75	1.00	1.00
D4	0.75	1.00	1.00	0.25	0.50	0.75	0.50	0.75	1.00	0.25	0.50	0.75	0.75	1.00	1.00	0.00	0.25	0.50
D5	0.50	0.75	1.00	0.00	0.25	0.50	0.25	0.50	0.75	0.50	0.75	1.00	0.50	0.75	1.00	0.25	0.50	0.75
D6	0.50	0.75	1.00	0.00	0.25	0.50	0.25	0.50	0.75	0.00	0.25	0.50	0.00	0.25	0.50	0.25	0.50	0.75
D7	0.00	0.00	0.00	0.00	0.25	0.50	0.50	0.75	1.00	0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.50	0.75
D8	0.25	0.50	0.75	0.00	0.00	0.00	0.50	0.75	1.00	0.50	0.75	1.00	0.75	1.00	1.00	0.75	1.00	1.00
D9	0.50	0.75	1.00	0.00	0.25	0.50	0.00	0.00	0.00	0.25	0.50	0.75	0.50	0.75	1.00	0.00	0.25	0.50
D10	0.50	0.75	1.00	0.00	0.25	0.50	0.25	0.50	0.75	0.00	0.00	0.00	0.25	0.50	0.75	0.75	1.00	1.00
D11	0.75	1.00	1.00	0.25	0.50	0.75	0.25	0.50	0.75	0.50	0.75	1.00	0.00	0.00	0.00	0.50	0.75	1.00
D12	0.50	0.75	1.00	0.50	0.75	1.00	0.00	0.25	0.50	0.50	0.75	1.00	0.00	0.25	0.50	0.00	0.00	0.00

***Step 2:* Aggregate assessments of expert groups and set up the group direct-influence fuzzy matrix $\tilde{Z}$ is de-fuzzyfied.**

Transform the fuzzy group assessments into crisp values and form the group direct-influence matrix Z. At this stage, the individual direct influence de-fuzzified matrix is aggregated to set up the group direct influence matrix. In this study, the individual fuzzy matrix obtained from *twelve* experts in two groups involved in the DEMATEL survey is de-fuzzyfied using the weighted average defuzzification method (equation 4.2) and aggregated, as shown in table 4.10.

$$x_{ij} = \frac{x_{ij}^{L} + 4x_{ij}^{M} + x_{ij}^{U}}{6} \qquad \textbf{Equation 4. 2}$$

Table 4.9: Group Direct-Influence DE-fuzzyfied matrix $\tilde{Z}$ using the weighted average method

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0.00	0.63	0.96	0.63	0.60	0.25	0.96	0.75	0.50	0.75	0.63	0.85
D2	0.38	0.00	0.60	0.85	0.50	0.25	0.63	0.73	0.75	0.75	0.85	0.38
D3	0.38	0.38	0.00	0.38	0.63	0.50	0.85	0.15	0.50	0.85	0.85	0.85
D4	0.38	0.85	0.38	0.00	0.75	0.15	0.96	0.63	0.63	0.63	0.85	0.25
D5	0.38	0.50	0.85	0.75	0.00	0.73	0.75	0.25	0.73	0.85	0.85	0.50
D6	0.60	0.60	0.75	0.75	0.50	0.00	0.85	0.38	0.73	0.50	0.50	0.63
D7	0.60	0.85	0.50	0.85	0.50	0.75	0.00	0.50	0.85	0.63	0.73	0.50
D8	0.75	0.75	0.75	0.75	0.63	0.50	0.63	0.00	0.75	0.63	0.96	0.85
D9	0.25	0.25	0.50	0.50	0.63	0.25	0.75	0.25	0.00	0.63	0.85	0.38
D10	0.85	0.63	0.75	0.63	0.50	0.75	0.75	0.38	0.63	0.00	0.73	0.73
D11	0.50	0.96	0.85	0.75	0.73	0.63	0.85	0.63	0.63	0.75	0.00	0.63
D12	0.85	0.38	0.75	0.38	0.50	0.63	0.63	0.75	0.38	0.63	0.38	0.00

Step 3. Apply the classical DEMATEL approach

The group direct-influence matrix Z, the normalized direct-influence matrix X, and the total-influence matrix T can be obtained. Then the value of (r + c) and (r − c) can be determined based on the total relation matrix, and the cause and effect diagram can also be constructed using these values.

a). Establish the normalized direct-influence matrix X,

$$X = Z \cdot S \qquad \text{Equation 4. 3}$$

$$\text{Where } S = min\left[\frac{1}{max\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{max\sum_{i=1}^{n}|a_{ij}|}\right] \qquad \text{Equation 4. 4}$$

Table 4.10: Normalized direct-influence matrix X

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0.00	0.08	0.12	0.08	0.08	0.03	0.12	0.09	0.06	0.09	0.08	0.11
D2	0.05	0.00	0.08	0.11	0.06	0.03	0.08	0.09	0.09	0.09	0.11	0.05
D3	0.05	0.05	0.00	0.05	0.08	0.06	0.11	0.02	0.06	0.11	0.11	0.11
D4	0.05	0.11	0.05	0.00	0.09	0.02	0.12	0.08	0.08	0.08	0.11	0.03
D5	0.05	0.06	0.11	0.09	0.00	0.09	0.09	0.03	0.09	0.11	0.11	0.06
D6	0.08	0.08	0.09	0.09	0.06	0.00	0.11	0.05	0.09	0.06	0.06	0.08
D7	0.08	0.11	0.06	0.11	0.06	0.09	0.00	0.06	0.11	0.08	0.09	0.06
D8	0.09	0.09	0.09	0.09	0.08	0.06	0.08	0.00	0.09	0.08	0.12	0.11
D9	0.03	0.03	0.06	0.06	0.08	0.03	0.09	0.03	0.00	0.08	0.11	0.05
D10	0.11	0.08	0.09	0.08	0.06	0.09	0.09	0.05	0.08	0.00	0.09	0.09
D11	0.06	0.12	0.11	0.09	0.09	0.08	0.11	0.08	0.08	0.09	0.00	0.08
D12	0.11	0.05	0.09	0.05	0.06	0.08	0.08	0.09	0.05	0.08	0.05	0.00

b). Construct the total-influence matrix T,

$$T = X \cdot (I - X)^{-1} \qquad \text{Equation 4. 5}$$

Were as ;

T= Total influence matrix; I = Identity Matrix and X=Normalized direct matrix

Table 4. 11: Total-influence matrix *T*

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0.45	0.59	0.68	0.62	0.56	0.45	0.75	0.50	0.59	0.66	0.69	0.59
D2	0.45	0.47	0.58	0.59	0.50	0.41	0.65	0.45	0.57	0.60	0.65	0.48
D3	0.43	0.49	0.48	0.51	0.49	0.42	0.64	0.37	0.51	0.58	0.62	0.52
D4	0.44	0.56	0.54	0.48	0.52	0.39	0.67	0.43	0.54	0.57	0.64	0.46
D5	0.47	0.55	0.63	0.60	0.47	0.48	0.69	0.42	0.59	0.64	0.68	0.52
D6	0.47	0.54	0.60	0.58	0.50	0.38	0.68	0.42	0.57	0.57	0.61	0.51
D7	0.50	0.60	0.60	0.62	0.53	0.49	0.62	0.46	0.61	0.62	0.68	0.53
D8	0.56	0.63	0.68	0.66	0.59	0.50	0.75	0.43	0.65	0.68	0.75	0.61
D9	0.35	0.41	0.47	0.45	0.43	0.34	0.55	0.32	0.38	0.48	0.54	0.40
D10	0.53	0.58	0.64	0.60	0.54	0.49	0.71	0.45	0.59	0.56	0.68	0.56
D11	0.53	0.65	0.69	0.66	0.60	0.51	0.77	0.50	0.63	0.68	0.64	0.58
D12	0.48	0.48	0.57	0.51	0.48	0.43	0.62	0.44	0.50	0.56	0.57	0.42

c). Calculate the sum of row & column of matrix T

Table 4.12: Total-influence matrix T with (r + c) and (r − c) values

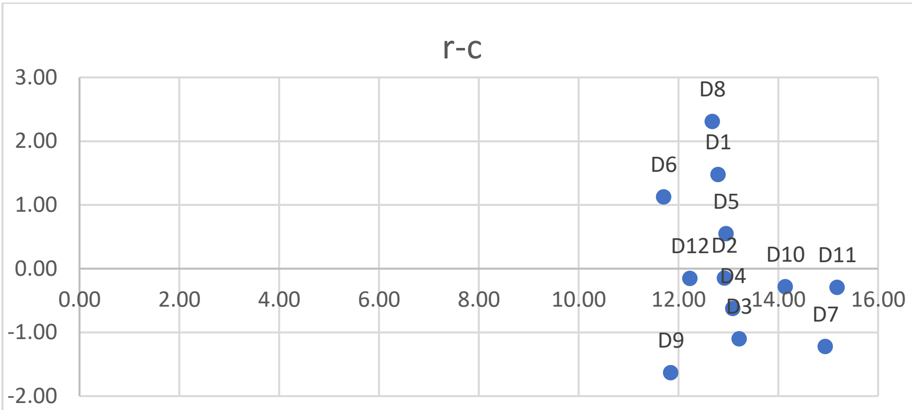
Whereas: r is the summation of the row and **c** is the summation of the column for each dimension

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	**r**	**c**	**r+c**	**r-c**
D1	0.45	0.59	0.68	0.62	0.56	0.45	0.75	0.50	0.59	0.66	0.69	0.59	7.14	5.66	12.80	1.48
D2	0.45	0.47	0.58	0.59	0.50	0.41	0.65	0.45	0.57	0.60	0.65	0.48	6.39	6.54	12.92	-0.15
D3	0.43	0.49	0.48	0.51	0.49	0.42	0.64	0.37	0.51	0.58	0.62	0.52	6.06	7.16	13.22	-1.10
D4	0.44	0.56	0.54	0.48	0.52	0.39	0.67	0.43	0.54	0.57	0.64	0.46	6.24	6.86	13.09	-0.62
D5	0.47	0.55	0.63	0.60	0.47	0.48	0.69	0.42	0.59	0.64	0.68	0.52	6.75	6.20	12.96	0.55
D6	0.47	0.54	0.60	0.58	0.50	0.38	0.68	0.42	0.57	0.57	0.61	0.51	6.41	5.29	11.70	1.13
D7	0.50	0.60	0.60	0.62	0.53	0.49	0.62	0.46	0.61	0.62	0.68	0.53	6.86	8.08	14.95	-1.22
D8	0.56	0.63	0.68	0.66	0.59	0.50	0.75	0.43	0.65	0.68	0.75	0.61	7.49	5.19	12.68	2.31
D9	0.35	0.41	0.47	0.45	0.43	0.34	0.55	0.32	0.38	0.48	0.54	0.40	5.11	6.74	11.85	-1.63
D10	0.53	0.58	0.64	0.60	0.54	0.49	0.71	0.45	0.59	0.56	0.68	0.56	6.93	7.21	14.14	-0.28
D11	0.53	0.65	0.69	0.66	0.60	0.51	0.77	0.50	0.63	0.68	0.64	0.58	7.44	7.74	15.18	-0.30
D12	0.48	0.48	0.57	0.51	0.48	0.43	0.62	0.44	0.50	0.56	0.57	0.42	6.04	6.19	12.23	-0.15

d). Build the cause-and-effect relationship diagram

The cause-and-effect diagram is constructed by mapping all coordinate sets of r_i+c_i *and* r_i-c_i to visualize the complex interrelationship and provide information to judge which are the most important Maintenance dimension and how they influence each other. A positive result of r-c shows that the dimension is in the cause category whereas the negative result is in the effect category.

Accordingly, D8(**Culture and Leadership**), D1(**Maintenance Policy and Strategy**), D6(**Building Design Life**), and D5(**Maintenance Information Management**) are causes of building maintenance management. D8(Culture and Leadership) is the higher cause amongst all causes and is followed by D1(**Maintenance Policy and Strategy**).



4.3.2. Determination of weights Maintenance dimensions using DEMATEL

The previous sections explained the procedure of analyzing experts' opinions using the Fuzzy DEMATEL hybrid method. In this section, the importance of maintenance dimensions from the focus group study is further analyzed using the fuzzy DEMATEL method. The final result shows their level of influence in measuring maintenance performances based on their weights.

As stated in the studies of Baykasoglu et al. (2013) and Dalalah et al. (2011), both stated in (Making and Kobry, 2017), DEMATEL method is also used to determine the weights of criteria using the following formula:

$$\omega_i = \left((t_i^+)^2 + (t_i^-)^2\right)^{1/2} \qquad \textbf{Equation 4. 6}$$

Where the values ω_i can be normalized from the equation,

$$W_i = \frac{\omega_i}{\sum_{i=1}^{n} \omega_i} \qquad \textbf{Equation 4. 7}$$

In the context of this study, the values t_i^+ and t_i^- They are equivalent to the values of r+1 and r-c, respectively.

Wi is the last criteria weight to be used in the decision-making process. As stated in (Making and Kobry, 2017), the approach is not accurate since, by using the above equations, the same weight can be assigned to any two criteria, i and j, i and j, for which $r + c = r - c$ but $r - c = |r - c|$ (whereby $r - c < 0$).

Making and Korbry (2017) have proposed a different approach to determine the criteria weights using DEMATEL, which does not have the drawback mentioned above. By assuming that the indicators r+c and r-c can be determined from the total influence matrix resulting from the direct influence diagram.

The average r+c value can be determined from,

$$(r + c)_i^{average} = \frac{1}{2}\big((r + c) + (r - c)\big) = \sum_{j=1}^{n}(r + c)_{i,j} \quad \textbf{Equation 4. 8}$$

The normalized weights, where $(\sum w_i = 1)$Equation (4.10) can be used.

$$w_i = \frac{(r+c)_i^{average}}{\sum_{i=1}^{n}(r+c)_i} \qquad \textbf{Equation 4. 9}$$

However, it should be noted that if other criteria dominate any criterion, the corresponding ratings of this criterion resulting from the direct-influence graph are equal to 0. This creates substantial difficulties since the corresponding row in the direct-influence matrix consists of zeros only. Hence when a zero is encountered, it is necessary to correct the weight values by adding the minimum results from each average weight to all the averaged weights. But in this study, there was no need for correcting, because 0 was not encountered.

According to the above-given formula, the weighted values are computed for each dimension, as shown in Table 4.14 below

r+c shows the importance of the dimension, whereas r-c shows the relation cause

The dimensions belonged in the cause group are D8, D1, D6, and D5, and the remaining dimensions belong to the effect group. A larger value of r-c denotes a higher influence of that dimension has on the other dimensions.

Table 4.13: Normalized weights of each Maintenance dimension as a maturity measurement perspectives

Notation	Maintenance Dimensions	r	c	r+c	r-c	1/2((r+c)+(r-c))	Weights
D1	Maintenance Policy and Strategy	7.14	5.66	12.8	1.48	7.14	0.09
D2	Human Resource Management	6.39	6.54	12.92	-0.15	6.39	0.081
D3	Technical and Functional Appropriateness	6.06	7.16	13.22	-1.1	6.06	0.077
D4	Maintenance Organization	6.24	6.86	13.09	-0.62	6.24	0.079
D5	Maintenance Information Management	6.75	6.2	12.96	0.55	6.75	0.086
D6	Building Design Life	6.41	5.29	11.7	1.13	6.41	0.081
D7	Maintenance Budget/Financial Perspective	6.86	8.08	14.95	-1.22	6.86	0.087
D8	Culture and Leadership	7.49	5.19	12.68	2.31	7.49	0.095
D9	Maintenance Materials and Spar part Management	5.11	6.74	11.85	-1.63	5.11	0.065
D10	Risk Management	6.93	7.21	14.14	-0.28	6.93	0.088
D11	Performance Management	7.44	7.74	15.18	-0.3	7.44	0.094
D12	Environmental and Social Impact of the Built asset	6.04	6.19	12.23	-0.15	6.04	0.077

As described above, D8 (**Culture and Leadership**), D1 (**Maintenance Policy and Strategy**), D6 (**Building Design Life**), and D5 (**Maintenance Information Management**) are categorized under the causes group of built asset maintenance management. As can be understood causes are are more important than effect since effects are results.Hence the cause dimensions have a high value on university maintenance management. This also can be seen from the average weight calculation (i.e., all of them are above 8%).

D8 **(Culture and Leadership**) is the most important of all the cause groups. This demonstrates that the lack of a maintenance policy in institutions is rooted in the leadership's degree of significance for maintenance. This is also ingrained in the culture.

Effect indicators are indicators that are affected by other indicators. D11 (**Performance Management**) is the highest among the effect group. This demonstrates that the execution of other indicators has a significant impact on D11. The next two effect indicators are D7 (**Maintenance**

Budget/Financial Perspective) and D10 (**Risk Management**). Other indicators also influences these dimensions.

All the indicators weighted average (6.48%-9.5%) and centrality **r+c** (11.70-15.8) are clustered within a narrow range. This shows that all the dimensions are more or less equivalent in importance for built asset maintenance management. Hence, all the dimensions need to be used to measure the maturity of maintenance management for built assets.

Similar steps have been utilized to compute the weights of the indicators under each dimension, as illustrated in section 4.3.2 above. Accordingly, the weights of indicators under each dimension are presented below.

Normalized weights of indicators for all the twelve (12) Maintenance maturity measurement are computed and is shown in table (Table 4.15) .

Table 4.14: Indicators under each maintenance maturity dimension with their respective Normalized weights

Built asset Maintenance Dimension	Indicators for Each Dimension	r	c	r+c	r-c	1/2((r+c)+(r-c))	Weights
Maintenance Policy and Strategy	Availability of Built Asset management strategy and planning	3.91	2.72	6.63	1.19	3.91	0.24
	Availability of built Asset management policy	4.08	2.46	6.53	1.62	4.08	0.25
	Alignment of Built Asset management objectives with Corporate objectives	3.79	2.86	6.65	0.93	3.79	0.23
	Built asset maintenance task planning and scheduling	2.63	4.07	6.7	-1.44	2.63	0.16
	Availability of defined built asset Maintenance approach/s	2.02	4.33	6.35	-2.31	2.02	0.12
Human Resource Management	Competency of in house maintenance staff	1.85	2.93	4.78	-1.08	1.846	0.235
	Training programs to maintenance staff	3.27	1.93	5.2	1.34	3.271	0.416
	Motivation and inspired team work of maintenance staff	2.75	3.01	5.76	-0.26	2.749	0.349
Technical and Functional appropriateness dimension	Building asset Capacity	5.87	6.51	12.39	-0.64	5.87	0.19
	Building asset Functionality	6.87	6.87	13.74	0.01	6.87	0.23
	Building asset Location	5.16	5.44	10.6	-0.28	5.16	0.17
	Building asset Condition	5.9	5.41	11.31	0.49	5.9	0.19
	Technical practicality of Building asset	6.56	6.14	12.69	0.42	6.56	0.22
Maintenance Organization	Organization of Maintenance department	6.25	5.85	12.1	0.4	6.249	0.284
	Alignment of Maintenance with organizational objectives	5.14	5.12	10.27	0.02	5.144	0.234
	Efficiency of maintenance process and work Instructions	5.18	5.63	10.81	-0.46	5.178	0.235
	Organizational position of maintenance department	5.43	5.39	10.82	0.03	5.427	0.247
Maintenance Information Management	Completeness, accuracy and validity of built asset data	24.28	24.32	48.6	-0.04	24.283	0.258
	Built asset registry and asset history to enhance asset knowledge	22.73	24.47	47.2	-1.74	22.735	0.241
	Use of Maintenance Information management system	23.48	22.7	46.18	0.78	23.479	0.249
	Use of data Capturing Technologies from exiting built asset	23.69	22.7	46.4	0.99	23.695	0.252

Built asset Maintenance Dimension	Indicators for Each Dimension	r	c	r+c	r-c	1/2((r+c)+(r-c))	Weights
Building Design Life	Evaluation of capital expenditure requirements	3.68	2.73	6.41	0.95	3.679	0.314
	Modernization plan of the Built asset	2.76	2.82	5.58	-0.06	2.756	0.235
	Disposal plan of built asset	1.95	3.16	5.11	-1.21	1.948	0.166
	Building remaining Life	3.33	3.00	6.34	0.33	3.332	0.284
Maintenance Budget/Financial Perspective	Operating cost	9.13	8.91	18.04	0.22	9.13	0.2
	Annual Maintenance Cost	9.53	9.19	18.72	0.35	9.53	0.21
	Differed Maintenance Cost	8.29	9.17	17.46	-0.89	8.29	0.18
	Utilization of Maintenance budget	10.02	10.05	20.07	-0.03	10.02	0.22
	Information and Knowledge about maintenance cost	9.28	8.92	18.19	0.36	9.28	0.2
Culture and Leadership	Awareness of people towards built asset management	16.65	15.38	32.02	1.27	16.65	0.21
	Top management Support	15.23	14.54	29.77	0.69	15.23	0.19
	Attitude of employees	15.76	16.62	32.38	-0.86	15.76	0.2
	Willingness of people to learn new methodologies and attend training	16.63	15.19	31.82	1.43	16.63	0.21
	Values and beliefs towards maintenance	14.89	17.43	32.32	-2.54	14.89	0.19
Maintenance Materials and Spare part Management	Maintenance Materials Inventory Management	0.64	2.07	2.71	-1.42	0.64	0.16
	Classification of Maintenance stock items	1.34	1.08	2.42	0.26	1.34	0.34
	Inventory management policy	1.97	0.8	2.77	1.17	1.97	0.5
Risk Management	Risk assessment strategies and objectives	14.01	12.73	26.74	1.29	14.011	0.264
	Risk is embedded in to all activities to minimize asset performance	12.68	12.68	25.36	0	12.679	0.239
	Analysis of building failure, causes & effects to address risk	13.59	13.59	27.18	0	13.591	0.256
	Statutory compliance risk	12.73	14.01	26.74	-1.29	12.725	0.24
Performance Management	Value for money	6.09	4.19	10.27	1.9	6.09	0.21
	Maintenance efficiency indicator	6.6	6.22	12.82	0.37	6.6	0.23
	The building performance indicator measures the physical state of the building	5.69	5.98	11.68	-0.29	5.69	0.2
	Building Efficiency Index	5.69	5.59	11.29	0.1	5.69	0.2
	End user satisfaction	4.98	7.07	12.06	-2.09	4.98	0.17
Environmental and Social Impact of the Built asset	Impact of the Built Asset on the environment	1.87	2.54	4.41	-0.67	1.87	0.26
	Environmental Friendliness of the Built asset	3.11	1.68	4.78	1.43	3.11	0.42
	Social significance of the built asset	2.34	3.11	5.45	-0.76	2.34	0.32

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

As stated previously in the problem statement, "Another flaw in the human character is that everybody wants to build, and nobody wants to do maintenance" (Kurt Vonnegut, Jr.).

This research aims to assess the current level of maintenance practice, identify factors that influence building maintenance management practice, and develop a maintenance maturity/rating model that could be used to shift current maintenance practices for public university buildings facilities in Ethiopia.

Hence, the study focuses on building maintenance management and practices and how they influence the core business of teaching, learning, research, and community service at Ethiopian public universities.

The analysis of the first objective of this study is based on a sufficient sample of 75 responses obtained from 26 university managers, facility managers, and university staff involved in one or another in managing or using public university facilities in Ethiopia. From the analysis, the current building maintenance management practice can be characterized by:

- The lack of strategic consideration given to built asset maintenance management was evidenced by the actual conditions of buildings (observation) and interview analysis results.
- There is no clear maintenance policy supported by a proper strategic approach applicable for maintenance operations in public universities in particular and building facilities in Ethiopia. This is mainly due to the absence of a public entity responsible for managing and maintaining public buildings in an organized way.
- Sewerage lines, water supply lines, fixtures, and electrical lines and fittings have been requiring more frequent maintenance operations, suggesting that the quality of service lines construction and maintenance operations performed on these components are questionable.

- The lack of data, documents, and maintenance manuals required for built asset maintenance operations is a critical challenge in maintenance management.

The second objective of this study was to identify the factors that influence the proper practice of building maintenance management in public universities in Ethiopia. These factors were grouped under seven categories: factors on statutory requirements, design, construction, maintenance management, Maintenance team operation, maintenance budget and community culture (learning, and growth). Accordingly; lack of preventive Maintenance methods and lack of maintenance and schedules (of maintenance management), a lack of as-built documentation and unavailability of a database for maintenance activities (of maintenance team operations), lack of effective maintenance culture from (the community culture, learning and growth category) and poor construction quality (factors of construction quality) are identified as the top five critical factors affecting the proper practice of facility maintenance management practices in Ethiopia.

The final objective is to develop a built asset maintenance maturity rating model that public universities can use as a self-assessment tool to shift from the current level to an advanced progression level based on twelve dimensions/perspectives measured by 3 to 6 indicators. The weight-age of each dimension and indicator is analyzed using fuzzy-DEMATEL multi-criteria decision making (MCDM).

From the (MCDM) analysis, the cause-and-effect diagram was constructed by mapping all coordinate sets of r_i+c_i and ri-ci to visualize the complex interrelationship and judge the most important built asset maintenance maturity dimension how they influence each other. Accordingly, D8 (Culture and Leadership), D1 (Maintenance Policy and Strategy), D6 (Building Design Life), and D5 (Maintenance Information Management) are categorized under the cause group of the DEMATEL analysis for built asset maintenance maturity dimension, indicating their importance. D8 (Culture and Leadership) is the highest cause amongst all causes and is followed by D1 (Maintenance Policy and Strategy), which agrees with the findings in the previous objective. According to DEMATEL MCDM, the dimensions categorized under the cause group (r-c being positive value) are more important than the effect group dimensions, D2, D3, D4, D7, D9, D10, D11, and D12 (with negative r-c values).

As stated above, D8 (Culture and Leadership) is the most significant of the cause groups. This demonstrates that the key reason for institutions' absence of a maintenance policy is the leadership's acknowledgment of the necessity of built asset maintenance. This is firmly ingrained in the culture as well.Finally, a built asset maturity rating model is proposed based on the weights calculated from DEMATEL, MCDM analysis weights for dimensions and indicators under each dimension to be used as a self-assessment tool by public universities in Ethiopia.

5.2. Recommendation

The following recommendations are made to various groups based on the study's findings:

University administration bodies

Public university management bodies are recommended to manage their built asset to support universities' corporate objectives by incorporating a built asset management plan as part of their strategic plan. Building maintenance management policy should be developed by university facility management or maintenance management department to increase the efficiency and effectiveness of building maintenance activities.

Policy makers

The author recommends government higher officials establish a public body responsible for the management and maintenance (built asset registration, condition survey, and maintenance strategy development and disposal plan) of public buildings in a systematized way based on appropriate maintenance policy and strategy.

Future researchers

Further research should include universities in different regions of the country as case studies to see whether there are better building conditions and management practices to back up the survey study's conclusions. Furthermore, the maintenance and management of newly constructed high-rise structures in Addis Ababa are potential problem areas that require additional research to propose better maintenance management solutions.

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APPENDICES

Appendix 1: Publishable Manuscript

DEVELOPING FACILITIES MAINTENANCE MATURITY RATING MODEL FOR PUBLIC UNIVERSITY BUILDINGS IN ETHIOPIA

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ABSTRACT

In Ethiopia, a significant amount of funds is invested in mega projects like dams, highways, railways, airports, power plants, public buildings, etc. These investments are showing unprecedented expansion which, by some estimates, has shown a 9-fold growth of the GDP of the construction sector. However, once these projects, be it mega or otherwise, are completed and ownership is transferred, the post-construction phase of asset management is noticeably neglected, if not ignored totally. And this national reality is witnessed in the building facilities of public universities in the country. In this research paper, a modest attempt is made to examine the building maintenance practice of the nation, factors affecting proper maintenance management, and challenges faced. A thorough investigation of the current situation of building facilities of public universities in Addis Ababa is made. Along with that significant focus is made to develop a viable maturity rating model for building maintenance management of public universities in Ethiopia. A multi-case study was conducted on the three public universities in Addis Ababa. The research approach of this study is both deductive and inductive research. Both quantitative and qualitative data are collected from primary and secondary data sources by document analysis, observation, and semi-structured interviews of the FM office and project office representatives of each public university. All the semi-structured interviews, document analysis, and observation data were analyzed using the thematic and statistical analysis method. The three main objectives of this study are effectively addressed. When it comes to identifying factors that influence the proper practice of building maintenance management in public universities in Ethiopia, the main factors were grouped under seven categories and five critical factors. Finally, a built asset maturity rating model is proposed based on the weights calculated by DEMATEL, MCDM analysis weights that can be used as a self-assessment tool by public universities in Ethiopia.

Keywords: Facility Management Asset, Maintenance, Maturity Rating Model, DEMATEL

BACKGROUND

Based on previous unpublished master's thesis works, maintenance management seems to be an ignored sector in the Ethiopian Construction Industry, facing multiple challenges for several reasons. For instance, Nibret (2015) identified the following seven key challenges in managing public university building facilities: lack of building operation and maintenance policy; unavailability of professional facility managers; unavailability of organized Facility and Maintenance Management department under public organizations; poor planning of facility management; unavailability of training for building maintenance staffs; lack of regular building condition survey; and inaccessibility and inability to use technologies like computerized maintenance system to simplify building facility management.

In addition, Sahelu (2015) identified corrective maintenance as the only type of maintenance used in Addis Ababa's public hospitals. Even the practice of corrective maintenance was found to be ineffective.

From these studies, one can understand that there is a great demand for the development of a maturity rating model that has the potential to minimize the existing challenges of facility and maintenance management practice in Ethiopia. This helps identify current practice, determine strengths & weaknesses, analyze the gap, capture the level of awareness and understanding, and pinpoint stakeholders' needs, which paves the way to design a policy framework.

Maintenance management integrates multiple disciplines to influence the efficiency and productivity of economies of societies, communities, and organizations and how individuals interact within the built environment. Facility and Maintenance Management affects the health, well-being, and quality of life in the world's societies and populations through the services it manages and delivers (ISO, 2018). While Facility and Maintenance Management has such a broad impact, recognizing its principles, policies, and practices at a global level is low; the practice in the case of a developing country like Ethiopia is even at a much lower level.

Moreover, prior studies indicate a lack of system that helps the built environment be safe, productive, and convenient to end-users in the Ethiopian construction industry (Nibret, 2015; Takele, 2017; Nuru, 2020). Hence, this study attempts to design a maintenance maturity model that could be used as an input for asset owners, public property managers, and private building owners to improve the performance of the Facility and Maintenance Management sector based on best practices and benchmarks. A maturity model is developed that is tailored to the practices of maintenance management by taking public universities in the country as case studies. This model can be used as a tool for improvement as it can explain the aspects and criteria that can be improved by universities in a stepwise manner and does not become a burden. The model can also be used for other institutions and/or government organizations by making a few adaptations/modifications to meet their needs.

Research Question

This research addresses the following research questions:

- What is the maintenance management practices of public university building facilities in Ethiopia?
- What are the factors that affect the maintenance management practice of building facilities in Ethiopia?
- What type of maintenance management maturity model can be used to shift the existing level of maintenance management practice to an advanced level?

Research Objectives

The study aims to assess the current level of maintenance practice and develop a maintenance maturity/rating model that can serve as an input in shifting current maintenance practices of buildings.

The specific objectives of this study are listed as follows:

- Assess current practices of maintenance management by taking public university building facilities in Ethiopia as case studies
- Explore factors that influence the practice of building maintenance management
- Develop a maintenance maturity rating model that can help shift current maintenance practices into improved levels

LITERATURE REVIEW

Construction Process and Asset Life-cycle Delivery

Building maintenance management is a fundamental component of facility management (FM), which integrates many disciplines that affect the efficiency and productivity of economics of societies, communities, and organizations, as well as how people interact with the built environment. FM affects the health, well-being, and quality of life of much of the world's societies and population through the services it manages and delivers (ISO, 2018E). While FM has such a broad impact, recognition of its principles and practices at a global level has been lacking. Moreover, in the case of developing countries, the sustainable facilities management process and practices are unclear and immature (Zakaria, Hashim and Ahzahar, 2018) and (Olayinka, 2018).

Every asset has a life-cycle, and infrastructure is no exception. These cycles cover the asset's entire life cycle, from conception to decommissioning, this includes the planning and design phases, construction (implementation), and service (operation) life phases. (Rahman and Vanier, 2004).

Organizations are trying to comprehend the implications of the ISO 55000 Asset Management Standard, which is rapidly developing in physical asset management. Each company has its own reasons for adopting Asset Management standards and principles, but they ultimately come to the same conclusion: Would investing in an asset management system deliver a long-term competitive advantage? Will companies obtain the required value from their assets if they employ an asset management system to optimize cost, risk, and performance throughout the asset life-cycle?.

Understanding the essential components of an asset management system is crucial to determine whether deploying it is worthwhile. The Asset Management System Framework established by the life-cycle cost engineering (LCE), provides the key links between the elements of an asset management system and the value that the system may generate. Leadership, policy, and strategy are broad factors required for developing the organization's commitment to an effective asset management system, according to ISO 55000 these components outline the governing principles and explain how asset management will help the business achieve its goals and objectives.

Public Infrastructure Asset Management in Ethiopia

Organizations, whether commercial or public, are required to provide the highest value in asset management and related services (e.g. education and health sectors). According to the World Bank (2019), the federal government of Ethiopia does not maintain a comprehensive and consolidated register of its fixed assets. Presently, fixed-assets management is decentralized at the budget unit level. It was reported that asset registers maintained by these budget units do not provide information on the age and usage of assets. This report rates the current practice of public asset management at the budget unit level as “D,” with “A” being the best practice.

Though Article 65 of the Federal Government Procurement and Property Administration Proclamation No. 649/2009 dictates all heads of budget units to record the date, description, quantity, and cost of acquisition and indicate the custody and usage of fixed assets, there is, however lack of clear and comprehensive asset management policy at the federal government level. If the policy was implemented properly, each budget agency would have been required to maintain an asset register for buildings, roads, bridges, dams, irrigation systems, heavy equipment’s and etc. However, the World Bank (2019) report indicated that there are no records of land, buildings, and subsoil assets.

Public infrastructure asset implementing agencies like Ethiopian Roads Authority(ERA) spend 50 Billion ETB annually, Addis Ababa City Roads Authority(AACRA) spent 3.9 to 5.8 Billion ETB annually for the past three consecutive years, Ministry of Science and Higher Education, (MOSHE) spent 20-25 Billion ETB annually for the past three years and Ministry of Health, (MOH) spent 9-15 Billion ETB annually for the past three consecutive years, hence these agencies spent a lot of money on public infrastructure assets (MoF, 2021). Hence, how agencies now acquire, hand over, and manage constructed facility assets after construction, as well as how they decide their long-term usage, must be analyzed and appraised. Nonetheless, no uniform policy, method, or asset management approach based on cutting-edge technology has been created. As a result, public infrastructures require proper management and maintenance over their entire life cycle in order to get the best value for the resource invested (MoF, 2021).

Public University Establishment and Expansion

It is strongly believed that higher education in Ethiopia has a base on the traditional church education system of the Ethiopian Orthodox Church. The Church has been training priests and spiritual leaders in its own disciplines for more than 1,700 years as argued by Bishaw & Melesse (2017). In Ethiopia, modern education ‘in a university setting’ is only around 70 years old. Ethiopian universities are divided into generations based on their founding year, namely 1st generation, 2nd generation, 3rd generation, and 4th generation. Eight (8) universities are classified as first generation, thirteen (13) as second generation, and the remaining eleven (11) and twelve (12) universities are classified as third generation and fourth generation universities, respectively.

Leadership of Public Universities in Ethiopia

The 2003 Higher education proclamation of Ethiopia identified three major bodies with authorities for the management of public universities: the ***Board*** to act as the head of the general administration accountable to the Ministry; the ***Senate*** which is accountable to the head of the University; and ***University President*** who is considered as CEO’s of the university.

Facility Management Practice

The international association of facility management, IFMA defined FM as ,“a profession that encompasses multiple disciplines to ensure functionality, comfort, safety and efficiency of the built environment by integrating people, place, process and technology”(Iso, 2018). The practice of (FM) is the process by which organizations guarantee that their buildings, systems, and services support core activities even while contributing to the attainment of their strategic goals under stable business conditions. FM services were first provided in the 1950s and 1960s in the USA and were fully developed in the 1970s, while in Europe FM practices had started to develop in the 1980s (Nielsen, 2012). The United Kingdom was the first country in Europe where FM practices began to grow. Back then, the United Kingdom was recognized as Europe's most important FM market, followed by Germany and France (Sari, 2018). The FM practices in Asia and Africa are still considered newcomers in the industry if compared to those in Europe and the USA. Hong Kong as the door to Asia and the meeting point of western and Asian culture has become one of the leading countries of FM in Asia. FM in Hong Kong has begun in 1994 under the local IFMA (Isa et al., 2016) and (Maliene, Alexander and Lepkova, 2008). Ethiopian FM practice has numerous challenges including lack of policy or standards, lack of skilled manpower in the Public University buildings, lack of Integrated FM, and inefficient FM planning (Belaynesh Nibret, 2015). In general, Ethiopia is still considered a greenhorn in the FM industry when compared to other countries, particularly developed ones. Currently, internationally, FM has expanded far beyond the realms of real estate management and the tradition of building maintenance to the level where facilities are considered as strategic business resources and have developed into integrated facilities management services.

Building Maintenance Strategy and Policy

Building maintenance management is a fundamental component of facility management (FM). BS 3811:1984 defined Maintenance as a combination of any actions carried out to retain an item or restore it to an acceptable condition. The term acceptable condition seems to be more subjective and needs further explanation. According to British Standards Institution (1993), maintenance is defined as "The Combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function." Chanter & Swallow defines maintenance as "Work which is undertaken to keep, restore or improve every facility, i.e., every part of the building, its services and surrounds to a currently acceptable standard and to sustain the utility and value of the facility" (Chanter and Swallow, 2007) according to Al-Zubaidi the prime aim of building maintenance is to preserve a building in its initial effective state, as far as practicable, so that it serves its purpose effectively (Al-Zubaidi, 1997).

Atkin and Brooks (2015) stated the importance of a Building Maintenance strategy "A well-defined maintenance strategy will support the organization's business objectives; whereas a poorly defined strategy, or none at all, could have significant adverse on safety, legal and commercial consequences" (Brooks, 2015). The authors also relate the importance of maintenance in fulfilling the environmental and social responsibility commitments and target its dependence on a clear maintenance strategy. The strategy needs to be dynamic to accommodate the evolving needs of business objectives.

Maintenance strategy should be prepared in a way that can meet current and future needs by considering the facility's capacity to deliver the service demanded from it.

- It must be reviewed annually to ensure that it meets the business' objectives
- It must consider the total cost of ownership (Life-cycle costing approach)
- It should be an integral part of the facility management strategy.

Policies give standards for decision-making, but they also allow for a certain flexibility. They show the "why" behind a specific action. A policy is a set of general rules and regulations that serve as the framework for making day-to-day decisions.

A maintenance policy should be developed to support the preparation of operational plans in line with the maintenance strategy. The policy should outline the scope and actions to be taken to meet business objectives and how those relate to goals defined in the facility management strategy to maintenance (Brooks, 2015)

Factors Influencing the Practice of Building Maintenance Management

Different scholars have identified the crucial determining factors that can impact the course of Building Maintenance management from multiple contexts and perspectives for various functional buildings, focusing on developing countries. For instance (Buys & Nkado,2006; Islam et al., 2019; Talib et al., 2014; Dahal & Dahal,2020; Zillante, 2007; Faremi, 2009; Uguwu et al., 2018; Ogunmakinde, 2015; Mkilania, 201) have identified the diverse factors that influence the successful implementation of Maintenance practices in the context of both developed and developing countries. Hossanain et al. (2013) and Jandali & Sweis (2018), on the other hand, identified and grouped these characteristics into seven influential groups listed below: Statutory requirements, design phase, construction phase, maintenance department, maintenance budget, maintenance group operations, and community perception about maintenance industry.

Building Maintenance Maturity Model

Maturity models came into the scene based on Crosby's (1979) Quality Management Maturity Grid, which established a model based on five incremental stages of maturity for quality management in an organization. (Fryer, Ogden, and Anthony, 2013) proposed five maturity stages based on (Bessant et al., 2001) to develop continuous improvement skills, allowing firms to plan and grow the quality of organizational processes by developing a strategy to increase their ongoing improvement abilities. The ISO 9004:2009 (2009) standard includes a quality management maturity model.

A maturity model is a conceptual framework made up of constituent pieces that define the maturity of the area of interest. In certain situations, it also explains the processes that the organization will need to develop to achieve the desired future.

Another definition presents maturity as the development of systems and processes that are repetitive by nature, setting a high probability that each one of them is successful. However, repetitive processes and systems are not by themselves a guarantee of success. They only increase its likelihood. Developing maturity is a continuous process. Improvements in maturity depend on a concentrated effort to create, improve and foster communication between executives and professionals. To achieve the outlined strategic objectives, organizations use maturity scales to measure results and the level or degree of maturity that the organization finds itself regarding project management practices (Talita Ferreira de Souza, 2015).

Maintenance Management Maturity Models

In the field of quality, Antil (1991) suggested a model that has been driven by and heavily based on Crosby's (1979) maturity model. Fernandez et al. (2003) used this model to determine where organizations stand in maintenance to build and implement a computerized maintenance

management system (CMMS) that meets their demands. According to the concept, maintenance progresses from a mostly reactive state in the early stages to a preventive and predictive state later. It includes some areas of maintenance management, such as problem-solving methodologies, a software tool to support the management of maintenance activities, and concerns linked to posture in maintaining companies' equipment, with its four classes of evaluation.
Wireman (1992) also developed a maturity model for maintenance management that follows the structure of Crosby's quality model and transforms terminology connected with quality to terms associated with maintenance in certain circumstances. The classes include topics such as the organization's maintenance posture, maintenance resources, maintenance organization, improvement initiatives, and system information and qualification. The maintenance resources class adopts goals that determine the percentage of resources wasted to define each maturity stage. In applying the model to various organizations and activity areas, defining stages by fixed goals may result in inaccessible stages and unequal difficulty in reaching the same level in various companies. When it comes to how well a given task is conducted, the class associated with worker qualification uses intangible issues. Importantly, the model combines two crucial aspects of maintenance: maintenance information and improvement actions, into a single category.

This study's maintenance maturity rating model will be based on the building Maintenance process and departmental organization perspectives as an evaluation dimension to adapting the models from the above-discussed models. The new maintenance management maturity model to be developed will also be based on the focus group discussion results, which has involved professionals from academia, industry practitioners, university FM, and Maintenance managers.

One of the ways to address the challenges in building maintenance and FM is to improve the outcome of the decision-making process with a structured and systematic approach. Since building maintenance decisions are complex with conflicting criteria, an MCDM approach may effectively address these challenges in the process of building the maturity rating model.

The application of multiple criteria decisions making (MCDM) enables decision-makers to create their own set of essential criteria/dimensions for evaluating the maturity of building maintenance management for a built asset.

The present study employed twelve main maturity dimensions in which 51 (fifty-one) indicators are used to measure built asset maturity level in Table 1. The description for each dimension is written in the table below.

	Dimensions /Perspective	Indicators (KPIs)	Descriptions	References
D1	**Maintenance Policy and Strategy**	Availability of Built Asset management strategy and planning (D11)	a long-term optimized approach to managing the built assets, derived from, and consistent with, the organizational strategic plan and the asset management policy.	(Maletič *et al.*, 2020),(Omar, Ibrahim and Omar, 2017),(Oliveira,2020),(PAS5,2008) and (ISO55000)
		Availability of built Asset management policy (D12)	Built asset Policy is a set of common rules and regulations that serve as the foundation for built asset maintenance decision making.	(Maletič *et al.*, 2020), (Seeley,1987),(Omar, Ibrahim, and Omar, 2017), (ISO55000,2014),(Brooks,2015), (Olarewanju,2015)
		Alignment of Built Asset management objectives with Corporate objectives (D13)	Refers to the alignment of built asset maintenance objectives with corporate business objectives of the organization	(Seeley,1987), (Maletič et al., 2020)
		Built asset maintenance task planning and scheduling (D14))	It involves analyzing the current condition of the building, anticipating future requirements, and bringing the past to focus.	(Omar, Ibrahim and Omar, 2017), (Olarewanju,2015),Cholasuke et al (2004
		Availability of defined built asset Maintenance approach/s (D15)	The balance of maintenance approach for each class of building asset between corrective (when it failed), preventive (maintain regularly), predictive (maintain before it failed), and proactive(maintain the root causes as against the symptoms)	(Hirsch, Anderson, and Melo, 2013), (Olarewanju,2015),(Oliveira,2020),Cholasuke et al (2004)
D2	**Human Resource Management**	Competency of in house maintenance staff (D21)	The ability of staff to apply knowledge and skills to achieve intended results/Knowledge and competencies; development of employee competency	(Maletič *et al.*, 2020), (ISO55000,2014)
		Training programs to maintenance staff (D22)	Availability of good quality training programs in different trades for the maintenance staff	Overachieve,2019), (Olarewanju,2015); Misnanb and Mariah Awanga,2012
		Motivation and inspired teamwork of maintenance staff (D23)	Availability of a conducive and supportive environment that facilitates inspiration and teamwork among maintenance staff	(Olarewanju,2015),Cholasuke et al. (2004)
D3	**Technical and Functional Appropriateness**	Building asset Capacity (D31)	The physical capacity of the built asset to support the level of current and future service activity	(Queensland government, 2017)
		Building asset Functionality (D32)	The suitability and flexibility of the building asset for current and future service delivery.	(Queensland government, 2017)
		Building asset Location (D33)	The physical location of the building asset, relative to current and future demand for services. In dynamic demographics and infrastructure planning, this indicator is an important consideration.	(Queensland government, 2017) and (Olarewanju,2015)
		Building asset Condition (D34)	The physical condition of the building asset appropriate for current and future service activity	(Queensland government, 2017), Deniz Besiktepe et.al (2020),Johnson and Wyatt, Yau, 2012 1999, Ali, Kamaruzzaman,Sulaiman, & Peng,2010
		Technical practicality of Building asset (D35)	The time to complete, reliability to function, regulation and bureaucracy, and site accessibility of built asset to maintenance	Deniz Besiktepe et.al (2020), Kim, Sunitiyoso, & Medal (2019)

D4	**Maintenance Organization**	Organization of Maintenance department (D41)	Delegation of duties, roles, and responsibilities to all maintenance staff and allocation of resources to tasks	(Olarewanju,2015)
		Alignment of Maintenance with organizational objectives (D42)	The maintenance department is organized in a way to aligns with the strategic business objectives	(Olanrewaju and Abdul-Aziz, 2015)
		The efficiency of the maintenance process and work Instructions (D43)	The maintenance organization's Mission Statement, underlying purposes, and values should promote user happiness and productivity. the integration of the asset management system into the quality management system	Johannes, Koos et al ,2021), (Olanrewaju and Abdul-Aziz, 2015)
		Organizational position of maintenance department (D44)	It refers to the organizational location of the maintenance department as (strategic, tactical, and operational) as one of the important strategic units or departments within the organization	(Olarewanju,2015)
D5	**Maintenance Information Management**	Completeness, accuracy, and validity of built asset data (D51)	Measures the accuracy, completeness, and validity of built asset data	Volker,2013
		Built asset registry and asset history of enhancing asset knowledge (D52)	sound registration of asset data as a basic pillar of built asset management	Volker,2013
		Use of Maintenance information management system (as-built documentation) (D53)	Existence of a defined maintenance information management system such as CMMS, CAFM, and BIM-FM) used to store, transfer and retrieve built asset information	Volker,2013,Cholasuke et al (2004), (Queensland, 2017)
		Use of data Capturing Technologies from exiting built asset(D54)	Collecting data from existing built assets using technologies (laser scanners, drones, sensors, and detectors) as input for information modeling	Volker,2013,Cholasuke et al (2004), (Queensland, 2017)
D6	**Building Design Life**	Evaluation of capital expenditure requirements (D61)	Organization's investment decision in existing and new fixed assets to maintain or grow the business.	Bevilacqua and Braglia,2000),(Mansfield and Pinder, 2008), (Horenbeek and Pintelon, 2014)
		Modernization plan of the Built asset (D62)	The process of adapting an asset to the forces of technological obsolescence or functional obsolescence by replacing it with a newer asset.	(Mansfield and Pinder, 2008)
		Disposal plan of the built asset (D63)	A plan used by local governments and municipalities to manage their portfolio of a built asset	Campbell and Reyes-Picknell,2006
		Building remaining Life (D64)	An estimate of the building asset's remaining useful or economic life in terms of its future potential to sustain the delivery of services or the costs of ownership and use not being viable.	Flores-Colen, Brito, & Freitas, 2010 (Queensland government, 2017)

METHODOLOGY

The objective of this research is to assess the current level of maintenance practice and develop a maintenance maturity/rating model that can serve as an input in shifting the current maintenance practices of buildings. A multi-case study was conducted on the three public universities in Addis Ababa. The research approach of this study is both deductive and inductive research. Both quantitative and qualitative data are collected form primary and secondary data sources by document analysis, observation and semi-structured interviews of the FM office and project office representatives of each public university. All the semi-structured interviews, document analysis, and observation data were analyzed using the thematic and statistical analysis method.

The population of this study for the survey part of the study is assumed to be all university building facilities found in Ethiopia. For objectives one and two, the study adopts a systematic random sampling technique for the quantitative approach and purposive sampling for qualitative approaches by which viable data can be obtained from a specific group of people, as argued by (Grisham and Fellows, 2008) and to conduct a content analysis of cases in the qualitative approach (Djamba and Neuman, 2002). In purposive sampling, the members for a sample are selected according to the study's purpose. The purposive sampling method is criticized for its bias and absence of randomization while collecting data. However, this error can be eliminated by choosing an appropriate data source from the most reliable professionals, as stated in (Djamba and Neuman, 2002). Hence, this study focused on achieving the criteria by collecting data from university presidents, vice presidents, professors, facility maintenance managers, and university construction projects coordination officers who are highly involved with university facilities management to acquire reliable and high-quality information. For objective three, a focus group discussion was performed, taking participants from professionals who have high attachment to university project construction (consultants and construction firms), university facility managers, maintenance managers, and individuals from the Ministry of Education and academia who are involved in teaching and research activities in Ethiopia.

A focus group comprises target participants with a moderator(s); it can have two (dyad), three (triad), four to six (mini-group), 7–10 (small group), or 11–20 participants (super-group) (Chan et al., 2012). However, a small group is usually adopted for research that seeks to understand participants' deep feelings (Chan et al., 2012).

As recommended by many researchers, for the current study, an optimal mini-to-small group size of 5–10 participants can be used to maintain a balance between depth and breadth in the discussion (Chan et al., 2012)(Chan, Leung, and Yu, 2012). Hence, in this study, Focus Group Discussion was used as a research instrument to collect data to achieve the third objective.

RESULT AND DISCUSSION

This section includes the analysis of the three main objectives addressed in this study. The first subsection covers the current maintenance management practices of public university building facilities in Ethiopia. The second part of the analysis explores the factors that influence the practice of building maintenance management. The third part describes developing a building maintenance maturity rating model that can help shift current maintenance practices to improved levels.

Current practices of maintenance management in public university

From the respondents' background depicted below in Table 2, 50 % of the respondents are lecturers (university professors who might have been involved in facility-related activities and had experience in managing maintenance or facing difficulties in using existing facilities as an end-user),19.1% of the respondents are Vice presidents who are the strategic level FM managers, (11.8%), Construction project managers involved in the management university facilities during planning and construction (10.3%) are either FM or Maintenance managers directly involved in FM activities, and students (8%). Moreover; (34.70%) of the respondents have an engineering background by profession. The level of academic achievement and experience would be a metric in an online survey to measure the respondents' capability, skill, and level of knowledge. Regarding their highest academic qualification, 13.3% were full professors or associates, 36 % held a Ph.D., and 44 % had taken a master's degree.. Information regarding their experience is 56% of had more than ten years of experience managing or using university facilities. Out of 207 distributed survey questions to respondents, 76 responses were received, providing a response rate of 36.71 %. Out of 76 respondents, only one response was rejected due to an incomplete response. All questions were fully answered, and there were no ambiguous responses. As stated in (Tan et al., 2014), a 10%–20% response rate is acceptable in a research survey. And, the response rate of this survey is pretty much above the minimum threshold.

Strategic consideration in facilities Maintenance

According to the analysis, 70.6 % of respondents agreed that the issue of FM is addressed in the main strategic plan of public universities. The reality, however, is very different from the survey's analytical results. and the interview results can be used to justify the discrepancy. Respondents were also asked for their thoughts on how the Maintenance Management plan aligns with the university's overall strategic plan. About 62.66 % of the respondents agree that maintenance activity is guided by the university's strategic plan. Furthermore, 86.66 % agree that FM department operations should play an important role in fulfilling the university's core business. Despite this, 73.33 % of respondents reported that there are building defects owing to incorrect maintenance or no maintenance operations done physically on facilities in Ethiopian public universities, as evidenced by the real states of structures on the ground.

1. Availability of Building Maintenance policy in the university

Only 36% of the respondents believed in the existence of a maintenance policy in the university. The rest, 64% of the respondents, responded that no maintenance policy is applicable for maintenance operations in public universities. Moreover, all the six interviewees also confirmed the lack of policy is one of the key determinants of good maintenance practices.

2. Organizational Management level of Facility management

The management position and capability of the Maintenance department or directorate impact establishing appropriate policy and preparing an integrated plan within the university's main strategies. However, only 22% of maintenance managers are at a strategic level, 50% at the tactical level, and 23% at the operational level, which indicates that less concern is given to building facility management with a limited decision-making capacity, especially at the tactical and operational level.

3. Maintenance strategy or approach in use by public universities

For an efficient maintenance Management process, a preventive approach is preferred over corrective maintenance, where corrective maintenance has to complement preventive maintenance. However, 74.65% of the respondents indicated that public universities are practicing only corrective maintenance strategies, resulting in unplanned expenditures for unplanned maintenance activities.

4. Maintenance Procurement strategy in public universities

The procurement strategy is another determinant of proper maintenance practice. Accordingly, the study has tried to identify the maintenance strategy used by most public universities. However, the result indicated the existence of mixed approach, which is 27 % in-house and 45.97%. Respondents were requested the availability of FMM information during the operation and maintenance stages of facilities. Accordingly, most of the respondents (78.35%) indicated the difficulty of getting FM-related information for Maintenance operations in public universities in Ethiopia.

5. Building Defects in public university buildings

The poor practice of building maintenance management can be verified by the number and availability of unrectified building and facilities defects in Ethiopia's asset portfolio of public universities. Respondents were asked to rate how buildings are free from defects and convenient for the core business of universities. Accordingly, 73.33 % of the respondents agree that there are several unrectified building defects indicating poor building maintenance practices in public buildings in Ethiopia.

6. Facilities or Building components that require frequent maintenance

Respondents were asked to indicate the facilities or building components that require more frequent maintenance. According to tier response sewerage lines, water supply lines, and fixtures account for 49.33 %, and electrical lines and fixtures account for 30.67 %. This indicates that service lines' construction quality and maintenance operation made on these components is doubtful, is also in compliance with the observation made for selected case university facilities in Addis Ababa.

7. Availability of data, documents, and manuals required for maintenance operations

This research has also evaluated the availability of maintenance manuals, drawings, and data needed for maintenance activities. As a result, the analysis of the questionnaire survey, Addis Ababa case studies, and face-to-face interviews showed a key difficulty in the loss of data transferring and information from developer to owner during project handover. According to the results of the questionnaire survey, 78.38 % of respondents agreed that there is a lack of information and an acceptable file management system (the filing system is mostly traditional). This is one of the most pressing issues confronting maintenance departments in Ethiopia's public universities. During the face-to-face interview and site observation, the outcome is validated. Furthermore, in public universities, there is a lack of organized maintenance information management systems. This was also indicated by 72.0% affirmation.

Critical factors affecting the practice of Building Maintenance Management

This section describes the most critical factors that influence the proper practice of Facilities Maintenance in public universities in Ethiopia. The mean and SD for each factor were calculated, followed by a ranked order analysis using the RII value (equation 1). When two or more factors have the same RII value, the SD values are compared, and the lower SD is considered the higher rank. If the RII value and SD are both the same, they were assigned to the same rank as argued in Tan et al. (2014) and Islam et al. (2019) for similar studies. The RII was derived from summarizing the importance of each critical factor that influences the practice of facility maintenance management in public universities of Ethiopia.

$$RII = \frac{\sum w}{AN} = \frac{5n_5+4n_4+3n_3+2n_2+1n_1}{5N} \qquad \text{Equation 10}$$

Where, W = weighting as assigned on Likert's scale by each respondent in a range from 1 to 5, where 1 = strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5 = strongly Agree. N =Total number in the sample.

Table 2: Critical factors that influence the practice of FMM practices

Serial		Critical Factor	Mean	SD	N	RII	Rank
1	Statutory (SRF)	Lack of building maintenance standards, policy, codes, Strategy and procedure	4.133	0.9772	75	0.827	9
2		The method of awarding maintenance contracts	3.493	0.9778	75	0.699	32
3		Unavailability of Specialized Maintenance contractors	3.880	1.0522	75	0.776	23
4		Unavailability of FM or Maintenance productivity standards and specification	4.093	0.9469	75	0.819	14
5	Design (DRF)	Error in Design	3.733	0.9910	75	0.747	26
6		Construction materials quality, specification and selection	4.120	0.9720	75	0.824	13
7		Failure to consider life cycle costing analysis	4.147	0.8806	75	0.829	8
8		Non-involvement of Maintenance/FM professionals during design phase	3.676	1.1599	75	0.746	27
9		Inefficient Architectural and or/Structural design	3.667	0.9202	75	0.733	28
10		Design Complexity	2.667	0.9910	75	0.533	33
11		Inadequate experience of Design Professionals	3.520	0.9913	75	0.704	30
12	Construction (CRF)	Poor Construction Quality	4.240	0.8194	75	0.848	5
13		Lack of Communication and Collaboration skill	3.987	0.8620	75	0.797	19
14		Faulty/Poor workmanship quality during construction	4.067	0.8751	75	0.813	17
15		Unavailability and/or poor quality of replacement parts & components	3.905	0.9955	75	0.792	20
16		Lack of coordination between construction & maintenance groups	4.173	0.8601	75	0.835	6
17		Inaccuracy of as-Built Drawings	3.773	0.9942	75	0.755	25
18	Maintenance Management (MMDF)	Lack of preventive maintenance method	4.467	0.6844	75	0.893	1
19		Lack of Maintenance Plans & Schedules	4.400	0.6576	75	0.880	2
20		Inadequate training to Maintenance personnel	4.160	0.8227	75	0.832	7
21		Unavailability and lack of skilled and appointed maintenance staff	3.867	1.0569	75	0.773	24
22	Maintenance Budget (MBRF)	Insufficient/ Unavailability of Budget for Maintenance of buildings	3.667	1.1663	75	0.733	29
23		Failure to forecast the accurate maintenance expenditures	4.133	0.9633	75	0.827	10
24		Difficulty in procurement of spare parts/ Procurement rules, regulations	3.947	1.0253	75	0.789	21
25	Maintenance Team Operations (MTOF)	Low concern of future maintenance of existing maintenance team	4.014	0.6971	75	0.825	11
26		Poor maintenance work done by the maintenance unit of the institution	4.068	0.7822	75	0.824	12
27		Poor work rectification done on buildings.	4.067	0.7769	75	0.813	18
28		Lack of Building Maintenance manual	4.093	0.9325	75	0.819	15
29		Lack of as built documentation/Database of maintenance works	4.307	0.8378	75	0.861	3
30	Community Culture, Growth and learning (CCGLF)	Lack of effective Maintenance culture	4.280	0.8631	75	0.856	4
31		Misuse of facilities by occupants /attitude of users	4.093	0.8570	75	0.819	16
32		Delay in occupancy after completion	3.507	1.0827	75	0.701	31
33		Underestimating the impact of FM	3.893	1.1098	75	0.779	22

Note: Bold values highlights the top most Eighteen RII values and ranking, with a mean value >4.0

As indicated in Table 2, the respondents ranked lack of preventive Maintenance method (mean =4.47) as the most critical factor that affect maintenance practices often caused by the absence of appropriate maintenance strategy or approach, which indicated that university maintenance operations are not led by proper strategy. This factor was also the most critical, as confirmed by Talib et al. (2014) and Jendali & Sweiss (2018) in Malaysia and Jordan.

The lack of preventive maintenance methods affects maintenance operations' entire process and practice as the maintenance staff is highly engaged in unplanned day-to-day operations. It can be seen from the data in Table 2 that lack of maintenance and schedules is the second most influential factor impacting the practice of facility maintenance management (mean 4.40, RII=0.88). The result indicates that proper maintenance planning and scheduling are identified as non-existent in public universities in Ethiopia, which is in congruence with the findings of previous studies Malaysia (Islam, Nazifa, and Mohamed, 2019), whereby the lack of a maintenance management plan and the schedule was attributed to causing high maintenance budgets which ultimately resulted in high cost of maintenance operations.

The third top-ranked critical factor is the lack of as-built documentation and the unavailability of the database for maintenance activities (mean = 4.47, RII value 0.861), table 2. The outdated traditional filing system and lack of maintenance activities are critical challenges (Mkilania, 2016) in public institutes in a similar context.

The community culture, learning, and growth that arise from the community’s learning, cultural background of facility users hinder the proper practice of FMM in public universities. Lack of effective maintenance culture has affected maintenance practices (Mkilania, 2016; Akinsola et al., 2012) and are critical challenge in developing countries like Tanzania and Nigeria.

The survey result shows that poor construction quality is one of the most influencing factors (5th), with an RII of 0.848 in Table 2. This value also indicates that how construction stage supervision (Ajetomobi and Olanrewaju, 2015), poor quality components (Ajayi, 2014), and poor craft quality Jandali & sweis (2018) are highly associated with the quality management system used during the construction stage can significantly affect maintenance operations. Moreover, design stage factors such as failure to consider life cycle cost analysis and non-involvement of FM professionals during design and construction stages can attribute to poor construction quality.

Lack of coordination and communication between construction and maintenance groups is ranked in the 6th, (mean= 4.17 & RII=0.835), in Table 2 is also considered a more influencing factor in FMM practices of public universities in Ethiopia. This result repeats the findings of Hassanain et al. (2013) in Soudi Arabia and Jandali & Sweis (2018) in Jordan. Efficient use of recent developments in information management, including building information modeling, can improve the coordination and communication gap amongst involved stakeholders in the construction and maintenance stages (Moreno, Olbina, and Issa, 2019).

Development of Building Maintenance Maturity model

To identify the maintenance maturity dimensions and indicators under each dimension, the mixed fuzzy DEMATEL method was used. Twelve maintenance dimensions and three to six indicators under each maintenance dimension were identified. This section will present and discuss the result from the fuzzy DEMATEL hybrid method. The method is used to evaluate the cause-and-effect relationship among maintenance dimensions and indicators through the focus group study to identify building maintenance maturity measurement dimensions and indicators to develop a building maintenance maturity model. For this purpose, the focus group discussion was performed with participants who were requested to provide their expert opinion using the DEMATEL questionnaire. Acquiring the result of the Fuzzy DEMATEL analysis based on the expert's judgment was the first step.

Procedure for Fuzzy DEMATEL Analysis

DEMATEL(Decision making trial and evaluation laboratory) is a commonly used MCDM method to analyze causal relationships, which requires a group of experts judgment in pairwise form (Asan et al., 2018). As the expert's judgments are subjective and have some inaccuracies and vagueness in a real-life situation, a fuzzy set theory that applies fuzzy number is introduced to solve such a problem in decision-making (Uygun, 2016). Therefore, this study applies a fuzzy DEMATEL hybrid method using Triangular Fuzzy Numbers (TFNs).

Step 2: **Aggregate assessments of expert groups and set up the group direct-influence fuzzy matrix $\tilde{Z}$ is de-fuzzyfied.**

Transform the fuzzy group assessments into crisp values and form the group direct-influence matrix *Z* At this stage, the individual direct influence de-fuzzified matrix is aggregated to set up the group direct influence matrix. In this study, the individual fuzzy matrix obtained from *twelve* experts in two groups involved in the DEMATEL survey is de-fuzzyfied using the weighted average defuzzification method (equation 2) and aggregated, shown in table 3.

$$x_{lj} = \frac{x_{ij}^{L} + 4x_{ij}^{M} + x_{ij}^{U}}{6} \qquad \textbf{Equation 11}$$

Table 3: Group Direct-Influence DE-fuzzyfied matrix $\tilde{Z}$ using the weighted average method

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0.00	0.63	0.96	0.63	0.60	0.25	0.96	0.75	0.50	0.75	0.63	0.85
D2	0.38	0.00	0.60	0.85	0.50	0.25	0.63	0.73	0.75	0.75	0.85	0.38
D3	0.38	0.38	0.00	0.38	0.63	0.50	0.85	0.15	0.50	0.85	0.85	0.85
D4	0.38	0.85	0.38	0.00	0.75	0.15	0.96	0.63	0.63	0.63	0.85	0.25
D5	0.38	0.50	0.85	0.75	0.00	0.73	0.75	0.25	0.73	0.85	0.85	0.50
D6	0.60	0.60	0.75	0.75	0.50	0.00	0.85	0.38	0.73	0.50	0.50	0.63
D7	0.60	0.85	0.50	0.85	0.50	0.75	0.00	0.50	0.85	0.63	0.73	0.50
D8	0.75	0.75	0.75	0.75	0.63	0.50	0.63	0.00	0.75	0.63	0.96	0.85
D9	0.25	0.25	0.50	0.50	0.63	0.25	0.75	0.25	0.00	0.63	0.85	0.38
D10	0.85	0.63	0.75	0.63	0.50	0.75	0.75	0.38	0.63	0.00	0.73	0.73
D11	0.50	0.96	0.85	0.75	0.73	0.63	0.85	0.63	0.63	0.75	0.00	0.63
D12	0.85	0.38	0.75	0.38	0.50	0.63	0.63	0.75	0.38	0.63	0.38	0.00

Step 3. Apply the classical DEMATEL approach

The group direct-influence matrix Z, the normalized direct-influence matrix X, and the total-influence matrix T can be obtained. Then the value of (r+c) and (r−c) can be determined based on the total relation matrix, and the cause-and-effect diagram can also be constructed using these values.

e). *Establish the normalized direct-influence matrix X,*

$$X = Z \cdot S \qquad \textbf{Equation 12}$$

$$\textbf{Where } S = min\left[\frac{1}{max\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{max\sum_{i=1}^{n}|a_{ij}|}\right] \qquad \textbf{Equation 13}$$

Table 4: Normalized direct-influence matrix *X*

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0.00	0.08	0.12	0.08	0.08	0.03	0.12	0.09	0.06	0.09	0.08	0.11
D2	0.05	0.00	0.08	0.11	0.06	0.03	0.08	0.09	0.09	0.09	0.11	0.05
D3	0.05	0.05	0.00	0.05	0.08	0.06	0.11	0.02	0.06	0.11	0.11	0.11
D4	0.05	0.11	0.05	0.00	0.09	0.02	0.12	0.08	0.08	0.08	0.11	0.03
D5	0.05	0.06	0.11	0.09	0.00	0.09	0.09	0.03	0.09	0.11	0.11	0.06
D6	0.08	0.08	0.09	0.09	0.06	0.00	0.11	0.05	0.09	0.06	0.06	0.08
D7	0.08	0.11	0.06	0.11	0.06	0.09	0.00	0.06	0.11	0.08	0.09	0.06
D8	0.09	0.09	0.09	0.09	0.08	0.06	0.08	0.00	0.09	0.08	0.12	0.11
D9	0.03	0.03	0.06	0.06	0.08	0.03	0.09	0.03	0.00	0.08	0.11	0.05
D10	0.11	0.08	0.09	0.08	0.06	0.09	0.09	0.05	0.08	0.00	0.09	0.09
D11	0.06	0.12	0.11	0.09	0.09	0.08	0.11	0.08	0.08	0.09	0.00	0.08
D12	0.11	0.05	0.09	0.05	0.06	0.08	0.08	0.09	0.05	0.08	0.05	0.00

f). *Construct the total-influence matrix T,*

$$T = X \cdot (I - X)^{-1} \qquad \textbf{Equation 14}$$

Were as ;

T= Total influence matrix; I = Identity Matrix and X=Normalized direct matrix

Table 5: Total-influence matrix *T*

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0.45	0.59	0.68	0.62	0.56	0.45	0.75	0.50	0.59	0.66	0.69	0.59
D2	0.45	0.47	0.58	0.59	0.50	0.41	0.65	0.45	0.57	0.60	0.65	0.48
D3	0.43	0.49	0.48	0.51	0.49	0.42	0.64	0.37	0.51	0.58	0.62	0.52
D4	0.44	0.56	0.54	0.48	0.52	0.39	0.67	0.43	0.54	0.57	0.64	0.46
D5	0.47	0.55	0.63	0.60	0.47	0.48	0.69	0.42	0.59	0.64	0.68	0.52

D6	0.47	0.54	0.60	0.58	0.50	0.38	0.68	0.42	0.57	0.57	0.61	0.51
D7	0.50	0.60	0.60	0.62	0.53	0.49	0.62	0.46	0.61	0.62	0.68	0.53
D8	0.56	0.63	0.68	0.66	0.59	0.50	0.75	0.43	0.65	0.68	0.75	0.61
D9	0.35	0.41	0.47	0.45	0.43	0.34	0.55	0.32	0.38	0.48	0.54	0.40
D10	0.53	0.58	0.64	0.60	0.54	0.49	0.71	0.45	0.59	0.56	0.68	0.56
D11	0.53	0.65	0.69	0.66	0.60	0.51	0.77	0.50	0.63	0.68	0.64	0.58
D12	0.48	0.48	0.57	0.51	0.48	0.43	0.62	0.44	0.50	0.56	0.57	0.42

g). *Calculate the sum of row & column of matrix T*

Table 6: Total-influence matrix T with (r + c) and (r − c) values

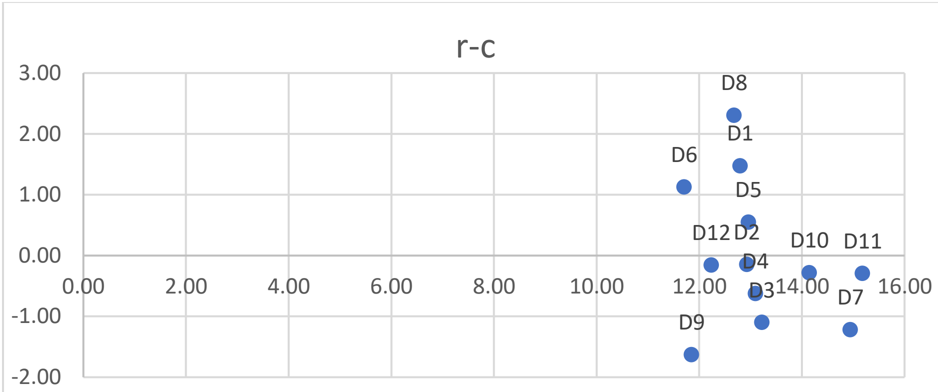
Whereas: **r** is the summation of the row and **c** is the summation of the column for each dimension

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	**r**	**c**	**r+c**	**r-c**
D1	0.45	0.59	0.68	0.62	0.56	0.45	0.75	0.50	0.59	0.66	0.69	0.59	7.14	5.66	12.80	1.48
D2	0.45	0.47	0.58	0.59	0.50	0.41	0.65	0.45	0.57	0.60	0.65	0.48	6.39	6.54	12.92	-0.15
D3	0.43	0.49	0.48	0.51	0.49	0.42	0.64	0.37	0.51	0.58	0.62	0.52	6.06	7.16	13.22	-1.10
D4	0.44	0.56	0.54	0.48	0.52	0.39	0.67	0.43	0.54	0.57	0.64	0.46	6.24	6.86	13.09	-0.62
D5	0.47	0.55	0.63	0.60	0.47	0.48	0.69	0.42	0.59	0.64	0.68	0.52	6.75	6.20	12.96	0.55
D6	0.47	0.54	0.60	0.58	0.50	0.38	0.68	0.42	0.57	0.57	0.61	0.51	6.41	5.29	11.70	1.13
D7	0.50	0.60	0.60	0.62	0.53	0.49	0.62	0.46	0.61	0.62	0.68	0.53	6.86	8.08	14.95	-1.22
D8	0.56	0.63	0.68	0.66	0.59	0.50	0.75	0.43	0.65	0.68	0.75	0.61	7.49	5.19	12.68	2.31
D9	0.35	0.41	0.47	0.45	0.43	0.34	0.55	0.32	0.38	0.48	0.54	0.40	5.11	6.74	11.85	-1.63
D10	0.53	0.58	0.64	0.60	0.54	0.49	0.71	0.45	0.59	0.56	0.68	0.56	6.93	7.21	14.14	-0.28
D11	0.53	0.65	0.69	0.66	0.60	0.51	0.77	0.50	0.63	0.68	0.64	0.58	7.44	7.74	15.18	-0.30
D12	0.48	0.48	0.57	0.51	0.48	0.43	0.62	0.44	0.50	0.56	0.57	0.42	6.04	6.19	12.23	-0.15

h). Build the cause-and-effect relationship diagram

The cause-and-effect diagram is constructed by mapping all coordinate sets of ri+ci and ri-ci to visualize the complex interrelationship and provide information to judge which are the most important Maintenance dimension and how they influence each other. A positive result of r-c shows that the dimension is in the cause category whereas the negative result is in the effect category.

Accordingly, D8 (Culture and Leadership), D1 (Maintenance Policy and Strategy), D6 (Building Design Life), and D5 (Maintenance Information Management) are causes of building maintenance management. D8 (Culture and Leadership) is the higher cause amongst all causes and is followed by D1 (Maintenance Policy and Strategy).



Determination of weights Maintenance dimensions using DEMATEL

The previous sections explained the procedure of analyzing experts' opinions using the Fuzzy DEMATEL hybrid method. In this section, the importance of maintenance dimensions from the focus group study is further analyzed using the fuzzy DEMATEL method. The final result shows their level of influence in measuring maintenance performances based on their weights.

As stated in the studies of Baykasoglu et al. (2013) and Dalalah et al. (2011), both stated in (Making and Kobry, 2017), DEMATEL method is also used to determine the weights of criteria using the following formula:

$$\boldsymbol{\omega_i} = \left((\boldsymbol{t_i^+})^2 + (\boldsymbol{t_i^-})^2\right)^{1/2} \qquad \textbf{Equation 15}$$

Where the values $\boldsymbol{\omega_i}$ can be normalized by the following equation,

$$\boldsymbol{W_i} = \frac{\boldsymbol{\omega_i}}{\sum_{i=1}^{n} \boldsymbol{\omega_i}} \qquad \textbf{Equation 16}$$

In the context of this study, the values t_i^+ and t_i^- are equivalent to the values of r+1 and r-c, respectively.

Wi is the last criteria weight to be used in the decision-making process. As stated in (Making and Kobry, 2017), the approach is not accurate since, by using the above equations, the same weight can be assigned to any two criteria, i and j, i and j, for which $r + c = r - c$ but $r - c = |r - c|$ (whereby $r - c < 0$).

Making and Korbry (2017) have proposed a different approach to determine the criteria weights using DEMATEL, which does not have the drawback mentioned above. By assuming that the indicators r+c and r-c can be determined from the total influence matrix resulting from the direct influence diagram.

The average r+c value can be determined from,

$$(r + c)_i^{average} = \frac{1}{2}\left((r + c) + (r - c)\right) = \sum_{j=1}^{n}(r + c)_{i,j} \quad \textbf{Equation 17}$$

The normalized weights, where ($\sum w_i = 1$)Equation (4.10) can be used.

$$w_i = \frac{(r+c)_i^{average}}{\sum_{i=1}^{n}(r+c)_i}$$ **Equation 18**

However, it should be noted that if other criteria dominate any criterion, the corresponding ratings of this criterion resulting from the direct-influence graph are equal to 0. This creates substantial difficulties since the corresponding row in the direct-influence matrix consists of zeros only. Hence when a zero is encountered, it is necessary to correct the weight values by adding the minimum results from each average weight to all the averaged weights. But in this study, there was no need for correcting, because 0 was not encountered.

According to the above-given formula, the weighted values are computed for each dimension, as shown in Table 4.14 below

r+c shows the importance of the dimension, whereas r-c shows the relation cause

The dimensions belonged in the cause group are D8, D1, D6, and D5, and the remaining dimensions belong to the effect group. A larger value of r-c denotes a higher influence of that dimension has on the other dimensions.

Table 7 : Normalized weights of each Maintenance dimension as a maturity measurement perspective

Notation	Maintenance Dimensions	r	c	r+c	r-c	1/2((r+c)+(r-c))	Weights
D1	Maintenance Policy and Strategy	7.14	5.66	12.8	1.48	7.14	0.09
D2	Human Resource Management	6.39	6.54	12.92	-0.15	6.39	0.081
D3	Technical and Functional Appropriateness	6.06	7.16	13.22	-1.1	6.06	0.077
D4	Maintenance Organization	6.24	6.86	13.09	-0.62	6.24	0.079
D5	Maintenance Information Management	6.75	6.2	12.96	0.55	6.75	0.086
D6	Building Design Life	6.41	5.29	11.7	1.13	6.41	0.081
D7	Maintenance Budget/Financial Perspective	6.86	8.08	14.95	-1.22	6.86	0.087
D8	Culture and Leadership	7.49	5.19	12.68	2.31	7.49	0.095
D9	Maintenance Materials and Spar part Management	5.11	6.74	11.85	-1.63	5.11	0.065
D10	Risk Management	6.93	7.21	14.14	-0.28	6.93	0.088
D11	Performance Management	7.44	7.74	15.18	-0.3	7.44	0.094
D12	Environmental and Social Impact of the Built asset	6.04	6.19	12.23	-0.15	6.04	0.077

As described above, D8 (**Culture and Leadership**), D1 (**Maintenance Policy and Strategy**), D6 (**Building Design Life**), and D5 (**Maintenance Information Management**) are categorized under the causes group of built asset maintenance management. As can be understood causes are more important than effect since effects are results. Hence, the cause dimensions have a high value on university maintenance management. This also can be seen from the average weight calculation (i.e., all of them are above 8%).

D8 **(Culture and Leadership**) is the most important of all the cause groups. This demonstrates that the lack of a maintenance policy in institutions is rooted in the leadership's degree of significance for maintenance. This is also ingrained in the culture. Effect indicators are indicators that are affected by other indicators. D11 (**Performance Management**) is the highest among the effect group. This demonstrates that the execution of other indicators has a significant impact on D11. The next two effect indicators are D7 (**Maintenance Budget/Financial Perspective**) and D10 (**Risk Management**). Other indicators also influence these dimensions.

All the indicators weighted average (6.48%-9.5%) and centrality **r+c** (11.70-15.8) is clustered within a narrow range. This shows that all the dimensions are more or less equivalent in importance for built asset maintenance management. Hence, all the dimensions need to be used to measure the maturity of maintenance management for built assets. Similar steps have been utilized to compute the weights of the indicators under each dimension. Accordingly, the weights of indicators under each dimension are presented below. Normalized weights of indicators for all the twelve (12) Maintenance maturity measurement are computed and is shown in table 8.

Built asset Maintenance Dimension	Indicators for Each Dimension	r	c	r+c	r-c	1/2((r+c)+(r-c))	Weights
Maintenance Policy and Strategy	Availability of Built Asset management strategy and planning	3.91	2.72	6.63	1.19	3.91	0.24
	Availability of built Asset management policy	4.08	2.46	6.53	1.62	4.08	0.25
	Alignment of Built Asset management objectives with Corporate objectives	3.79	2.86	6.65	0.93	3.79	0.23
	Built asset maintenance task planning and scheduling	2.63	4.07	6.7	-1.44	2.63	0.16
	Availability of defined built asset Maintenance approach/s	2.02	4.33	6.35	-2.31	2.02	0.12
Human Resource Management	Competency of in house maintenance staff	1.85	2.93	4.78	-1.08	1.846	0.235
	Training programs to maintenance staff	3.27	1.93	5.2	1.34	3.271	0.416
	Motivation and inspired team work of maintenance staff	2.75	3.01	5.76	-0.26	2.749	0.349
Technical and Functional appropriateness dimension	Building asset Capacity	5.87	6.51	12.39	-0.64	5.87	0.19
	Building asset Functionality	6.87	6.87	13.74	0.01	6.87	0.23
	Building asset Location	5.16	5.44	10.6	-0.28	5.16	0.17
	Building asset Condition	5.9	5.41	11.31	0.49	5.9	0.19
	Technical practicality of Building asset	6.56	6.14	12.69	0.42	6.56	0.22
Maintenance Organization	Organization of Maintenance department	6.25	5.85	12.1	0.4	6.249	0.284
	Alignment of Maintenance with organizational objectives	5.14	5.12	10.27	0.02	5.144	0.234
	Efficiency of maintenance process and work Instructions	5.18	5.63	10.81	-0.46	5.178	0.235
	Organizational position of maintenance department	5.43	5.39	10.82	0.03	5.427	0.247
Maintenance Information Management	Completeness, accuracy and validity of built asset data	24.28	24.32	48.6	-0.04	24.283	0.258
	Built asset registry and asset history to enhance asset knowledge	22.73	24.47	47.2	-1.74	22.735	0.241
	Use of Maintenance Information management system	23.48	22.7	46.18	0.78	23.479	0.249
	Use of data Capturing Technologies from exiting built asset	23.69	22.7	46.4	0.99	23.695	0.252

Table 8: Indicators under each maintenance maturity dimension with their respective Normalized weights

Built asset Maintenance Dimension	Indicators for Each Dimension	r	c	r+c	r-c	1/2((r+c)+(r-c))	Weights
Building Design Life	Evaluation of capital expenditure requirements	3.68	2.73	6.41	0.95	3.679	0.314
	Modernization plan of the Built asset	2.76	2.82	5.58	-0.06	2.756	0.235
	Disposal plan of built asset	1.95	3.16	5.11	-1.21	1.948	0.166
	Building remaining Life	3.33	3.00	6.34	0.33	3.332	0.284
Maintenance Budget/Financial Perspective	Operating cost	9.13	8.91	18.04	0.22	9.13	0.2
	Annual Maintenance Cost	9.53	9.19	18.72	0.35	9.53	0.21
	Differed Maintenance Cost	8.29	9.17	17.46	-0.89	8.29	0.18
	Utilization of Maintenance budget	10.02	10.05	20.07	-0.03	10.02	0.22
	Information and Knowledge about maintenance cost	9.28	8.92	18.19	0.36	9.28	0.2
Culture and Leadership	Awareness of people towards built asset management	16.65	15.38	32.02	1.27	16.65	0.21
	Top management Support	15.23	14.54	29.77	0.69	15.23	0.19
	Attitude of employees	15.76	16.62	32.38	-0.86	15.76	0.2
	Willingness of people to learn new methodologies and attend training	16.63	15.19	31.82	1.43	16.63	0.21
	Values and beliefs towards maintenance	14.89	17.43	32.32	-2.54	14.89	0.19
Maintenance Materials and Spare part Management	Maintenance Materials Inventory Management	0.64	2.07	2.71	-1.42	0.64	0.16
	Classification of Maintenance stock items	1.34	1.08	2.42	0.26	1.34	0.34
	Inventory management policy	1.97	0.8	2.77	1.17	1.97	0.5
Risk Management	Risk assessment strategies and objectives	14.01	12.73	26.74	1.29	14.011	0.264
	Risk is embedded in to all activities to minimize asset performance	12.68	12.68	25.36	0	12.679	0.239
	Analysis of building failure, causes & effects to address risk	13.59	13.59	27.18	0	13.591	0.256
	Statutory compliance risk	12.73	14.01	26.74	-1.29	12.725	0.24
Performance Management	Value for money	6.09	4.19	10.27	1.9	6.09	0.21
	Maintenance efficiency indicator	6.6	6.22	12.82	0.37	6.6	0.23
	The building performance indicator measures the physical state of the building	5.69	5.98	11.68	-0.29	5.69	0.2
	Building Efficiency Index	5.69	5.59	11.29	0.1	5.69	0.2
	End user satisfaction	4.98	7.07	12.06	-2.09	4.98	0.17
Environmental and Social Impact of the Built asset	Impact of the Built Asset on the environment	1.87	2.54	4.41	-0.67	1.87	0.26
	Environmental Friendliness of the Built asset	3.11	1.68	4.78	1.43	3.11	0.42
	Social significance of the built asset	2.34	3.11	5.45	-0.76	2.34	0.32

Conclusion

As stated previously in the problem statement, “Another flaw in the human character is that everybody wants to build, and nobody wants to do maintenance” (Kurt Vonnegut, Jr.).

This research aims to assess the current level of maintenance practice, identify factors that influence building maintenance management practice, and develop a maintenance maturity/rating model that could be used to shift current maintenance practices for public university buildings facilities in Ethiopia.

Hence, the study focuses on building maintenance management and practices and how they influence the core business of teaching, learning, research, and community service at Ethiopian public universities.

The analysis of the first objective of this study is based on a sufficient sample of 75 responses obtained from 26 university managers, facility managers, and university staff involved in one or another in managing or using public university facilities in Ethiopia. From the analysis, the current building maintenance management practice can be characterized by:

- The lack of strategic consideration given to built asset maintenance management was evidenced by the actual conditions of buildings and interview analysis results.
- There is no clear maintenance policy supported by a proper strategic approach applicable for maintenance operations in public universities in particular and building facilities in Ethiopia. This is mainly due to the absence of a public entity responsible for managing and maintaining public buildings in an organized way.
- Sewerage lines, water supply lines, fixtures, and electrical lines and fittings have been requiring more frequent maintenance operations, suggesting that the quality of service lines construction and maintenance operations performed on these components are questionable.
- The lack of data, documents, and maintenance manuals required for built asset maintenance operations is a critical challenge in maintenance management.

The second objective of this study was to identify the factors that influence the proper practice of building maintenance management in public universities in Ethiopia. These factors were grouped under seven categories: factors on statutory requirements, design, construction, maintenance management, Maintenance team operation, maintenance budget and community culture (learning, and growth). Accordingly; lack of preventive Maintenance methods and lack of maintenance and schedules (of maintenance management), a lack of as-built documentation and unavailability of a database for maintenance activities (of maintenance team operations), lack of effective maintenance culture from (the community culture, learning and growth category) and poor construction quality (factors of construction quality) are identified as the top five critical factors affecting the proper practice of facility maintenance management practices in Ethiopia.

The final objective is to develop a built asset maintenance maturity rating model that public universities can use as a self-assessment tool to shift from the current level to an advanced progression level based on twelve dimensions/perspectives measured by 3 to 6 indicators. The weight-age of each dimension and indicator is analyzed using fuzzy-DEMATEL multi-criteria decision making (MCDM).

From the (MCDM) analysis, the cause-and-effect diagram was constructed by mapping all coordinate sets of r_i+c_i and ri-ci to visualize the complex interrelationship and judge the most important built asset maintenance maturity dimension how they influence each other. Accordingly, D8 (Culture and Leadership), D1 (Maintenance Policy and Strategy), D6 (Building Design Life), and D5 (Maintenance Information Management) are categorized under the cause group of the DEMATEL analysis for built asset maintenance maturity dimension, indicating their importance. D8 (Culture and Leadership) is the highest cause amongst all causes and is followed by D1 (Maintenance Policy and Strategy), which agrees with the findings in the previous objective. According to DEMATEL MCDM, the dimensions categorized under the cause group (r-c being positive value) are more important than the effect group dimensions, D2, D3, D4, D7, D9, D10, D11, and D12 (with negative r-c values).

As stated above, D8 (Culture and Leadership) is the most significant of the cause groups. This demonstrates that the key reason for institutions' absence of a maintenance policy is the leadership's acknowledgment of the necessity of built asset maintenance. This is firmly ingrained in the culture as well. Finally, a built asset maturity rating model is proposed based on the weights calculated from DEMATEL, MCDM analysis weights for dimensions and indicators under each dimension to be used as a self-assessment tool by public universities in Ethiopia.

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Appendix 2: Online Survey questionnaire

Research Title: Developing Built Asset Maintenance Maturity Rating Model for Public University Buildings in Ethiopia"

- ***Objective One: Assessment of Current Facilities Maintenance Management Practice of Public University Buildings***
- ***Objective two: Explore Critical Success Factors that Influence the Building Maintenance Management Practice: Ethiopian Perspective***

A Guide for Structured Interview/Questionnaire Survey for Study in Progress

A research team is established to undertake studies for academic purpose at EiABC, Addis Ababa University in collaboration with Bauhaus University of Weimar, Germany. The study theme is entitled ***"Developing Built Asset Maintenance Maturity Rating Model for Public University Buildings in Ethiopia***". In this regard, the research team kindly requests you to respond to these questions, to meet the objectives and contribute to the study.

Your participation and cooperation is important to this research work, and will be helpful towards the effort in improving the Performance Management of the Built-Environment, especially in developing Policies and Strategies at a sectorial level.

Data and information collected through this instrument will be kept confidential and analysed only for this research work without reporting the personnel or company/university data. This research work is possible only through your kind support and cooperation. Thus, we kindly request you to devote your few minutes to respond to these questions.

Sincerely,

Zewdu Seblework, MSc Candidate, EiABC, Addis Ababa University

Part I: Background of Respondent

S.N	***Questions***	***Response***
1	Name of the University	
4	Total Number of Students	
5	Total Number of Staff	
6	Total Number of Buildings/Blocks	
7	What is your Position	
8	Your Professional Background	
9	Educational Level	
10	Total Professional experience	
11	Year of Experience in current position	

Part II: General Questions - Buildings & Building Conditions Assessment

2.1.Number of Buildings Operated by the public university

- Student Residence (Dormitory)______________________________
- Library Buildings ____
- Lecture Halls____.
- Class room Buildings____
- Office Buildings____
- Student cafeteria____
- Laboratories____
- Assembly Halls____
- Staff Residence____
- Others____
- Total =____

2.2.When your university's building facilities did started operation?

☐ 1-5 years ago
☐ 5-10 years ago
☐ 10-15 years ago
☐ 5-20 years ago
☐ 20-25 years ago
☐ It was over 25 years ago

2.3. Which one of the following facilities demands more frequent maintenance during operation?

☐ Buildings (Class rooms, Library, Cafeterias, Lecture halls, Staff Residence, Laboratories, Assembly halls)

☐ Internal road network

☐ Water supply lines

☐ Sanitary appliances

☐ Electrical fixtures

☐ Electrical installation

☐ Waste water lines

☐ Treatment plan

Any other------------------------------- -- -------------------------

2.4.Do you have estimated value of buildings owned, rented & leased if any by the university? ☐ No ☐ Yes

If yes. Please write the estimate in ETB ____

2.5.Do believe that some of the building facilities in your university have some defects due to improper practice of Building Maintenance?

☐ Yes definitely

☐ Definitely

☐ N/A

☐ I am not sure

☐ There is no defect at all

2.6.How do you make Facility condition assessment and survey inspection in the university : (select all if applicable)

☐ Visual inspection

☐ Use of hand tools, meters, sensors, etc.

☐ Use of building assessment & inspection software

☐ Recording video & images of building condition and components

☐ Not done

2.7.Frequency of Facility condition assessment is typically done:

☐ Once in Six Months

☐ Once in a year

☐ Once in two years

☐ Once in three to five years.

☐ Not done

2.8. The facility condition findings are used for: (select all, if applicable):

- ☐ Short term facility planning
- ☐ Long-term facility planning
- ☐ Routine operations and maintenance
- ☐Establishing benchmarks for measuring equipment/component's life
- ☐ Preventive maintenance
- ☐ Not applicable

2.9. Does your university have a directorate/department to coordinate maintenance and repair of equipment, buildings, infrastructure and facilities related work?

☐ Yes ☐ No ☐ I do not know

2.10. How do you receive work orders from facility users if when a defect or failure happens?

- ☐ Phone
- ☐ Paper based form
- ☐ Email
- ☑ Fax
- ☐ Specify if any other----------------

Part III: Facility Maintenance Management

3.1. What type of Building Maintenance approach is under practice in Your University?

Short term facility planning

☐ Corrective (concerns about a reactive action in response to a cause of failure or break down.)

☐ Preventive (periodical undertaking of routine tasks necessary to maintain component or system in a safe and efficient operating condition)

☐ Predictive (detect the system degradation and conduce maintenance on the actual condition of the building)

☐ Other______________________

3.2. What type of Procurement strategy does the University's Maintenance use?

- ☐ In-house
- ☐ Outsource
- ☐ In-house and outsource
- ☐ Other_________________

3.3. Is there any substantial maintenance activities made on a building after it started service?

☐ Yes ☐ No

3.4. If your answer is yes to question **(3.3)** how the budget was allocated for the maintenance activities?

Please Explain

____
____
____
____
____

3.5. How do you rate the importance of non-core business activity/FM, Maintenance management/ for the success of your core business/ Teaching, Learning and Research/ to perform properly?

- ☐ Very Important
- ☐ Important
- ☐ N/A
- ☐ Less important
- ☐ Not important

3.6. Does your university has clear organizational structure, which helps to properly manage and enhance the performances of the constructed facilities?

☐ Yes ☐ No

3.7. Where does the management level of FM/Maintenance management lie in the university's organizational structure?

- ☐ Strategic level (President Office, Vice president)
- ☐ Functional /tactical/ (Directorate)
- ☐ Operational (Maintenance department)

3.8. How many maintenance staffs are there in the directorate/department?

- ☐ 1-5
- ☐ 5-10
- ☐ 10-15
- ☐ More than 15

3.9. How is the composition of Maintenance team

☐ A team composed of professional engineers (Civil and Related, Electrical, Mechanical and others)

☐ A team composed of one professional engineer, Electrician, Plumber, welder and wood worker

☐ A team composed of Electrician, Plumber, welder and wood worker

3.10. Are there regular meetings conducted to discuss the maintenance plan?

☐ Yes - Which frequency? ☐ By day, ☐ by week, ☐ by month, ☐ by year ☐ No

3.11. Who participates in the meetings?

☐ Head of the department ☐ Outsourcing firm's ☐ others: ________________________________

3.12. Does your university have a written facility maintenance plan that guides your planning for facility improvement?

☐ Yes ☐ No ☐ I do not know

3.13. Is facility maintenance planning a component of the overall strategic plan?

☐ Yes ☐ No ☐ I do not know

If it addresses the issue of Building Maintenance Management, Do your University have annual/ Periodic/Maintenance plan?

☐ Yes ☐ No ☐ I do not know

3.14. What is the planning technique used?

Preventive Maintenance	Corrective Maintenance
1. ☐ Critical Path Method (CPM) 2. ☐ Line of balance (LOB) 3. ☐ Program Evaluation and Review Techniques (PERT) 4. ☐ Other	1. ☐ Critical Path Method 2. ☐ Line of Balance 3. ☐ Program Evaluation and Review Techniques 4. ☐ Other

3.15. Which management parameters are taken into account to plan the maintenance? (Prioritization)

Preventive Maintenance	Corrective Maintenance
☐ Time available ☐ Resources available ☐ Costs involved ☐ Risk involved ☐ Occupant satisfaction ☐ Normative ☐Manufacturers recommendations ☐ Other:____________________	☐ Time available ☐ Resources available ☐ Costs involved ☐ Risk involved ☐ Occupant satisfaction ☐Normative ☐ Other:____________________

3.16. How is the structure of the maintenance plan?

Preventive Maintenance	Corrective Maintenance
1. ☑ Long term (☐ week ☐ month ☐ year) 2. ☐ Midterm (☐ week ☐ month ☐ year) 3. ☐ Short term (☐ day ☐ week) 4. Not done______________________________ 5. Other__________________________________	1. Long term (☐ week ☐ month ☐ year) 2. Midterm (☐ week ☐ month ☐ year) 3. Short term (☐ day ☐ week) 4. Outsourced__________________________ 5. Other______________________________

Part V: Critical success factors that influence the practice of Building Maintenance Management

The scale ranges from 1 to five likert scale Where (1=strongly disagree, 2=disagree, 3 neither agree nor disagree, 4=agree and 5=strongly agree)

A)	***Factors Pertaining to Statutory Requirements***	1	2	3	4	5
A_1	Lack of building maintenance standards, policy, codes, Strategy, procedure and their implementation	☐	☐	☐	☐	☐
A_2	The method of awarding maintenance contracts/ unavailability of Specialized Maintenance contractors,	☐	☐	☐	☐	☐
A_3	Unavailability of FM productivity standards and specification	☐	☐	☐	☐	☐
B)	***Factors Pertaining to Design Stage***	☐	☐	☐	☐	☐
B_1	Error in Design	☐	☐	☐	☐	☐
B_2	Construction materials quality, specification and selection	☐	☐	☐	☐	☐
B_3	Failure to consider life cycle costing analysis	☐	☐	☐	☐	☐
B_4	Non-involvement of Maintenance/FM professionals during design phase	☐	☐	☐	☐	☐
B_5	Inefficient Architectural and or/Structural design	☐	☐	☐	☐	☐
B_6	Design Complexity	☐	☐	☐	☐	☐
B_7	Inadequate experience of Design Professionals	☐	☐	☐	☐	☐
C)	***Factors Pertaining to Construction Stage***	☐	☐	☐	☐	☐
C_1	Poor Construction Quality	☐	☐	☐	☐	☐
C_2	Lack of Communication and Collaboration skill	☐	☐	☐	☐	☐

C_3	Faulty/Poor workmanship quality during construction	☐	☐	☐	☐	☐
C_4	Unavailability and/or poor quality of replacement parts & components	☐	☐	☐	☐	☐
C_5	Lack of coordination between construction & maintenance groups	☐	☐	☐	☐	☐
C_6	Inaccuracy/ unavailability of as-Built Drawings/ Design	☐	☐	☐	☐	☐
D)	***Factors Pertaining to Maintenance Management***	☐	☐	☐	☐	☐
D_1	Lack of preventive maintenance method	☐	☐	☐	☐	☐
D_2	Lack of Maintenance Plans & Schedules	☐	☐	☐	☐	☐
D_3	Inadequate training to Maintenance personnel	☐	☐	☐	☐	☐
D_4	Unavailability and lack of skilled and appointed maintenance staff	☐	☐	☐	☐	☐
E)	***Factors Pertaining to Maintenance Budget***	☐	☐	☐	☐	☐
E_1	Insufficient/ Unavailability of Budget for Maintenance of buildings	☐	☐	☐	☐	☐
E_2	Failure to forecast the accurate maintenance expenditures	☐	☐	☐	☐	☐
E_3	Difficulty in procurement of spare parts/ **Procurement** rules, regulations	☐	☐	☐	☐	☐
E_4	Inflation of Maintenance cost	☐	☐	☐	☐	☐
F)	***Factors Pertaining to operations conducted by the maintenance team***	☐	☐	☐	☐	☐
F_1	Low concern of future maintenance of existing maintenance team	☐	☐	☐	☐	☐
F_2	Low concern of future maintenance of existing maintenance team	☐	☐	☐	☐	☐

F_3	Poor maintenance work done by the maintenance unit of the institution	☐	☐	☐	☐	☐
F_4	Poor work rectification done on buildings.	☐	☐	☐	☐	☐
F_5	Lack of Building Maintenance manual	☐	☐	☐	☐	☐
F_6	Lack of documentation/Database of maintenance works (Data recording and storage)	☐	☐	☐	☐	☐
G)	***Factors Pertaining to community perception about maintenance industry***	☐	☐	☐	☐	☐
G_1	Lack of effective Maintenance culture	☐	☐	☐	☐	☐
G_2	Misuse of facilities by occupants after completion of construction/attitude of users	☐	☐	☐	☐	☐
G_3	Delay in occupancy after completion/not using building after completion	☐	☐	☐	☐	☐
G_4	Lack of understanding and awareness of the importance of maintenance work/ Underestimating the impact of FM	☐	☐	☐	☐	☐

Part VI: Improving the Current Practice of University Building Maintenance Management

6.1. Do you believe that there is a need to improve the current practice of Building Maintenance Management in your University?

☐ Yes ☐ No ☐ I do not know

6.2. If your Answer is Yes for question 6.1, Please indicate your level of agreement for the improvement mechanisms listed below.
The scale ranges from 1 to five likert scale Where (1=strongly disagree, 2=disagree, 3 neither agree nor disagree, 4=agree and 5=strongly agree)

6.2	***How Maintenance management Can be improved in your University***	1	2	3	4	5
	Building Maintenance Management shall be part of University's Strategic plan	☐	☐	☐	☐	☐
	Sufficient Budget shall be allocated Building Maintenance activities	☐	☐	☐	☐	☐
	Building Maintenance shall be statutory requirement	☐	☐	☐	☐	☐
	Decision making process in Maintenance Management needs to be improved	☐	☐	☐	☐	☐
	Develop and Implement Maintenance Policy, strategy and systems in all levels of Management	☐	☐	☐	☐	☐
	Perform regular auditing and evaluation of Facilities Performance	☐	☐	☐	☐	☐
	Applying advanced Technology (BIM, CAFM, and CMMS) for Building Maintenance Management	☐	☐	☐	☐	☐
	Changing the strategy of Maintenance Procurement (from in house to outsourcing)	☐	☐	☐	☐	☐
	Students, teachers and other staffs of the university shall have a simple and manageable reporting system/apps for building defects.	☐	☐	☐	☐	☐

Appendix 3: Interview questionnaire

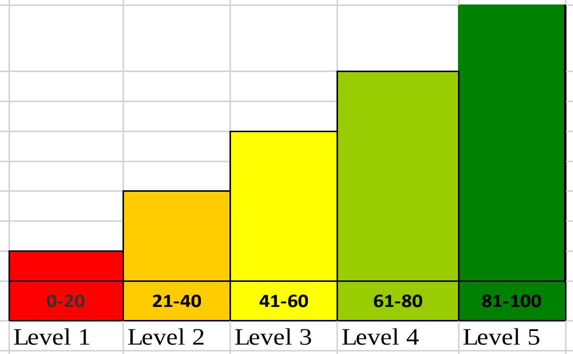
1. Your Current role/position/ in the University
2. Your University Name
3. Academic Status
4. Experience in University
5. Building Facility Maintenance and Management is part of the University's Strategic plan
6. From the strategic plan, the University Facility Maintenance Management body prepares an annual and Periodic plan
7. The University has Building Maintenance Policy and Strategy
8. Building Maintenance Management plays a significant role in achieving the university's Core Business
9. The Management Level of Building Facilities Maintenance Management in the University
10. Which category of University's Facilities demands more frequent maintenance during operation
11. The University Building Facilities do not require Maintenance Because most of the buildings are fit for their purposes
12. The University has a directorate/department responsible to coordinate maintenance and repair of equipment, buildings, infrastructure, and facilities-related work.
13. What is the Building Facility Maintenance approach of the University?
14. The type of Building Facility Maintenance Procurement strategy of the University
15. Data and Information (drawings, Contracts, Maintenance data, and attributes) are a critical challenge for Maintenance Management in the University
16. There is an organized Building (data) Information Management system within the university
17. There is a need to have an organized Information Management system in the university to store facility related data, Information.

Appendix 3: Built Asset Maintenance Management Maturity Rating Model

Built Asset Management Maturity Assessment Tool

Built Asset Maintenance Maturity Assessment Dimensions and Indicators		Normalized Weights	Maturity Levels					Organizations to complete these four columns (K to O)				
			Aware 0-20	Basic 21-40	Core 41-60	Intermediate 61-80	Advanced 81-100	Current Score	Appropriate Target	Reason for scores	Evidence to support score	planned or un
D1) Maintenance Policy and Strategy		0.09										
D11	There exist Built Asset management strategy and plan that is used to manage built assets maintenance activities	0.240	The organization is aware of the benefits of built asset management	Corporate expectations are expressed in relation to the development of built asset Plans and objectives	Built asset Policy, Strategy and Objectives are developed, and aligned to corporate goals and strategic context	Strategic context (internal, external, customer environment) is analyzed and implications for Built asset management System documented in the built asset plan and Strategy	Built asset Policy and Strategy is fully integrated into the organization's business processes and subject to defined audit, review and updating procedures	100	0			
D12	Maintenance operations are led by built Asset management policy	0.250						100				
D13	Built Asset management objectives are aligned with Corporate objectives	0.230						100				
D14	There is Built asset maintenance task planning and scheduling practices in the organization	0.160						100				
D15	Availability of defined built asset Maintenance approach/s	0.120						100				
D2) Human Resource Management		0.081										
D21	There is Competent in house maintenance staff	0.235	Maintenance staffs have low competence punctual training motivated by high impact problems.	Skills development plan for maintenance employees nonaligned with the area's and corporate objectives	Skills development plan aligned with the area's needs and organizational objectives	Skill development plan aligned the area's needs. Polyvalent built asset maintenance employees with involvement of productive staffs in certain tasks.	Skill development plan aligned with the objectives of the core business and the built asset maintenance area. At this stages, Employees, involved in improvement activities.	100				
D22	Training programs are available to maintenance staff	0.416						100				
D23	The organization has maintained motivated and inspired team work of maintenance staff	0.349						100				
D3) Technical and Functional appropriateness		0.077										
D31	Building asset has good Capacity for the intended function	0.190	inadequate data and information to confirm current performance against built asset management objectives.	Adequate data and information to confirm current performance against built asset management objectives.	Condition and performance information is suitable to be used to plan maintenance and renewals over the short term.	Future condition and performance information is modeled to assess whether asset management objectives can be met in the long term. Contextual information such as demand is used to estimate likely performance.	The type, quality and amount of data are optimized to the decisions being made. The underlying data collection programme is adapted to reflect the built asset's life cycle stage.	100				
D32	The Built asset is suitable and flexible for the current and future service delivery.	0.230						100				
D33	The location of the building asset is convenient in relation to current and future demand for services	0.170						100				
D34	The physical condition of the built asset appropriate for current and future service	0.190						100				
D35	The Built asset is technically practicable in terms of the time to complete, reliability to function, regulation and bureaucracy and site accessibility of built asset to maintenance	0.220						100				
D4) Maintenance Organization		0.079										
D41	Delegation of duties, roles and responsibilities to all maintenance staffs and allocation of resource to tasks are clear	0.284	There exist maintenance organization but is not well defined. The position of the maintenance department is subordinate. The maintenance work process is not clear	There exist maintenance organization but is not well defined. The position of the maintenance department is subordinate. The maintenance work process is defined on paper but application is not thoroughly flowed	There exist maintenance organization and is clearly defined. The position of the maintenance department is at strategic level. The maintenance work process is defined on paper and there are procedure to follow for its application	There exist maintenance organization and is clearly defined. The position of the maintenance department is at strategic level. The maintenance work process is defined on paper and the application thoroughly followed and monitored.	There exist maintenance organization and is clearly defined. The position of the maintenance department is at strategic level. The maintenance work process is defined on paper and the application thoroughly followed and monitored. the procedures are reviewed contentiously for improvement	100				
D42	Maintenance department is organized in a way to align with the strategic business objectives	0.234						100				
D43	Efficiency of maintenance process and work Instructions	0.235						100				
D44	the organizational location of maintenance department as (strategic, tactical and operational) as one of the important strategic units or departments with in the organization	0.247						100				
D5) Maintenance Information Management		0.086										
D51	There exist complete, accurate and valid built asset data	0.258	The organization has an intention to develop an electronic built asset register/AMIS.	Built asset register can record core asset attributes - size, material, location, age etc. Asset information reports can be manually generated for built asset Plan input.	Built asset register enables hierarchical reporting (at component level to facility level). Customer service request tracking and planned maintenance functionality enabled. System enables manual reports to be generated for valuation and renewal forecasting.	Spatial relationship capability. More automated built asset performance reporting on a wider range of information.	Asset and customer service systems are integrated and all advanced built asset management functions are enabled including asset information modeling (AIM). Asset optimization analysis can be performed.	100				
D52	Built asset and asset portfolio are properly registered and there is full knowledge of asset	0.241						100				
D53	Use of Maintenance Information management system is practiced in the organization	0.249						100	0			
D54	Use of data Capturing Technologies from exiting built asset is practiced in the organization	0.252						100				
D6) Building Design Life		0.081										
D61	Evaluation of capital expenditure requirements made for existing built assets And Capital replacement decision	0.314	There is awareness of the importance of evaluating maintenance activities taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced.	building reaming life is registered, there is a plan when it should be disposed how it should be modernized and when and how it should be replaced.	maintenance activities are executed taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced.	maintenance activities are executed and the performance is evaluated taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced.	maintenance activities are executed and the performance is evaluated taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced. And the plan. and the plan is continuously revised.	100				
D62	There is a modernization plan for Built asset	0.235						100				
D63	Disposal plan of built asset is available/prepared	0.166						100				
D64	Building remaining Life is analyzed and documented	0.284						100				
D7) Maintenance Budget/Financial Perspective		0.086										
D71	There is a knowledge of annual operating cost of the building asset in the asset portfolio	0.200	Financial planning is largely an annual budget process, but there is intention to develop longer term forecasts. The organizational focus is on the operating statement rather than the balance sheet.	Built assets are re-valued in accordance with financial reporting and accounting standards. Five to nine year financial forecasts are based on extrapolation of past trends and broad assumptions about the future.	Asset revaluations based on reliable asset data. Ten year financial forecasts based on current comprehensive asset management plans with detailed supporting assumptions/reliability factors. Significant assumptions are specific and well reasoned. Expenditure captured at a level useful for AM analysis.	10 year plus financial forecasts based on current comprehensive AMPs with detailed supporting assumptions/reliability factors and high confidence in accuracy. Funding sources are fully understood and matched with expenditure forecasts over the long term. Alternative funding sources have been fully explored. Asset expenditure information is linked with asset performance information.	The organization publishes reliable ten year+ financial forecasts based on comprehensive, advanced built asset management plans with detailed underlying assumptions and high confidence in accuracy. Advanced financial modelling provides sensitivity analysis, evidence-based whole of life costs and cost analysis for level of service options.	100				
D72	Annual Maintenance Cost of specific asset is known and well recorded	0.210						100				
D73	All maintenance work that has planned within a financial year/there is no differed maintenance	0.180						100				
D74	All Maintenance budget is utilized during the planned time	0.220						100				
D75	Maintenance expenditure is recorded and there is full knowledge about cost of maintenance per asset	0.200						100				
D8) Culture and Leadership		0.095										
D81	There exist awareness of people towards the importance of built asset maintenance	0.210	Vision & values undefined or not shared. Leaders dictate / command & control; otherwise disengaged	Vision & Values published, but not lived. Leaders dictate but gather feedback sporadically	Vision & Values communicated & understood. Leaders engage with direct reports only, but do model desired behaviors and values	Vision & Values collaboratively developed.Leaders empower many employees through on going engagement	Vision & Values fully integrated into organization culture. Leaders & employees fully engage in a continuous dialog based on a team-based culture	100				
D82	There is a support from top management towards implementing strategic asset management	0.190						100				
D83	There is good attitude of employees for maintenance	0.200						100				
D84	Maintenance staffs are Willing to learn new methodologies and attend training	0.210						100				
D85	Values and beliefs towards maintenance is good	0.190						100				
D9) Maintenance Materials and Spar part Management		0.065										
D91	There exist classification of spare parts and forecasting of demand for planned maintenance tasks	0.160	Materials and spare parts are not classified and no forecast of future demand	Materials and spare parts classification exists and future demands are forecast based on historical consumption	Materials and spare parts classification exists and future demands are forecast defined empirically and based on historical consumption	Materials and spare parts classification exists based on set of criteria and future demands are forecast defined empirically and based on historical consumption,design lifetime and maintenance strategy	Materials and spare parts classification exists based on function/impact. Inventory characteristics defined for each category. Inventory levels are regularly reviewed based on forecast and maintenance strategy	100				
D92	There is classification of maintenance items based on relevant characteristics	0.340						100				
D93	The management of inventory is based on organization inventory management policy and strategy	0.500						100				
D10) Risk Management		0.088										
D101	Risk assessment strategies and objectives are well defined	0.264	Risk management is identified as a future improvement	Critical services and assets understood and considered by staff involved in maintenance / renewal decisions. Risk framework developed	Critical assets and high risks identified. Documented risk management strategies for critical assets and high risks.	Current resilience level assessed and improvements identified. Systematic risk analysis to assist key decision-making. Risk register regularly monitored and reported. Risk managed and prioritized consistently across the organization.	Resilience strategy and programme in place including defined levels of service for resilience. A formal risk management policy in place. Risk is quantified and risk mitigation options evaluated. Risk is integrated into all aspects of decision making.	100				
D102	Risk is embedded in to all activities to improve asset performance	0.239						100				
D103	The analysis of building failure, causes & effects is performed to address risk	0.256						100				
D104	The built asset is in compliance with local Standards, codes, laws and regulations, which is identified as a result of an audit, discovery or the introduction of new legislation	0.240						100				
D11) Performance Management		0.094										
D111	Strategic and operational decisions on built assets are e made with commercial awareness for value for money	0.210	There is no defined key performance indicators	Key performance indicators are established and the execution has started with a focus on technical and economic indicators determined for all asset portfolio	Key performance indicators analyzed periodically with a focus on technical and economic indicators determined for all asset portfolio	Technical, economic and organizational indicators aligned with corporate strategic objectives of the organization, calculated and analyzed periodically, to support the decision making process.	Technical, economic and organizational indicators aligned with corporate strategic objectives of the organization, calculated and analyzed periodically, to support the decision making process and giving rise to improvement project's reliable data	100				
D112	Maintenance operation is achieving its maintenance goals, like reducing downtime or cutting costs.	0.230						100				
D123	The overall state of the built asset or asset portfolio, according to the performance of its components and systems	0.200						100				
D124	The built asset services is efficient with regard to energy usage, occupant comfort, and climate conditions	0.200						100				
D12) Environmental and Social Impact of the Built asset		0.077										
D121	Impact of the Built Asset on the environment	0.260	there is awareness of the impact a building has in the environment and on the society	there is a plan on how to reduce the negative impact a building has in the environment and on how the society can be benefited form the building	there is a execution of the plan on how to reduce the negative impact a building has in the environment and on how the society can be benefited form the building	the performance of the execution on minimizing the impact of the building on the environment and the positive impact on the society is evaluated continuously	the performance and the plan of the execution on minimizing the impact of the building on the environment and the positive impact on the society is evaluated continuously and the plan is revised frequently to accommodate for new discoveries and trend change	100				
D122	environmentally friendliness of the Built asset	0.420						100				
D123	The social significance of the built asset is considered in maintenance decisions	0.320						100				

Summary results							
Dimension	Dimension Weight	Indicator	Indicator's Weight	Summary Results	Current Score	Appropriate Target	Difference
D1	0.09	D11	0.24	24.00	9.0	0	-100
		D12	0.25	25.00		0	-100
		D13	0.23	23.00		0	-100
		D14	0.16	16.00		0	-100
		D15	0.12	12.00		0	-100
D2	0.081	D21	0.235	23.50	8.1	0	-100
		D22	0.416	41.60		0	-100
		D23	0.349	34.90		0	-100
D3	0.077	D31	0.190	19.00	7.7	0	-100
		D32	0.230	23.00		0	-100
		D33	0.170	17.00		0	-100
		D34	0.190	19.00		0	-100
		D35	0.220	22.00		0	-100
D4	0.079	D41	0.284	28.41	7.9	0	-100
		D42	0.234	23.38		0	-100
		D43	0.235	23.54		0	-100
		D44	0.247	24.67		0	-100
D5	0.086	D51	0.258	25.80	8.6	0	-100
		D52	0.241	24.10		0	-100
		D53	0.249	24.90		0	-100
		D54	0.252	25.20		0	-100
D6	0.081	D61	0.314	31.40	8.09	0	-100
		D62	0.235	23.50		0	-100
		D63	0.166	16.60		0	-100
		D64	0.284	28.40		0	-100
D7	0.086	D71	0.200	20.00	8.69	0	-100
		D72	0.210	21.00		0	-100
		D73	0.180	18.00		0	-100
		D74	0.220	22.00		0	-100
		D75	0.200	20.00		0	-100
D8	0.095	D81	0.210	21.00	9.5	0	-100
		D82	0.190	19.00		0	-100
		D83	0.200	20.00		0	-100
		D84	0.210	21.00		0	-100
		D85	0.190	19.00		0	-100
D9	0.065	D91	0.160	16.00	6.5	0	-100
		D92	0.340	34.00		0	-100
		D93	0.500	50.00		0	-100
D10	0.088	D101	0.264	26.40	8.79	0	-100
		D102	0.239	23.90		0	-100
		D103	0.256	25.60		0	-100
		D104	0.240	24.00		0	-100
D11	0.094	D111	0.210	21.00	9.49	0	-100
		D112	0.230	23.00		0	-100
		D123	0.200	20.00		0	-100
		D124	0.200	20.00		0	-100
		D125	0.170	17.00		0	-100
D12	0.077	D121	0.260	26.00	7.7	0	-100
		D122	0.420	42.00		0	-100
		D123	0.320	32.00		0	-100
	0.999			Summary of Results	100		



Built Asset Management Maturity Assessment Tool

Built Asset Maintenance Maturity Assessment Dimensions and Indicators		Normalized Weights	Maturity Levels					Organizations to complete these four columns (K to O)				
			Aware 0-20	Basic 21-40	Core 41-60	Intermediate 61-80	Advanced 81-100	Current Score	Appropriate Target	Reason for scores	Evidence to support score	planned or underway
D1) Maintenance Policy and Strategy		0.09										
D11	There exist Built Asset management strategy and plan that is used to manage built assets maintenance activities	0.240	The organization is aware of the benefits of built asset management	Corporate expectations are expressed in relation to the development of built asset Plans and objectives	Built asset Policy, Strategy and Objectives are developed, and aligned to corporate goals and strategic context	Strategic context (internal, external, customer environment) is analyzed and implications for Built asset management System documented in the built asset plan and Strategy	Built asset Policy and Strategy is fully integrated into the organization's business processes and subject to defined audit, review and updating procedures	20	35			
D12	Maintenance operations are led by built Asset management policy	0.250						15	40			
D13	Built Asset management objectives are aligned with Corporate objectives	0.230						20	35			
D14	There is Built asset maintenance task planning and scheduling practices in the organization	0.160						30	40			
D15	Availability of defined built asset Maintenance approach/s	0.120						30	40			
D2) Human Resource Management		0.081										
D21	There is Competent in house maintenance staff	0.235	Maintenance staffs have low competence punctual training motivated by high impact problems.	Skills development plan for maintenance employees nonaligned with the area's and corporate objectives	Skills development plan aligned with the area's needs and organizational objectives	Skill development plan aligned the area's needs. Polyvalent built asset maintenance employees with involvement of productive staffs in certain tasks.	Skill development plan aligned with the objectives of the core business and the built asset maintenance area. At this stages, Employees, involved in improvement activities.	35	40			
D22	Training programs are available to maintenance staff	0.416						15	40			
D23	The organization has maintained motivated and inspired team work of maintenance staff	0.349						10	30			
D3) Technical and Functional appropriateness		0.077										
D31	Building asset has good Capacity for the intended function	0.190	inadequate data and information to confirm current performance against built asset management objectives.	Adequate data and information to confirm current performance against built asset management objectives.	Condition and performance information is suitable to be used to plan maintenance and renewals over the short term.	Future condition and performance information is modeled to assess whether asset management objectives can be met in the long term. Contextual information such as demand is used to estimate likely performance.	The type, quality and amount of data are optimized to the decisions being made. The underlying data collection programme is adapted to reflect the built asset's life cycle stage.	35	40			
D32	The Built asset is suitable and flexible for the current and future service delivery.	0.230						40	45			
D33	The location of the building asset is convenient in relation to current and future demand for services	0.170						60	60			
D34	The physical condition of the built asset appropriate for current and future service	0.190						60	70			
D35	The Built asset is technically practicable in terms of the time to complete, reliability to function, regulation and bureaucracy and site accessibility of built asset to maintenance	0.220						20	35			
D4) Maintenance Organization		0.079										
D41	Delegation of duties, roles and responsibilities to all maintenance staffs and allocation of resource to tasks are clear	0.284	There exist maintenance organization but is not well defined. The position of the maintenance department is subordinate. The maintenance work process is not clear	There exist maintenance organization but is not well defined. The position of the maintenance department is subordinate. The maintenance work process is defined on paper but application is not thoroughly flowed	There exist maintenance organization and is clearly defined. The position of the maintenance department is at strategic level. The maintenance work process is defined on paper and there are procedure to follow for its application	There exist maintenance organization and is clearly defined. The position of the maintenance department is at strategic level. The maintenance work process is defined on paper and the application thoroughly followed and monitored.	There exist maintenance organization and is clearly defined. The position of the maintenance department is at strategic level. The maintenance work process is defined on paper and the application thoroughly followed and monitored. the procedures are reviewed contentiously for improvement	35	55			
D42	Maintenance department is organized in a way to align with the strategic business objectives	0.234						20	40			
D43	Efficiency of maintenance process and work Instructions	0.235						25	40			
D44	the organizational location of maintenance department as (strategic, tactical and operational) as one of the important strategic units or departments with in the organization	0.247						25	40			
D5) Maintenance Information Management		0.086										
D51	There exist complete, accurate and valid built asset data	0.258	The organization has an intention to develop an electronic built asset register/AMIS.	Built asset register can record core asset attributes - size, material, location, age etc. Asset information reports can be manually generated for built asset Plan input.	Built asset register enables hierarchical reporting (at component level to facility level). Customer service request tracking and planned maintenance functionality enabled. System enables manual reports to be generated for valuation and renewal forecasting.	Spatial relationship capability. More automated built asset performance reporting on a wider range of information.	Asset and customer service systems are integrated and all advanced built asset management functions are enabled including asset information modeling (AIM). Asset optimization analysis can be performed.	20	35			
D52	Built asset and asset portfolio are properly registered and there is full knowledge of asset	0.241						25	35			
D53	Use of Maintenance Information management system is practiced in the organization	0.249						25	40			
D54	Use of data Capturing Technologies from exiting built asset is practiced in the organization	0.252						5	15			
D6) Building Design Life		0.081										
D61	Evaluation of capital expenditure requirements made for existing built assets And Capital replacement decision	0.314	There is awareness of the importance of evaluating maintenance activities taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced.	building reaming life is registered, there is a plan when it should be disposed how it should be modernized and when and how it should be replaced.	maintenance activities are executed taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced.	maintenance activities are executed and the performance is evaluated taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced.	maintenance activities are executed and the performance is evaluated taking into consideration of the building life, when it should be disposed how it should be modernized and when and how it should be replaced. And the plan. and the plan is continuously revised.	20	35			
D62	There is a modernization plan for Built asset	0.235						10	20			
D63	Disposal plan of built asset is available/prepared	0.166						5	30			
D64	Building remaining Life is analyzed and documented	0.284						10	30			
D7) Maintenance Budget/Financial Perspective		0.086										
D71	There is a knowledge of annual operating cost of the building asset in the asset portfolio	0.200	Financial planning is largely an annual budget process, but there is intention to develop longer term forecasts. The organizational focus is on the operating statement rather than the balance sheet.	Built assets are re-valued in accordance with financial reporting and accounting standards. Five to nine year financial forecasts are based on extrapolation of past trends and broad assumptions about the future.	Asset revaluations based on reliable asset data. Ten year financial forecasts based on current comprehensive asset management plans with detailed supporting assumptions/reliability factors. Significant assumptions are specific and well reasoned. Expenditure captured at a level useful for AM analysis.	10 year plus financial forecasts based on current comprehensive AMPs with detailed supporting assumptions/reliability factors and high confidence in accuracy. Funding sources are fully understood and matched with expenditure forecasts over the long term. Alternative funding sources have been fully explored. Asset expenditure information is linked with asset performance information.	The organization publishes reliable ten year+ financial forecasts based on comprehensive, advanced built asset management plans with detailed underlying assumptions and high confidence in accuracy. Advanced financial modelling provides sensitivity analysis, evidence-based whole of life costs and cost analysis for level of service options.	30	40			
D72	Annual Maintenance Cost of specific asset is known and well recorded	0.210						35	55			
D73	All maintenance work that has planned within a financial year/there is no differed maintenance	0.180						15	30			
D74	All Maintenance budget is utilized during the planned time	0.220						70	80			
D75	Maintenance expenditure is recorded and there is full knowledge about cost of maintenance per asset	0.200						30	40			
D8) Culture and Leadership		0.095										
D81	There exist awareness of people towards the importance of built asset maintenance	0.210	Vision & values undefined or not shared. Leaders dictate / command & control; otherwise disengaged	Vision & Values published, but not lived. Leaders dictate but gather feedback sporadically	Vision & Values communicated & understood. Leaders engage with direct reports only, but do model desired behaviors and values	Vision & Values collaboratively developed.Leaders empower many employees through on going engagement	Vision & Values fully integrated into organization culture. Leaders & employees fully engage in a continuous dialog based on a team-based culture	40	55			
D82	There is a support from top management towards implementing strategic asset management	0.190						30	60			
D83	There is good attitude of employees for maintenance	0.200						25	40			
D84	Maintenance staffs are Willing to learn new methodologies and attend training	0.210						35	55			
D85	Values and beliefs towards maintenance is good	0.190						25	40			
D9) Maintenance Materials and Spar part Management		0.065										
D91	There exist classification of spare parts and forecasting of demand for planned maintenance tasks	0.160	Materials and spare parts are not classified and no forecast of future demand	Materials and spare parts classification exists and future demands are forecast based on historical consumption	Materials and spare parts classification exists and future demands are forecast defined empirically and based on historical consumption	Materials and spare parts classification exists based on set of criteria and future demands are forecast defined empirically and based on historical consumption,design lifetime and maintenance strategy	Materials and spare parts classification exists based on function/impact. Inventory characteristics defined for each category. Inventory levels are regularly reviewed based on forecast and maintenance strategy	35	40			
D92	There is classification of maintenance items based on relevant characteristics	0.340						30	40			
D93	The management of inventory is based on organization inventory management policy and strategy	0.500						25	40			
D10) Risk Management		0.088										
D101	Risk assessment strategies and objectives are well defined	0.264	Risk management is identified as a future improvement	Critical services and assets understood and considered by staff involved in maintenance / renewal decisions. Risk framework developed	Critical assets and high risks identified. Documented risk management strategies for critical assets and high risks.	Current resilience level assessed and improvements identified. Systematic risk analysis to assist key decision-making. Risk register regularly monitored and reported. Risk managed and prioritized consistently across the organization.	Resilience strategy and programme in place including defined levels of service for resilience. A formal risk management policy in place. Risk is quantified and risk mitigation options evaluated. Risk is integrated into all aspects of decision making.	20	35			
D102	Risk is embedded in to all activities to improve asset performance	0.239						25	35			
D103	The analysis of building failure, causes & effects is performed to address risk	0.256						15	30			
D104	The built asset is in compliance with local Standards, codes, laws and regulations, which is identified as a result of an audit, discovery or the introduction of new legislation	0.240						20	40			
D11) Performance Management		0.094										
D111	Strategic and operational decisions on built assets are made with commercial awareness for value for money	0.210	There is no defined key performance indicators	Key performance indicators are established and the execution has started with a focus on technical and economic indicators determined for all asset portfolio	Key performance indicators analyzed periodically with a focus on technical and economic indicators determined for all asset portfolio	Technical, economic and organizational indicators aligned with corporate strategic objectives of the organization, calculated and analyzed periodically, to support the decision making process.	Technical, economic and organizational indicators aligned with corporate strategic objectives of the organization, calculated and analyzed periodically, to support the decision making process and giving rise to improvement project's reliable data	35	55			
D112	Maintenance operation is achieving its maintenance goals, like reducing downtime or cutting costs.	0.230						15	30			
D123	The overall state of the built asset or asset portfolio, according to the performance of its components and systems	0.200						40	50			
D124	The built asset services is efficient with regard to energy usage, occupant comfort, and climate conditions	0.200						25	40			
D125	End users are satisfied from the maintenance service	0.170						25	30			
D12) Environmental and Social Impact of the Built asset		0.077										
D121	Impact of the Built Asset on the environment	0.260	there is awareness of the impact a building has in the environment and on the society	there is a plan on how to reduce the negative impact a building has in the environment and on how the society can be benefited form the building	there is a execution of the plan on how to reduce the negative impact a building has in the environment and on how the society can be benefited form the building	the performance of the execution on minimizing the impact of the building on the environment and the positive impact on the society is evaluated continuously	the performance and the plan of the execution on minimizing the impact of the building on the environment and the positive impact on the society is evaluated continuously and the plan is revised frequently to accommodate for new discoveries and trend change	40	55			
D122	environmentally friendliness of the Built asset	0.420						35	45			
D123	The social significance of the built asset is considered in maintenance decisions	0.320						25	35			