



COLLEGE OF BUSINESS AND ECONOMICS

IMPROVING FACILITY MANAGEMENT BY IMPROVING EARLY DESIGN FOR OPERABILITY AND MAINTAINABILITY

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A Thesis Submitted to Collage of Business and Economics in Partial Fulfillment
of the Requirements for the Degree of Master of Arts in Executive MBA
(Department of Management)



Addis Ababa University College of Business and economics
Department of Management

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I. List of Abbreviations

FM	Facility Management
O&M	Operability and Maintainability
COM	Constructability Operability and Maintainability
RII	Relative Importance Index
ECPMI	Ethiopian construction project management Institute
DfM	Design for Maintainability
RHBs	Regional Health Bureaus
MAI	Maintenance Achievement Index

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V. DECLARATION

I declare that this thesis is my original work and has not been presented for a degree in other university and all source of materials used for the thesis have been duly acknowledged.

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May, 2020

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This thesis has been submitted for examination with my approval as university advisor.

Mohammed said (PhD)

VI. Abstract:

Construction infrastructure defects arising from project initiation and premature executive decisions at early project conceptualization are the most basis for the latter drawback faced by the Facility managers and maintenance and operation executing staffs. Design and construction are known to have significant effects on the level of maintenance during the operational phases which translate into high costs which lead to customer dissatisfaction. In this research, attempts are made to assess via field surveys, literature reviews, and semi-closed questionnaires to indicate the significance of early consideration and integration of post-construction experience into the design and construction defects on the maintenance of infrastructures in Addis Ababa. In total, thirty questionnaires were distributed to executive decision-makers in various government offices, consultants, contractors, and building owners who are responsible for the design, construction, and maintenance of residential buildings in order to get the anticipated data for analysis. 22 questionnaires representing a response rate of 73% were retrieved and analyzed using descriptive and inferential statistics. The results of the survey revealed that 87% of higher officials indicated their role in initializing and conceptualizing projects is minimal with Relative Importance Index (RII) values. It has been found that it is critical for project initiators, designers, and other construction professionals to ensure the consideration of maintainability and operability concepts into infrastructure projects as early as possible.

KEYWORDS: Maintainability, Constructability, Infrastructures, Executive Decision makers, Integration

1. INTRODUCTION

1.1 Background of the study

It is impracticable to produce maintenance less structures but significant room remains for changes at the design and construction phases to bring minimize the amount of maintenance works required at a later date. (Olajide and Afolarin, Zulkarnain, 2015)

Facility operation, maintenance and management gets second-rate attention compared to Construction designs. In G. Britain it were noticed that projects continued to encounter problems in their early stages, (the Infrastructure UK Cost Review (2010)). A number of Problems in the construction industry arise from issues which would have been resolved at the initial stage of a construction concept design.

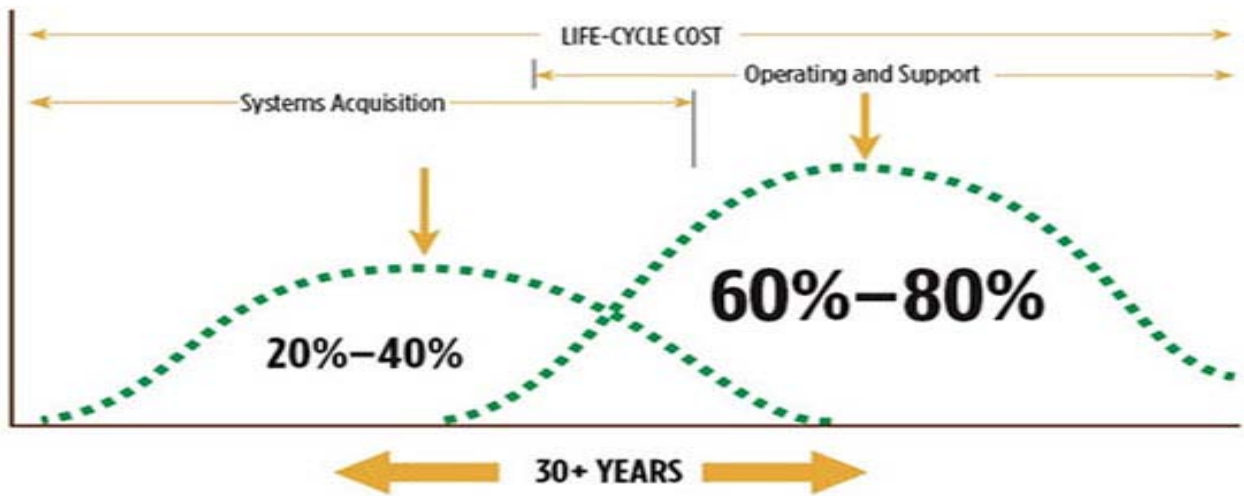
Project initiators usually focus in getting the design completed than testing for its constructability and maintainability requirements. The *UK Governance module 2016* identified that Projects often publicly announced timelines and costs before plans have been properly tested. The article also indicated a lack of project know-how particularly at portfolio level.

In Ethiopian facility maintenance has been given less application, and consequently it has subjected the community and the occupants to dwell with facilities providing partial service. For a developing Country such as Ethiopia maintenance budgets are less prioritized against new and cost efficient constructions (*Ing. Asmerom, jigiga symposium 2018*). Since this has a significant impact on the final expenses to the building owners, it's important that operations and maintenance issues are discussed during the initial phases of construction projects to optimize the life-cycle cost of a building. *Darrell Rounds, FMA®, CEM, 2018*, suggests that maintainability should be thoroughly explored through all the phases of project delivery.

After new buildings are delivered occupants face workmanship problems related to constructions, during the use of the facility and which lead to the rapid deterioration of the facility. *Ahmed (PhD) and Doaa, 2010*, stated that designers must consider these critical issues during the conceptual planning and design phases, in addition to the adequacy of operating and maintaining the schemes throughout the much significant operation of the facility stage. This requires the attentive involvement and input of the Facility management team even before construction is started.

In general the operation phase constitutes approximately 60% of the total lifecycle cost of a facility. Operations are more characterized by the maintenance and repair activities (M&R).

The most expensive and costly operational costs are Reactive maintenance and repairs.
(Sullivan et al. 2010, Mobley et al. 2008). / National institute of building Sciences page 8/



Credit: Defense Acquisition University website

Figure 1: Life cycle cost

Of all the maintainability practices owner-driven maintenance practices are basically reactive followed by more expence. In 1999 *University of Texas*, maintainability in Designing practice should be the primary procedure of an efficient maintenance program. Maintainability must be given adequate consideration in Design stage and enable an early integration of facility management and necessary construction information into project designs as early as possible.

1.2 Problem Statement

Although maintenance have a serious effect on project prices, most building facilities lack a correct system to deal with maintainability throughout the project life time. Litratuers have shown that, cost of capital, construction program, and envisioned purpose have received bigger stress during project design and construction. In several cases, design features has given less thought to long-run issues such as maintainability, operability, and human factors which would have significant role in the ease of carrying out maintenance tasks.

John R. Meierl and Jeffrey S. Russell, 2000, plainly put that miss planning for maintainability during the early, design, procurement, construction, and start-up of a facility may end up in diminished convenience and output, accumulated life-cycle operation and maintenance (O&M) expenditures, and higher maintenance retrofits.

The realistic cost effectiveness of a project is how well it fulfills its purpose and life cycle costs. As a proportion of operational costs, maintenance accounts for the largest share. (*John R. Meier and Jeffrey S. Russell 2000*)

In the case of Addis Ababa's city rail way transport facility, wear and tear is taking its toll with around a 3rd (1/3) of the forty one light rail cars out of action and undergoing repairs, aggravating delays and overcrowding. "Elias Kassa, an academician of railway science at the Norwegian University of Science and Technology", alleged designers did not incorporate the new light rail with the pre-existing bus system. (*March 2017. NAZRET .com*)

Despite operation and maintenance management have not been given proper attention in Ethiopia, huge sums are being invested in infrastructure. Take the Grand Renaissance Dam (GERD), light as well as heavy rail ways, thousands of kilometers of roads, Mass housing and university building infrastructures and number of hydroelectric dams and sugar factories are being constructed. Many governmental and private corporates have constructed variety of infrastructures so far. From the fact that there are hundreds of more infrastructure constructions on going, it is obvious that the number of infrastructures will be much more in the coming years. However, the need to keep this facility fully operational and providing their intended purpose and appropriate service to the end users is the missing point.

1.3 Research objectives

1.3.1 General objective

The general objective of this research is "to identify the gaps of corporate managers in considering facility management requirements at the early design stage and to indicate possible solutions."

1.3.2 Specific objectives

The specific objectives of the research are:

- 1) To identify both the Ethiopian practice as well as internationally accepted principles of effective and efficient operation and maintenance management of facilities/infrastructure projects.
- 2) To assess existing perspectives on facility operation and maintenance management and the challenges to consider in the early stages of infrastructure project studies and designs.

- 3) To device a mechanism that helps integrating international O&M practices with national requirements on pre facility construction and post facility occupations.

1.4 Research questions

The research questions that this thesis aims to answer are:

- 1) What are the current Ethiopian practices in achieving effective and efficient operational and maintenance management of facilities/infrastructures?
- 2) What is the awareness of higher-level managers in Ethiopia, (Those who can decide what kind of infrastructure projects to launch or what it must include), to incorporate operation and maintenance issue of a facility in the early stage of project initiation/project design stage?
- 3) How can the existing facility management practice in Ethiopia be upgraded in to the internationally acceptable Facility management standards and regularized to integrate the concept from the start of project design up to end of facility life cycle?

1.5 Scope of research

This research focuses on maintainability and operability problems of infrastructure projects that can be reduced if integrated at the initiation phase of projects. The scope of this research is limited to light rail train and mass housing development projects. Road projects and water supply and sanitation projects are not considered in this research.

1.6 Significance of the Research

Design for Maintainability is a concept that emphasizes the early incorporation of design and construction with operational and maintenance issues, preferably during the design stage. Outputs of this study will point out project initiators to be aware of the effect of design and construction phase problems on Operation and maintenance period. Most essentially it will be an important input for policy makers to take in the subjected Operability and maintainability issues at the early stage of project commencement. Regulatory bodies like Construction Regulatory Authority might device a number of quality assurance principles towards newly proposed projects.

1.7 Limitation of the study

All research faces limitations, and it's important to clarify such issues to ensure the results of the study are understood within such contexts. More importantly, future researchers can use this as a starting point (Too, 2009).

The primary limitations identified are:

- A case study method requires contributors to freely share information without introducing bias, this is difficult since all stakeholders will have some personal biases;
- Conducting interviews with higher level executives takes up a significant amount of their time, making it impossible to set up extended interviews with them, and it is difficult for them to fully comprehend the research problem due to such time limitations.

The researcher was the only individual who collected and analyzed the data. This may have added some bias into the data. However, the data analysis, the use of a document review method as another method of data collection, as suggested by Sackmann (1991) and Eisenhardt and Bourgeois (1988), has added a layer of impartiality and decreased the risk of bias.

1.8 Outline of the Thesis

This thesis is organized into the following 5 chapters:

- Chapter 1, Introduction, introduces the topic of study, and includes: background of the study, objectives, scope and significance of the study.
- Chapter 2, Literature Review, provides a summary of previous research in the area that is considered necessary to consider Facility management at the early stage of designing infrastructure projects.
- Chapter 3, Methodology, introduces the research framework that was designed by the researcher in order to answer the research questions;
- Chapter 4, Results and Discussions, discusses the results of the implementation of the methodology discussed in Chapter 3.
- Chapter 5, Conclusion and Recommendation, summarizes the results of the study, and discusses the conclusions and recommendations drawn from the information collected.

2. LITERATURE REVIEW

2.1 The need to consider Facility management issues at the first stage of an infrastructure construction

Rarely do designers get-back to measure building performance of facilities that they were accountable for designing, an indication of lack of communication between designers and facilities managers (*Arditi and Nawakorawit, 1999*). Moreover, such statement is still reflected as an exception rather than a regulation in project design and construction. The main hindrances are the strong emphasis on the capital investment and the lack of attention on the life cycle cost in building projects.

Many users of new buildings experience problems with the quality of the buildings, both in relation to the basic usability for the end users and in relation to difficult operation and maintenance for the professional users like facilities managers and the service staff. (*Per Anker Jensen, Kristian Kristiansen and Torben Damgaard, 2009*)

2.2 National operation and maintenance current practice

Newly constructed buildings now a days seem to require huge maintenance right after they are declared completed. The lesser attention paid to facility maintenance challenges during the project initiation and planning stage is a major contributing factor. In Addis Ababa government owned facilities has come to be concluded with issues of maintenance remarks. To add to the problem the Addis Ababa condominium G+7 buildings or the Addis Ababa light rail way elevators has rarely been functional at all time.



Figure 2: Bole Bulbula condominium site

“Eshetu Take, a resident at the Bole Bulbula condominium site told Walta TV that the seven-story building, where he lives in, has no elevator, electric lines, and water and sewage pipes.

Responding to the complaints of residents, Housing Construction Coordinator deputy manager with Addis Ababa Housing Construction Project Office, Teklu Fikru said that his office is going to purchase elevators and will solve all problems.”(*Simegn Feleke Walta TV News 03-Jan-2018*)

In addition to construction and maintainability problems in Ethiopia, the decisions made by executive managers fully focus on the design and construction phase, however ignore considering the need of the operational phase and maintenance period procedures. This happens because of incapability and failure of project initiators to visualize how the facility will be kept properly functional throughout its life cycle after construction. “The big problem in condominium construction is that some political appointees do not have much knowledge about engineering and significant numbers of people involved do not have the correct educational background” the source said. (*February 13, 2017 Capital (Ethiopian weekly newspaper)*)

2.3 Importance of Integrating O&M principles at the start of an infrastructure construction for a successful project

In numerous research works, researchers have advocated for the integration of ideas from stakeholders who are only involved during the later stages of the project life cycle in the planning and design stages as an effective method to successfully project accomplishment.

2.3.1 Infrastructure project life-cycle

The Project Life Cycle is a collection of several stages/phases of project delivery which provides the basic structure for an appropriate project management process (ASCE, 1990).

From the perception of an owner; basically, a project is considered to meet market demands or needs in a timely fashion. Numerous options may be considered in the conceptual planning phase, and the technological and economic practicability of each alternate will be measured and equated in order to choose the finest promising project. The financing arrangements for the planned substitutes must also be looked at, and the project will be programmed with according to the timing for its accomplishment and for presented cash flows. After the scope of the project is plainly determined, thorough engineering design will offer the blueprint for construction, and the conclusive cost estimation will help as the standard for cost regulator. In

the procurement and construction phase, the supply of materials and the configuration of the project on site must be wisely scheduled and organized. After the construction is concluded, there is commonly a brief period of start-up or shake-down of the constructed facility when it is first engaged. Lastly, the management of the facility is transferred to the proprietor for full habitation until the facility lives out its useful life and is labeled for demolition or alteration.

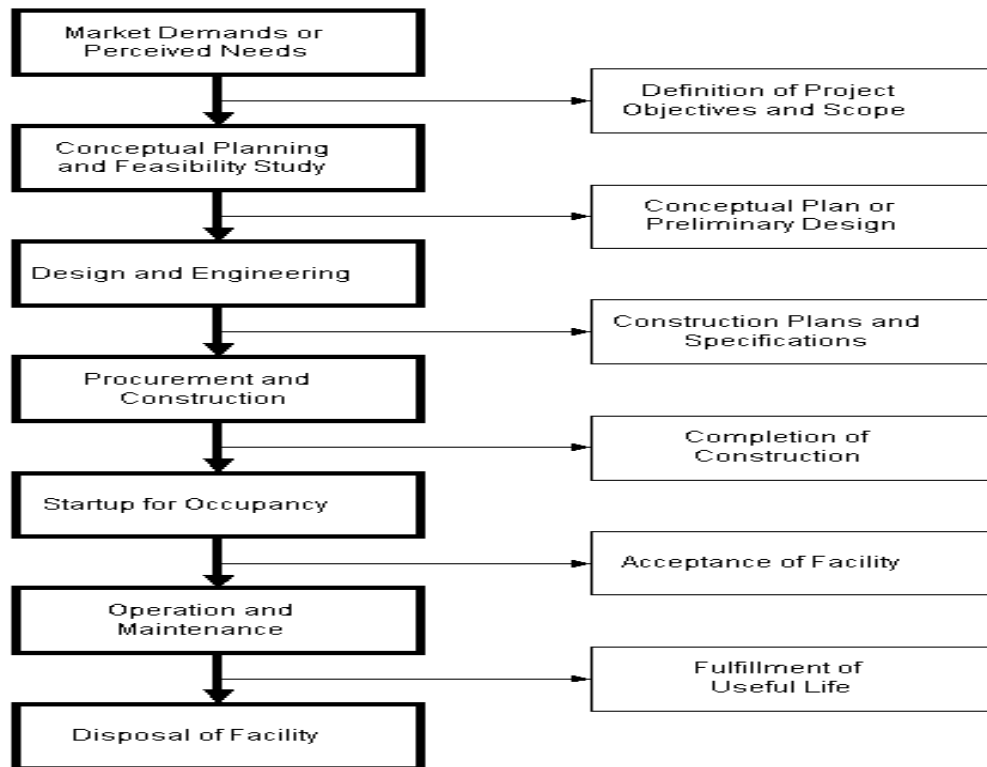


Figure 3: The Project Life Cycle of a Constructed Facility

Cambridge Dictionary (2019) describes infrastructure as “the basic systems and services, such as transport and power supplies, that a country or organization uses in order to work effectively”.

Possessors must distinguish that there is no single best methodology in forming a project management on the entire project's life cycle. All administrative tactics have merits and demerits, depending on the knowledge of the owner in construction management as well as the type, size and location of the project. It is significant for the owner to be aware of the methodology which is most suitable and advantageous for a specific project. In making choices, owners should be aware of the life cycle costs of constructed facilities rather than simply the original construction expenses. Saving insignificant sums of money during construction may not be valuable if the result is much greater functioning costs or not meeting the functional necessities for the new facility suitably.

Thus, owners must be very concerned with the excellence of the completed output as well as the budget of construction itself. Since facility functionality and maintenance is a portion of the project life cycle, the owners' anticipation to fulfil investment objectives during the project life cycle will need attention towards the cost of operation and maintenance. Therefore, the facility's operational management should also be taken in to account as early as possible, just as the construction practice should be kept in mind at the early stages of planning and programming.

2.3.2 Successfully delivered infrastructure projects.

A project management process is successfully delivered if it is completed on time and within budget, while at the same time it satisfies the expectations of the different project stakeholders (Lim & Mohamed, 1999; Nguyen et al., 2004). On the other hand, De Wit (1998) stated that the project success is fully achieved when there is a high level of satisfaction among the key people in the parent organization, the key people in the project team and the key people among the clients/users of the project.

A construction project's success can be measured in terms of whether it is fit on required purposes, functionality, and profitability (Takim & Akintoye, 2002). Belassi (1996) explained that project success can be measured as a combination of the success of the final product and the success of the project management process itself. Baccharini (1999) echoed a similar statement, saying that the success of the facilities and project management team may also be considered as a unit of measure for project success.

For certain stakeholders, the success of a project is the achievement of pre-defined goals, while perceive successes based on the outputs and use of the project. In general, users have a macro-level view of project success while contractors, and consultants have a micro-level view (Lim & Mohamed, 1999). This means, the users and clients check if the original concepts have been met, while construction professionals concentrate on checking whether predefined criteria have been met. It should also be noted that the success of a construction project, especially larger ones relies on various aspects such as human, project management, and external environment factors (Salleh, 2009).

Unfortunately, all project stakeholders are not usually integrated fully into the early phases of a construction project. This lack of integration has led to an isolation of professionals from technical developments and improper implementation of maintenance protocols.

2.3.3 Life cycle cost analysis

Until the 1960s, it was uncommon to set up formal procedures to plan and control the capital cost of construction work as an integral part of the design process. The methodology deployed informed the decision making process regarding the cost of alternative design solutions (at both outline and detailed levels) and their impact on the cost of the overall development. Within a relatively short period, the success of these systems led to attempts to bring the longer term operational costs into consideration. The term “life-cycle costing” became common in the industry by the late 1980s.

Life cycle costing is the process of putting costs associated with various points along a project’s lifetime on equal footing and summing them into a singular figure which allows for their fair comparison without the effects of time (inflation) on money. This can be done using a range of techniques.

While in most cases life cycle costing only includes costs incurred, any benefits which have actual monetary value should be taken into account. This ensure a full accounting of the costs and and benefits of the assests to be made and the cost-effectivness of the project to be studied clearly. Such techniques allow planners to make easy comparison to find the best option in terms of costs throughout the lifecycle of the asset in question. More importantly, the class of asset doesn’t affect the techniques.

The primary reason for the wide acceptance of LCC is its ability to look at costs beyond the initial costs such as capital costs. Instead, costs such as maintenance and operational costs as well as benefits due to certain design choices can be included.

2.4 Factors affecting facility management

2.4.1 Constructability of Designs and Drawings

To make sure as much of the benefits as possible are accrued, its critical to address constructability during the early project phases due to the financial impact of such decisions later on (Griffith & Sidwell, 1995). A design that is influenced by the construction, operation/maintenance of the end product has the greaetest chance of addressing the concerns of all stakeholders while reducing costs.

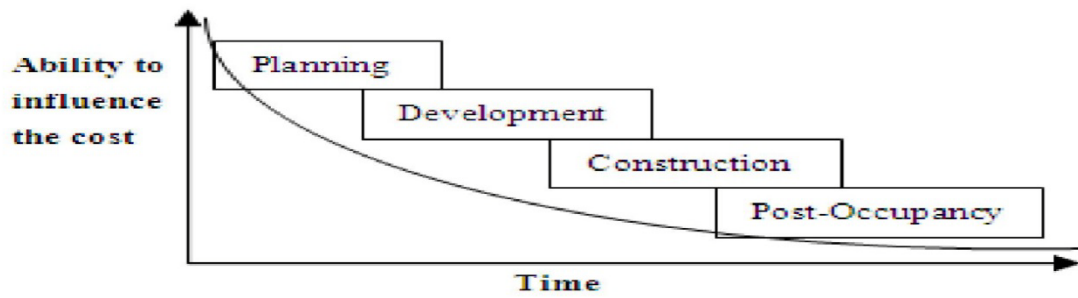


Figure 1. Cost influence curve (adapted from Griffith & Sidwell, 1997)

Figure 4: Cost influence curve (adapted from Griffith & Sidwell, 1997)

Numerous researchers have shown that the awareness amongst contractors toward the implementation of constructability review programs in projects is high. This includes, Building and Construction Authority, 2005; Construction Industry Review Committee, 2001; Glavinich, 1995; Gray & Hughes, 2001; Nima et al., 2002; Saghatforoush et al., 2009a, 2009b; and Uhlik & Lores, 1998). However, the level of awareness regarding issues that arise after the completion of the construction was either low or incomplete. The researchers have proposed that despite constructability assessment programs having many benefits for infrastructure projects, their focus is narrow. Usually, they focus only on the integration of constructability ideas into the planning and design only, and this reduces the possible impact on achieving successful projects.

2.4.2 Designing to operability and maintainability

Darrell Rounds 2018; defined Maintainability and considered as intrinsic to the design of the system, especially with regards to the ease, accuracy, safety, and economics of maintenance operations, where the initiative of maintainability is to increase effectiveness and efficiency of maintenance. The first step in a good maintenance program is the concept of Design for Maintainability (DfM) which relates maintenance goals and anticipated results to the design process itself.

2.4.3 Theories of operability and maintainability:

The shift of maintenance and operational considerations from the post-construction phases to the initial phases occurred due to increased awareness of the importance of such issues and their impact. Despite the two concepts being highly interrelated, most research on the topics has been done separately.

Operability is defined as the “ability to operate a system which is performing its intended use” by Uwohali-Incorporated (1996). A simpler definition by Trigunarsyah and Skitmore (2010) described it as the ease of operation. Operability is also seen as the integration of operational problems with the planning, design and construction stages, however, awareness of this topic remains low and this concept hasn’t been explored, especially in Ethiopia. Operability is also linked with the ideas of ‘fit for purpose’ and ‘maintainability’.

The design of a construction projects must consider both the construction of the works and their end use and be acceptable to both (Cox & Thompson, 1997; Frame, 2003). By having a clear understanding of the needs of the final users early in the construction life cycles helps designers come up with designs which are appropriate for the project’s purposes (Trigunarsyah & Skitmore, 2010). Currently, project documentation lacks the post-construction data, which leads to extra charges for the O&M staff (Russell, n.d.).

While many revisions have been made to the definitions of constructability, less attention has been paid to the early integration of operational and maintenance problems. This leads to high costs during the post-occupancy phases, which account for 50% to 80% of the total project life cycle costs (Griffin, 1993). Despite this knowledge, owners still pay for the high expenses of O&M reworks, especially in infrastructure projects. Therefore, its logical to assume that early consideration of O&M concerns can have a significant influence on the total life cycle costs and time.

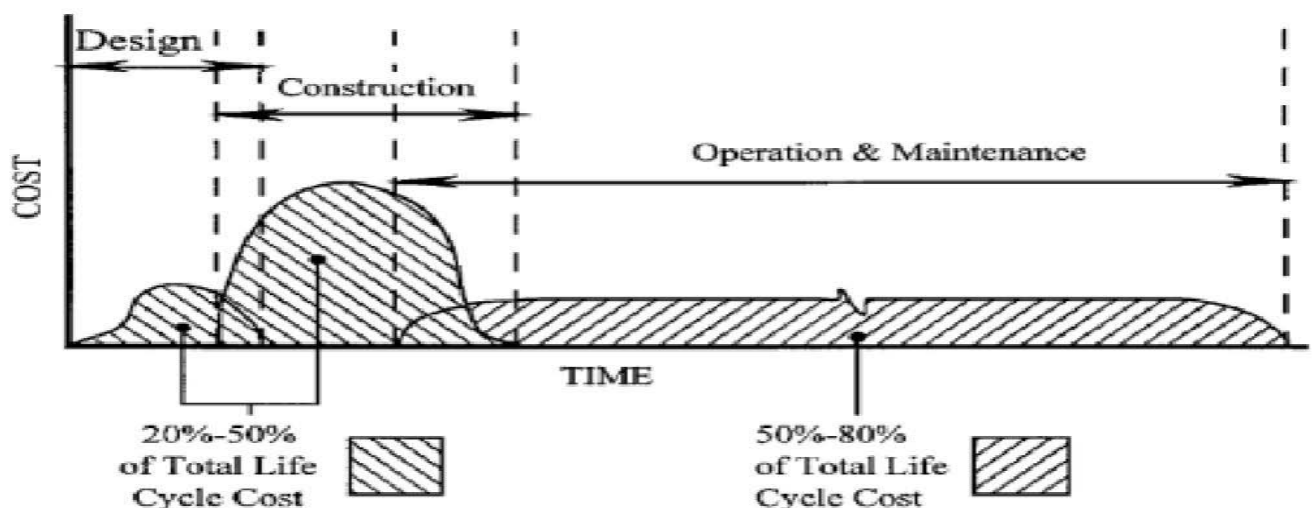


Figure 5: Life-cycle costing profile (Griffin, 1993)

A common example is the complicated and unfunctional design maps which have led to the delivery of faulty projects. In addition, accessibility, reliability and cleanability issues arise

due to the lack of early consideration of O&M issues. In order to eliminate such problems, the knowledge and experience of the whole team must be taken into consideration during the design. The measurement of the success of the project must also take the integration of all stakeholders, and the value-added through the establishment of needs of the client (Geile, 1996).

When conducting an operability review, the stakeholders in charge of the operation and maintenance of an infrastructure project work closely with the planning and design team. The added team members can then check if the operational qualities and consistencies have been met during the planning and design stages (Trigunarsyah & Skitmore, 2010). Geile (1996) argued that it is wasteful to not take the input of the client into consideration when planning a project. By considering the customers' viewpoints during the planning and design stages, significant savings can be made in the future both in terms of time and money. It is also possible to create projects that possess higher quality and longer life-cycle.

The design of an infrastructure project should be fit for its final use case. This requires designers to take into consideration the users' needs and expectations from the development of the project. The planners and designers should understand what the final project will look like and what the final purpose of the project is (Frame, 2003). A suggested method by Trigunarsyah and Skitmore (2010) was backward-pass planning which has the possibility of helping improve the operation of infrastructure projects' through efficient design.

A review of the Construction 21 project report by de Silva et al. (2004) found that there were eight keys for the successful creation of projects with good. There were:

1. Addition of life-cycle cost criterion for tendering
2. Maintainability scoring device
3. A longer liability period for the contractor
4. Consideration of the position of the designers and suppliers in providing data
5. Increased utilization of a "design and build" (D&B) type of contract
6. Improved availability of life-cycle cost information
7. Creation and use of maintainability guidelines
8. Providing training sessions to various stakeholders

Maintainability should be implemented so that the best outcomes are realized. Dunson and Williamson (1999) defined optimal maintainability as "the design characteristic which incorporates function, accessibility, reliability, and ease of servicing and repair into all active

and passive system components, that maximizes costs, and maximizes benefits of the expected life cycle value of a facility”.

The proper maintenance of infrastructure projects leads to an increase in the life of the infrastructure assets. At the same time, the overall maintenance costs are reduced and the benefits of the final delivered project are increased (Blanchard et al., 1995; de Silva, et al., 2004). This is achieved because of a smoother start-up process with a reduced need for reworks (Russell, n.d.). According to Zawawi & Syahrul, 2009, a well designed and implemented maintainability procedure leads to increased profits for owners. It also leads to an economical, accurate and safe maintenance system (Blanchard, et al., 1995). In summary, maintainability is the incorporation of maintenance considerations into the early planning and design phases. In many cases, this is still done separately from the other integration concepts.

A facility manager is responsible for the integration of corporate maintainability of projects into the design and construction stage (Ivory, et al., 2001). Meier and Russell (2000) suggest that a maintainability alert should be created for both project managers and those responsible for the maintainability as early as possible in the project. The post-occupancy stakeholders must also be consulted as early as possible (Dunston & Williamson, 1999). The incorporation of segregated concepts will enable planners and designers to see different aspects of the PLC in unison and to make their best decisions in the design sketches.

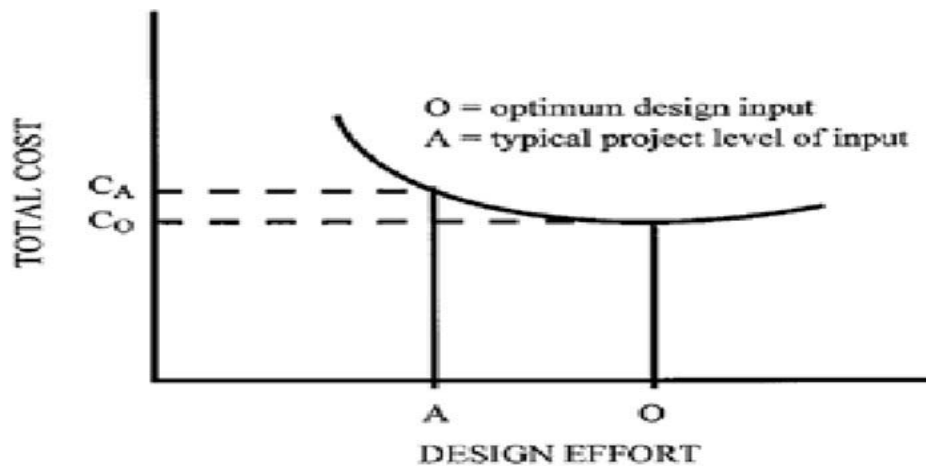


Figure 6: Optimum design input (McGeorge, 1988)

Economically, failures during the O&M phases of multi-faceted infrastructure projects are likely to lead to higher costs, compared with other types of projects. This is due to the higher costs of O&M phases and the lack of a framework that integrates various phases into one (Assaf, et al., 1996; Dunston & Williamson, 1999; Geile, 1996; Griffin, 1993; Ivory, et al.,

2001; Lam, 2007; Russell, n.d.). Currently available studies on the concepts of operability and maintainability are not sufficient enough yet and there remain many O&M problems identified in recent literature, specially in relation to multi-faceted infrastructure projects.

3. METHODOLOGY

3.1 RESEARCH DESIGN

To achieve the stated objectives, the research has followed an exploratory type research method. The researcher has used qualitative and quantitative approaches in this study to answer the basic research questions. The qualitative research approach used in this research has enabled the exploration of the principles needed for effective and efficient implementation of operability and maintainability on the national infrastructure projects.

3.2 Research flow

The research problem of this study addresses the lack of the appropriate integration of ideas generated by different stakeholders during various project life cycle phases leading to a reduced probability of project success in the Ethiopian construction industry. The separation of the concepts of operability and maintainability from the design has resulted in a high number of reworks and extra charges. Previous researches on the concept of Ethiopian O&M in inadequate to address and solve the existing project delivery problems within the industry. In consideration of the research problem, a broad review of literature in different areas was proposed in order to search for the post-construction phase issues. After analysis of these issues, a research framework that integrates the Constructability, operation and maintenane

principles into Ethiopian construction industry was suggested. The framework aims to show a way in achieving the optimal and successful delivery of infrastructure projects.

The following questions were designed to be answered in this research:

1. What are the current Ethiopian problems (current) and practices in achieving effective and efficient operational and maintenance management of facilities/infrastructures?
2. What are the perspectives of higher-level managers in Ethiopia, (Those who can decide what kind of infrastructure projects to launch or what must be include), to incorporate operation and maintenance issue of a facility in the early stage of project initiation/project design stage?
3. How can the existing facility management practice in Ethiopia be upgraded in to the internationally acceptable Facility management standards and regularized to integrate the concept from the start of project design up to end of facility life cycle?

As observed on the literature review sections, the previously available studies do not sufficiently address the research questions raised in this thesis. As previously discussed, there is a lack of a model that integrates all the project phases and the number of researches that explored the various problems in the O&M of infrastructure projects is small, in addition, there is a lack of a widely practiced model for the concept of constructability, operability and maintainability. This has led the research methodology to use a mix of deductive and inductive approaches. Furthermore, this research used a qualitative and quantitative investigation technique, to collect rich data from a variety of quality data-points.

3.3 Research method

According to Denzin & Lincoln, 2000 the research method of a project links the scholar to accurate data collection and exploration methods.

In this research, a dual approach of a case study as well as surveying method, collecting data from multiple data-points is used to forward the comprehensive O&M recommendations. Interviews were conducted in 2 separate rounds, and a review of relevant documents, was carried out to collect the necessary data. The data was then analyzed using qualitative and quantitative techniques.

A summary of the research questions/objectives, the selected method used to answer them, the data collection methods and data analysis technique applied, is presented in the following Table.

Table 1: Research Design

No	Research Question	Research Objective	Research Method	Data Collection Method	Data Analysis
1	What are the current Ethiopian practices in achieving effective and efficient operational and maintenance management of facilities/infrastructures?	To identify the current O&M practice in Ethiopian	Case study Statistical Survey	Semi-structured interview and FGD Literature-Reviews questioner	-Coding -SPSS
2	What are the perspectives of higher-level managers in Ethiopia, to incorporate operation and maintenance issue of a facility in the early stage of project initiation/project design stage?	To develop a model that tests the O&M principles and perspectives in Ethiopia	Case study Statistical Survey	Interviews Document-Reviews Questioner Check lists	-Coding -SPSS
3	How can the existing facility management practice in Ethiopia be upgraded in to the internationally acceptable Facility management standards and regularized to integrate the concept from the start of project design up to end of facility life cycle?	To identify and relate the international practice and prepare a model to fill the Ethiopian construction industry facility management gap	Case study Statistical Survey	Interviews Document-Reviews questioner	-Coding -SPSS

3.4 Data Type and Materials

Primary and Secondary data sources are used to filter out the major problems and challenges that the infrastructure design industry faces.

3.4.1 Primary data

The primary data sources used in this research include: drawings (architectural & engineering), observations by the researcher, and notes from the case study; interviews, small focus group discussion and questionnaires are used in this research's as a primary data source.

3.4.2 Secondary data

Secondary data sources for the research include review of literature in the fields of Construction Concept design and construction working drawings, and other which were important inputs to the research. Also include Architectural and engineering drawings, maps showing infrastructures with their need for maintenances.

3.5 Sources of Data and Collection Techniques

The research is based on the data collected from the sources discussed in the preceding table. Since the concept of maintenance hasn't been extensively studied, the researcher was forced to rely upon internet search on legitimate web sites. Few experts' discussion consisting of fellow colleagues that had at least worked on infrastructure construction was of great help to understanding the issue at hand.

3.5.1 Primary data source and collection techniques

Concerned government officials, Owners and managers, consultants, contractors and Professionals and Personal observation and experiences were the main sources of the primary data. Primary data was collected through:

3.5.2 Interview and FGD (focus group discussion)

a. Interviews

Interview with the stakeholder (client, contractor, BIM and consultant) and interview with the building and real-estate owners on their different project experience helps to get better information about the topic.

b. Focus group discussion

Focus group discussion was a good way and applied by gathering people from similar background or experience to discuss about a specific topic of interest

3.5.3 Checklist and questioner

A questionnaire with closed questions was prepared and distributed to correspondences in construction industry. Building, real-estate owners, infrastructure developers and managers, Consultants, client and contractors were the targets to distribute the questionnaires. The use of checklist in this study is to make observation easy and not to forget elements that should be observed. Before preparing checklist the scholar had reviewed some literatures.

a) Population of the study

For the purpose of this research purposefully selected limited samples from each of facility owners, infrastructures managers and developers, Category 1 Consultants and Grade 1 Contractors were targeted in order to collect the required data through questionnaire. A total of 63 actively participate were found in Addis Ababa. Based on the total population of the

study representative number of samples were addressed in order to collect the data from each of them.

b) Sampling method

A sampling equation was used to calculate the statistically significant sample sizes for the given population.

Equation 1 sampling method

$$S = \frac{Z^2 * (p) * (1-P)}{C^2}$$

Z = Z value (e.g. 1.91 for 90% confidence level)

p = percentage picking a choice, expressed as decimal (0.1 used for sample size needed)

c = confidence interval, expressed as decimal

The total number of higher officials and Director Generals who have direct involvement in initiating construction projects, Facility administration and management professionals, and 63 infrastructure managers were found in Addis Ababa, and using the formula, the sample size was found to be 33. Thus, among these 23 higher officials of Infrastructure project initiators and facility management professionals responded the questionnaire.

3.5.4 Case study approach

Data were gathered from a small number of groups through methods such as participant-observation, thorough discussions, and longitudinal revisions. While case studies can be explanatory with a preliminary research question, they can also be exploratory without any former propositions with the propositions unfolding in due course of the study (Rowley, 2002)

3.6 Data analysis

Once the required data was collected, a combination of techniques, including descriptive analysis, qualitative analysis and quantitative analysis was used to analyze the data based on the type of data collected. Descriptive method was used to analyze the data and interpret the results in quantitative and qualitative ways. The concepts collected from consultants and other concerned bodies through interviews and focus group discussions were analyzed using descriptive narrations. Questionnaire data analyzed using SPSS and excel. The results from the different sources were then triangulated and analyzed in unison.

Besides the interviews made during the case studies fully structured questioners were distributed to the participants. Thus, comprehensively Relative Importance Index (RII) and

Weighted mean score approaches were used through applying a Likert's scale to summarize and squeeze the data collected during survey. Relative Importance Index is calculated for each of the indicators and ranked accordingly. The RII derived to summarize the importance of each indicator.

Where,

W = weighting as assigned on Likert's scale by each respondent in a range from 1 to 5,

Where 1 = no impacts,

2 = negligible impact,

3 = marginal impact,

4 = moderate impact and

5 = major impact.

A = Highest weight (here it is 5)

N = Total number in the sample.

In the case of this Building Structural quality defects, this Likert scale considered as 1= less impact, 2 Moderate impact,

3= significant impact, 4= major impact, 5=Most impact while it has been thought in terms of impacts

Accordingly, the rating scale is arranged as follows:

1. Not important ($1.00 \leq \text{average index} < 1.50$) i.e. in the case of study it means Very less sever
2. Slightly Important ($1.50 \leq \text{average index} < 2.50$) i.e. less Sever
3. Moderately Important ($2.50 \leq \text{average index} < 3.50$) i.e. Moderately Sever
4. Very Important ($3.50 \leq \text{average index} < 4.50$) i.e. High Sever
5. Extremely Important ($4.50 \leq \text{average index} < 5.00$) i.e. Very high Sever

The defects are ranked according to their RII result using the calculation below

$$RII = \frac{(n1*1) + (n2*2) + (n3*3) + (n4*4) + (n5*5)}{A*n}$$

While Weighted average Score determined as $= \frac{(n1*1) + (n2*2) + (n3*3) + (n4*4) + (n5*5)}{n}$

4. RESULTS AND DISCUSSIONS

According to the Ethiopian Construction Project Management Institute Director General throughout the Infrastructure project constructions, design and construction phases are given higher weight and enormous amount of initial investment. Therefore, the causes why national infrastructure contracts are under-performing and failing to satisfy the expectations are attributed to these root causes:

- 1) Less attention given to the initial stages of project cycle to gather with inadequate risk identification and management;
- 2) Failure to treat project in its entire life cycle as a single system, i.e. low level of overall integrated project cycle management system facts and applications” (*Ing. Asmerom Tadesse, 2019, ECPMI*). All Infrastructure construction in Ethiopia are generally distinguished by the following points, Table 8.1, which designing cost is 65%- to- 75% lower than Supervision budget. This shows that new choices and changes takes place even though construction is evolving. On the other hand in developed countries such as United State of America and Canada Designing charges are three times greater than supervision costs. It is a good proof of much attention has been given to design detailing, which intern will reduce defects causing maintenance difficult.

Table 2: Distribution of the Consulting Services Fee - Ethiopia

Subsector	% share out of the total consulting service fee		
	Design	Supervision	Total
Building	32.46%	67.54%	100.00%
Water	31.61%	68.39%	100.00%
Road	24.55%	75.45%	100.00%
Aggregate (Industry)	28.00%	72.00%	100.00%

Table 3: Distribution of the Consulting Services Fee - International practices (US, Canada)

Design Related Services	65-75%
Construction Related Services	25-35%

5.1 Availability of Facility regulation Bodies

64% of the respondents said there is no specific body or association in Addis Ababa or Ethiopia at large, who provides any sort of Guidelines or regulations to assess performance of Facility management practices. Whereas 36% responded they don't know if there is or not a concerned legal body or an association or any sort of organization.

5.2 Availability of Facility management Department in the organizations

46% of the respondents explained that they do have Departments related to facility managements. While the remaining 54% said that they never have or they had some time in the past but now have it closed due to a number of reasons such as budget and skilled man power problems.

5.3 Level of Involvement of Facility mangers in the project initiation phase

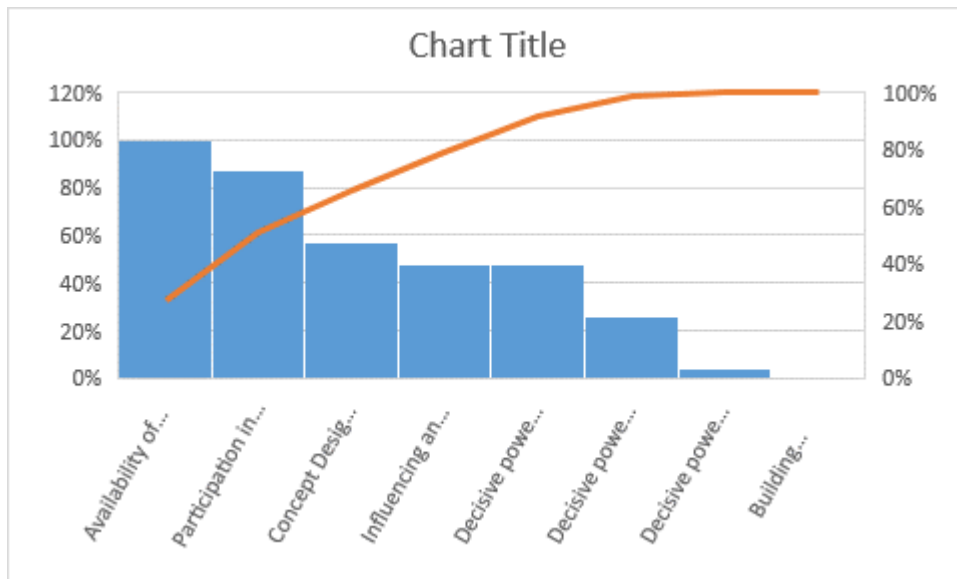
For the questions to identify the level of Facility mangers involvement, 100% of the respondents stated that they had no involvement what so ever in the strategic planning of their facility management, and emphasized that they had never found any opportunity to contribute to such novel activities as providing their perspectives for any planed construction to be designed in the operation and maintenance perspectives.

5.4 Level of higher Officials to influence Project initiation characteristics and participation levels

Both on the questioners and interview sessions participants have been asked to respond as followed

Descriptions	Very low	low	medium	High	very high
Influencing an Infrastructure project Initiations	48%	22%	13%	9%	9%
Participation in project conceptualization decisions	87%	13%	0%	0%	0%
Concept Design influencing mandate	57%	35%	9%	0%	0%
Availability of integrating Maintainability issues at the project conceptualization period	100%	0%	0%	0%	0%
Decisive power on the project Initiation phase	48%	22%	13%	9%	9%
Decisive power on the Design phase	26%	4%	61%	4%	4%
Decisive power on the Construction phase	4%	0%	30%	22%	43%
Building Operation and Maintenance	0%	0%	87%	13%	0%

As it is indicated in the above table public infrastructure projects do not have specific owners at the beginning. It begins at higher level political decision makers and then proceeds to the mid - level managers periodically. This can be clearly indicated by the following chart.



87% of higher officials indicated their role in initializing and conceptualizing of projects is minimal. And all of the participants commonly respond for there is no plat form, which brings decision makers to comment and influence infrastructure projects to include maintainability issues before project launch.

5.5 O&M Problems & Current Practices in Infrastructure Projects

5.5.1 Operation and Maintenance phase problems

As complications of different phases of construction projects are interconnected, it is apparent that the poor performance will have influence on proper usability of the built infrastructure thus affect the maintenance practice, Maintenance problems commonly arise when the building performance is not as per the designed criteria and designed quality (Ali et al.,2013). Any infrastructure call for maintenance to guarantee optimal performance over its life cycle, however this can be reduced by decreasing the problems which are initiated from design and construction phases. Crucial objective of maintenance embrace; preventing buildings (its constituents and facilities in worthy situation), building components and services to original standards before deterioration occurred, bear the value and utility of the building, reduce and slowdown the degree of deterioration of the structures, avoid crisis maintenance by regular and planned maintenance program and meet statutory requirements for health and safety (Gahlot and Sharma, 2006).

5.6 Problems affecting O&M of infrastructure projects

5.6.1 Design and construction phase problems and challenges

Operability of a building hangs on to the quality of its design to a great extent and to its construction (Kiong & Akasah, 2013; Waziri 2016). Complications originating from design and construction segment intensifies maintenance effort and maintenance budget (Khatam, 2003; Ali et al., 2013; Jimoh, 2016), it also touches the overall maintenance strategy. Overall, the different phases; design, construction and maintenance are closely related but not easily distinguished (Jimoh, 2016).

Currently in Ethiopia Design and construction shortcomings are affecting maintenance independently. Design faults affecting maintenance are:- architectural design flaws, lack of comprising buildability and maintainability in design, incomplete drawings components, specification complications, omitted design principles, late owner driven design changes, technology associated problems, insufficient assessment of project characteristics, defective structural design and faulty construction drawings, and the Construction period associated deficiencies influencing O&M processes :- begins from absence of appropriate supervision, a gap in communication between stakeholder, defective construction materials, poor quality control on site, construction methodology problems, project management drawbacks, incompetent workforce, non-conformance with specification and poor construction procedures.

5.7 Current Practice in public Building Maintenance Management

From the data collected from interviews, the construction phase, site documentation practice was taking place informally and follows no standard. None of the maintenance departments in the facilities had O&M strategic plans not even minimum condition standards at which the buildings should be maintained. Even though only some of the organizations have arranged for departments to take care of O&M issues, structure of this departments lacks consistence and clarity; low level of emphasis is given to building maintenance management and the awareness of maintenance importance is poor. Similarly, there are problems emanating from design phase that affect maintenance practice which could have been reduced through early involvement of maintenance in the design. However, this paper found that there is no such practice when new projects are being initiated. The general condition of the Ethiopian public procurement Agency puts it explicitly that as-built drawings, operation and maintenance manuals must be provided to the client/owner during the handing over period of projects. But,

unfortunately none of the organizations witnessed to provide full document and practice at all.

Budget shortages was mentioned as one of the challenges by all of the university respondents. The budget shortage includes all that associated with recording and maintenance inspection to the actual expense required to undertake physical repair and maintenance expenses. The problem is much more complicated in case of public condominium buildings, after it is transferred to the community it is not clearly stated who will be in charge of maintaining it or how and when maintenance will be taking place.

According to the Hawassa UIT report the top five variables are 1) lack of information transfer from construction project office to building maintenance department during project handover, 2) Lack of building standard, 3) absence of maintenance office involvement in design phase, 4) weak building condition assessment and planning trend and 5) poor building information recording practice.

5.8 Design and Construction Related Problems

In Addis Ababa public hospitals 81.5 % of the respondents mentioned plumbing system in the facilities as the major source of complaints. Water supply and repair/replace are also other maintenance related complaints. Choice of material to be replaced or repaired, clean ability and waste disposal systems at 72.5%, 54.5% and 54.5% follow the significance ratio respectively. 53% of the respondents explained that the lack of organized facility management system is the basic problem while 47% of the respondents said that lack of professional building facility managers is the basic problems.

Mendelsohn (1997) stated that 75% of the problems encountered on site are initiated at the design stage. Several design absences are identified during the carrying out period of construction project that may lead to rectification (Oyewobi et al., 2011). Mohammed et al. (2010) postulate that alterations in the plans by the owner, changeovers of material by the owner or the contractor, and late modifications in the design by the consultant are the main causes of discrepancies in building projects in Selangor, Malaysia. Grau, Back and Prince (2012) disclose that disagreements between designers and contractors are attributable to poor design planning, imprecision of design documents, high build cost of design options, delay of drawings, and irrational design fees. Tribelsky and Sacks (2010) found the flow of information in the process of detailed design where construction documents are prepared. Tenah (2001) notes that what looks like good on drawings or on the computer screen is sometimes problematic to build, and designers seek alterations in the plans during the

construction phase. These inconsistencies result in rework, changes in quantities, and delays and faults in construction. Kong and Gray (2006) point out that the most noticeable source of delays and following disagreements on construction projects in Malaysia was disputes between the contracting parties. Deviation from original design and delays result in minimized investment that largely decreases the whole growth of building construction and occasionally leads to unemployment. Wang (2000) stated that arguments between the stakeholders were frequent in projects marked by poor management. These can include approvals, reporting procedures, and inspections. Mohamad, Nekooie and Al-Harthy (2012) designated that nearly all projects experience numerous modifications, not only at the design phase but also throughout construction. Discrepancies in design and construction may result in delays in project duration, compromises in quality, or increase in cost. Reducing inconsistencies allow the project management crew to finish the project productively (Arain, Pheng and Assaf, 2006). It is significant to assess the eventual causes of disagreements throughout the project life-cycle

5.9 Contribution Factors to Building Defects and Failures in Addis Ababa

5.10A Case Study on an Addis Ababa housing development office revealed that

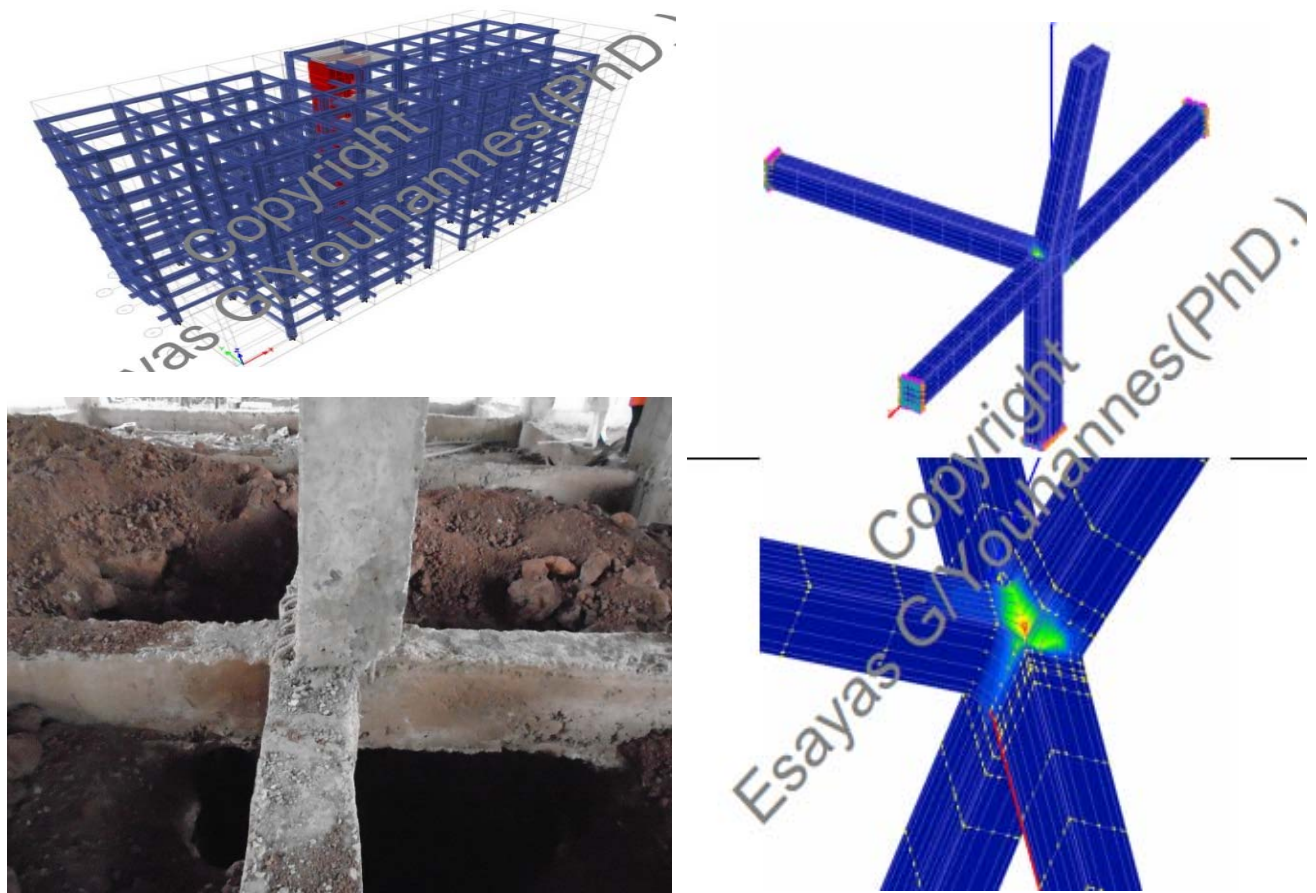


Figure 7: Structural quality Defects

1. The stability index $\square\Theta$, is found to be greater than 0.1. Which makes the structure to behave in a sway mode. Although this may not make the structure unstable, it possesses a danger of instability because the values are closer to the limiting value of 0.25, as per the recommendation of EBCS-8, 1995. Noteworthy limiting the stability index with range of 0.1 is advisable from stability and economic point of view.
2. Some beams particularly secondary beams fail to satisfy the minimum requirement for ultimate limit state regarding flexure as stipulated in the Ethiopian building code EBCS-2, 1995.
3. Column supporting the stair case is found to be highly slender and unstable, as it lacks bracing elements throughout the height of the building. This makes the entire staircase system unstable and requires extensive intervention.

5.11 Assessment of the building with existing conditions – material and member size variation

The investigation team visited the site and carry out the following tasks to identify the major defects and to provide remedial measures

The major defects are identified by the team, are the following

- Reduced concrete compressive strength
- Reduced column size at beam-column joint
- Reduced beam size at ground level and notable offset at ground level columns from center line to the foundation columns – Causing large eccentricity
- The quality of construction is sub-standard.
- Mechanical properties of the reinforcing bars used for the structural members and the amount of reinforcement provided are taken from the original design document. However partial validation on the number of reinforcing bars was made from the exposed elements particularly at the beam-column joints.
- The result of the cubic compressive strength of concrete for the structural members was determined from characteristics value of the test results and is found to be 16.74 Mpa (67% of the expected 25Mpa).

Faulty design can occur due to an increase of maintenance cost. Some maintenance problems arise where the design is low probability of achievement in practice though it was satisfactory in principle. The noble design accomplishment in the planning of buildings as worthy substances is assumed and distinguished, despite less established and valued is the need for

continuous maintenance. These are more or less the reasons of design failure concerning maintenance:

- a. Poor detailing and jointing
- b. Insufficient thickness of concrete cover
- c. Insufficient jointing between finishes faces
- d. Incorrect locating conduits and piping at critical structure location
- e. Insufficient length of owning
- f. Insufficient provision for thermal movement
- g. Insufficient structural design
- h. Ignore maintenance access when designing
- i. Not concerned on aggressive environment and weather condition effect
- j. Less consideration the availability of maintenance tool during designing a building
- k. Not relating exterior construction material selection to weather and climatic condition

The *findings* of the existing building structural assessment are:

Several beams particularly secondary beams fail to satisfy the minimum requirement for ultimate limit state against flexure as stipulated in the Ethiopian building code EBCS-2, 1995. Column supporting the stair case is found to be highly slender and unstable, as it lacks bracing elements throughout the height of the building. This makes the entire staircase system unstable and requires extensive intervention.

It is concluded that the assessed building requires major strengthening on some supporting members including beams and columns to be able to achieve the level of minimum requirement for ultimate limit state (no-collapse requirements) and suggested the remedial measures.

Overall, the field assessment associated with the structural assessment using 3d modeling indicates that the building block as is, fails to meet the minimum safety requirements and requires major strengthening as well as repair.

Ministry of Education Capacity Building Program for Higher Education was requested about the building operation and maintenance policy. As the institutes described there is no strategy which directs how to control and maintain the building in Higher Education rather the maintenance will be done on the interest of universities. However, the building maintenance policy offers support to the maintenance staffs to define appropriate maintenance strategy and standard.

Facility's history includes detailed information in the form of drawings and manuals for operating the facility. As the study outcomes showed that, no detailed record of buildings, which is used to know the situation of each building in all examined universities to use for maintenance purpose.

However, lack of detail documentation of buildings affects the performance and management of the facility.

As shown below in Figure, Debre Tabor, Debre Markos and Gondar universities practice only break down or emergency building maintenance type , 14% of the respondents in Bahir Dar university Marine campus practices routine maintenance type and the other 86% practices breakdown maintenance type.

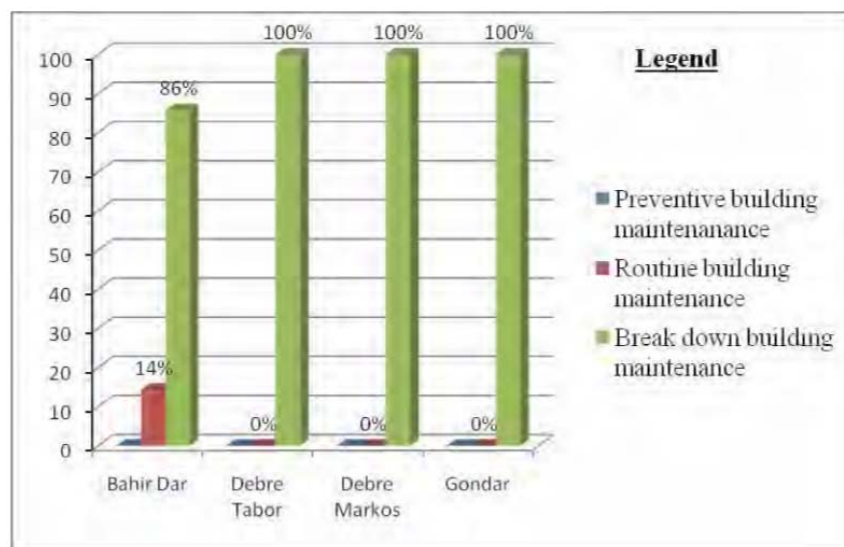


Figure 8: Types of maintenance

As presented in the above Figure, majority of universities practice break down maintenance type with the comparison of routine and preventive maintenance. Due to lack of preventive maintenance tasks include inspections, equipment checks, adjustments and overhaul at specified intervals cannot be done.

5.12Problems Hospitals Faced with Building Maintenance

Six most common problems in hospital building maintenance and their significance, according to the responses the main problems found in the hospital building maintenance was not enough staff, not enough budget and too many calls for service. In the others category the misuse of health facilities from patient's attendants were by far the biggest problem. The

management should give awareness how to handle the hospital properties to all people using the health facilities.

5.13 Major Sources of Maintenance Related Complaints

Bin Hashem, (2006) discussed that the main supporting system such as waste disposal, lift system, electrical system, firefighting system, plumbing and sanitary system, cleaning services, choice of materials, sound penetration and telecommunication system that should be working properly without any disturbance and affecting the entire hospital work process. The result on the maintenance type carried out by the public hospitals indicated that all hospitals under study have implemented immediate and corrective maintenance system.

According to the data gathered application of routine / periodic inspection is very rare. Delays in carrying out maintenance works at public health institutes in Addis Ababa are mainly due to non-availability of spare materials.

The main problems found in the hospital building maintenance are found to be not enough staff, not enough budget and too many calls for service. In the others category the misuse of health facilities from patient`s attendants were by far the biggest problem.

Individuals that Workshops and seminars are the major training types given to the maintenance operatives. The maintenance operatives are found not to be well motivated. This may be attributed to poor pay, lack of opportunities for training/development and lack of working tools, equipment, materials. Only few public hospitals of Addis Ababa have guideline to direct the maintenance activity and facilitate their maintenance department. But, in many cases, a maintenance log-book is used by maintenance operatives.

5.14 Design defects affecting maintenance (Baba Shehu Waziri)

1. Design Problems
2. Poor or no consideration of buildability and maintainability in the design
3. Problems with detailed drawings
4. Defects associated with specifications
5. Insufficient design standards
6. Changes to the design mandated by the client
7. Problems associated with the consultant
8. Incompatibility of the design and the existing technology
9. Poor risk assessment

10. Poor structural design
11. Defects in construction drawings

5.15 Construction defects influencing building maintenance

1. Poor supervision
2. Lack of communication among designers and contractors
3. Poor construction materials
4. Poor on-site quality control
5. Improper use of construction methods
6. Adverse site conditions
7. Usage of improper reinforcement
8. Utilization of new and untested materials
9. Uncoordinated effort among different disciplines
10. Poor civil construction
11. Contract administration related defects
12. Lack of mandatory tools for construction
13. Defective formwork
14. Inappropriately trained workforce
15. Inability to meet specifications
16. Poor construction methodology

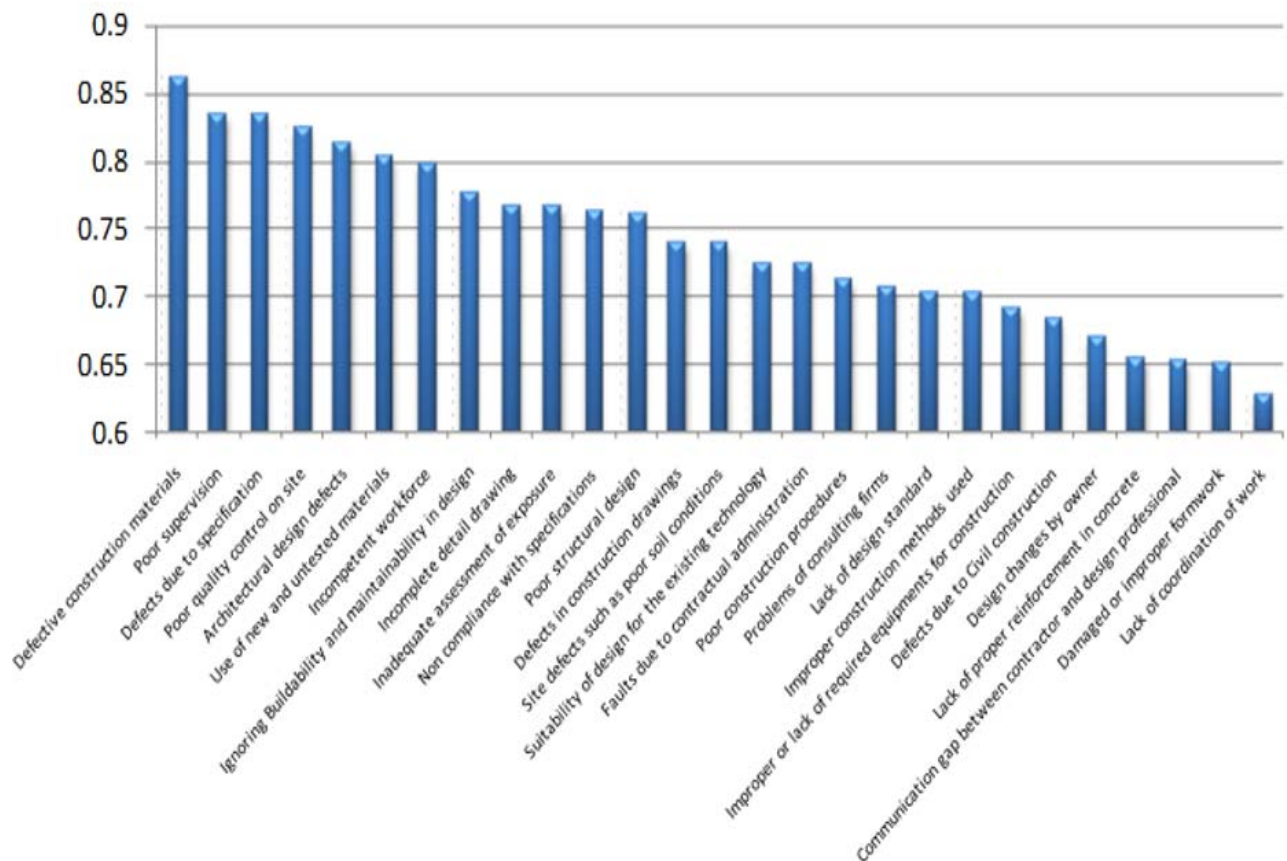


Figure 9: Ranking of all factors affecting maintenance

5.16 Major Causes in Faulty Design /Common Causes in Design Failures)

The most similar reasons design failures in Higher Education Institution establishments.

1. Poor commitment to follow well conventional design standards.
2. Ignorance of the basic physical properties of materials.
3. Poor communication between team.
4. Misjudgment of user and climatic condition.
5. Complex details.

5.17 Current international maintenance challenges are as follows

According to Ehsan Saghatforoush, 2014, Nuzaihan Aras Agus Salim, a, Naziah Muhamad Salleh and Nurul Fadzila Zahari; 2016 internationally the following mentenance challenges are identified as follows:

- Poor Communications
- Unfamillarity with maintenance operations
- Budget limitations
- Delayed Handover of Documents
- Absence of Preventive Maintenance

- Legislation and;
- Contracting Defects

5.18 CURRENT PRACTICES IN ADDRESSING O&M PROBLEMS

Early Programming

Decisions made during the initial phases can greatly impact the overall project objectives. Studies have shown that several practices adopted early on have reduced O&M problems.

Standardization

Mandating the use of master planning, and holding meetings with stakeholders has successfully prevented many O&M problems. Evidence has also indicated that its important to have a standard solution for a business.

Knowledge Sharing

Knowledge sharing a solution which involves the integration of those with knowledge of O&M operations into the planning stage and incorporating their input into the design.

Control of Handover Stage

Delegating control of the handover to an experienced individual and giving that person sufficient authority during the construction stage and ensuring that regular inspections and testing are performed can have significant benefits by ensuring that the projects meet the required standards.

Strengthening Communications

If a maintenance team is assigned to the project early on, communications problems could be avoided and teams could work together seamlessly. This includes the design and construction teams. This can stop problems before they occur and lead to savings later on.

Developing Knowledge and Experience

Providing training for O&M staff to familiarize them with the design of the planned services and facilities in the projects can improve their knowledge of operations. In addition to training, providing manuals earlier, was also found to be effective. Training costs can be reduced by providing the trainings before the completion of the project.

Regular Monitoring

It is important to have a system which allows for constant monitoring and fixing of issues before they become larger. This can also keep all staff informed. Respondents in a medical setting have stated that compromising was an important practice in their job, because clinical needs are prioritized over maintenance ones.

Cost Control

Research has shown that cost control is done on healthcare projects regularly. The techniques included seeking funds from the companies that initially installed a service or equipment, optimizing storage areas, using alternative maintenance methods, and using alternative materials.

Safety Considerations

Research has also shown that removal of safety hazards was a significant part of the time maintenance teams spent. This operation also took significant funding.

5.19 Summary of Current practice in addressing Operation and maintenance management

In this section, the findings based on the analysis of the interviews is presented based on the considerations of O&M personnel on operational issues. Qualitative analysis techniques allowed for an in-depth exploration of the O&M needs of different infrastructure projects.

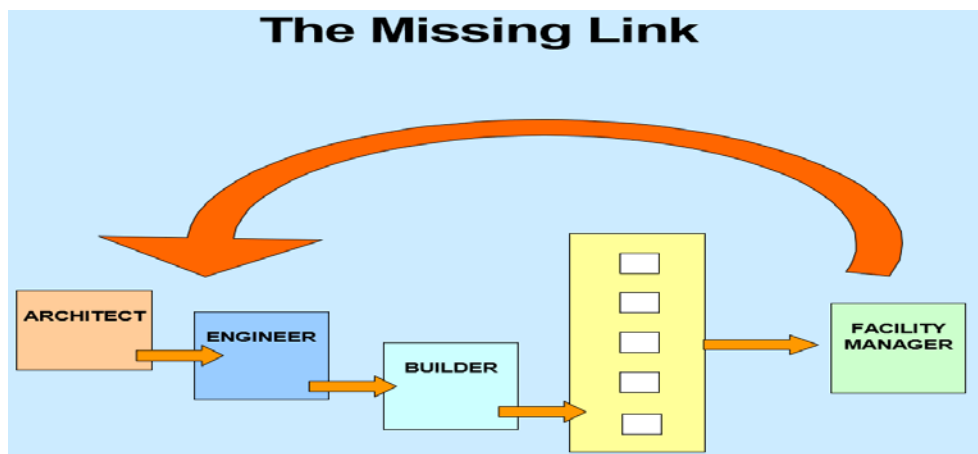


Figure 10: Proceedings of the CIB W070 2002 Global Symposium

5.19.1 Best Practices

With a reduction in budgets, and a more competitive industry, maintainability and operability has grown in significance to many companies. This paper shapes the suggested ideal methods for maintainability and defines the possible influence it can have on a number of projects.

The CII Maintainability Implementation Guide (1999) is one of the best sources for best practices and guidance available.

5.20 Maintainability put into practice

5.20.1 Corporate-level milestones

Maintenance has been transformed from a post-construction activity to a an essential part of the project initiation. By including it as early as possible, the probability of it solving problems later on is greatly increases. A company-wide program to ensure maintainability is addresses by all stakeholders is critical.

1: Dedicate to Fulfilling Maintainability

Step 1. Develop Higher Management Attentiveness

Step 2. Implement Self-Assessment and Recognize Obstacles

Step 3. Measure and Identify Benefits

Step 4. Develop Execution Plan

2: Form Maintainability Program

Step 1. Isolate Corporate Maintainability Advocate

Step 2. Develop Corporate Measures and Provisions

Step 3. Develop Lessons-Learned Database

6: Modernize Corporate Software package

Step 1. Assess Corporate Software package Helpfulness

Step 2. Review Organization and Processes

Step 3. Modernize Lessons-Learned Database

5.20.2 Project-level milestones

3: Achieve Maintainability Competences

Step 1. Form Project-Level Maintainability Accountability

Step 2. Place Project Management, Designers, and Suppliers

Direction of project participants enables actual implementation of the maintainability procedure. Orientation may include proper teaching sessions, internal and external networking, improvement evaluations, and right of entry to company and industry experts.

As a lowest, orientation and training should include the following:

- (1) Goals for all maintenance packages;
- (2) Execution guidelines;
- (3) Ideas regarding maintainability perceptions;
- (4) clarification of possible benefits;
- (5) Addressing of general project and company-specific obstacles; and
- (6) Inclusion of applicable maintainability texts.

Step 3. Cultivate Resources for Maintainability Examinations

4: Plan Maintainability Application

Step 1. Form a multidiscipline team with O&M staff included

Step 2. Define Maintenance Strategy

- Reactive maintenance: Maintenance that is done in response to a failure
- Preventive maintenance comprises time-driven maintenance jobs planned at fixed intervals to prevent interruption of equipment or structures.
- Predictive maintenance (condition monitoring) is a system whereby checks and analysis are performed to stay ahead of failures (Cost planning 1996).
- Proactive maintenance uses diagnostics information from predictive maintenance to solve the root causes of failures rather than fix the failures everytime they occur.

Step 3. Outline Project Maintainability Objectives

Maintainability objectives need to be well-thought-out in the framework of general project objectives, such as cost, schedule, and safety. Objectives should be recognized after five criteria:

- (1) Printed;
- (2) comprehensible;
- (3) Quantifiable;
- (4) Stimulating; and
- (5) Attainable (Patton 1980).

Maintainability objectives can be qualitative and quantitative.

Qualitative objectives for insertion on projects comprise:

- (1) Designs which integrate maintainability and operability;
- (2) maintenance activities recognized for each tool part and scheme;
- (3) experienced staff in place with end to end proper O&M teaching;
- (4) electronic maintenance administration method, open for maintenance tracing and regulation;
- (5) plan for precautionary and protective maintenance establishment;
- (6) maintenance Grade A practices in place;
- (7) Include team members as stakeholders in project; and
- (8) effective connection of equipment and reduced start-up period.

Quantitative objectives addition on capital projects contain:

- Reduce percentage of cost maintenance takes in proportion to replacement asset value;
- Reduction of average duration between breakdowns; rarer failures interpreted to higher operability
- Reduce time taken to complete maintenance works; this leads to a lower down time, and increased use

- Decrease life-cycle cost (LCC); reduce costs over the lifetime of the asset and essentially lower than the minimum initial cost.
- Improve user-friendliness;

Step 4. Incorporate Available Maintenance Tools and Techniques

Milestone 5: Device Maintainability Procedure

Contains six stages that define how to integrate maintainability into a definite project.

Step 1. Conduct Official Maintainability Consultations

Step 2. Put on Maintainability Ideas Strictly throughout Design specifications and evaluations to confirm that the project designs fully covers maintainability objectives. Maintainable design normally contains two kinds: (1) Design for maintainability; and (2) design for marginal repair costs.

Step 3. Consider Maintainability in Procurement Practices

(1) Maintenance characteristics; (2) spare parts obtainability; (3) former practical know-how; (4) supplier provision; (5) maintenance necessities;

Step 4. Recognize Construction Influence on Maintainability

Step 5. Manage and rate Project Program Success all over O&M section

Step 6. Undertake Maintenance training and supply Records

SUMMARY

The prior suggestions are the modest practices in O&M application at various levels. Corporate level steps are to improve and sustain project maintainability execution. Project-level maintainability steps and actions form the competences essential to set up and device maintainability on a singular out comes.

NSN	Operability and Maintainability Principles	Project Initiation		Design Development		Construction Process		Facility Management	
		Planning	Feasibility	Conceptual	Detailed Design	Construction Implementation	Construction Supervision	Operation	Maintenance
I	FOR PLANNING STAGE								
1	Integration	O&M must be a critical component of the project planning and design stages.							
2	O&M Standards Definition	Project planning and construction design must be based on the proper definition of the O&M standards of either the project or national standards.							
3	Program	The overall project program must be realistic and O&M-sensitive. It must be prepared at the earliest possible time within the planning and design stages.							
4	O&M Team Skills	The education and experience of the project team must take into account the needs of the project in terms of O&M.							
5	Accessibility			By considering accessibility during the design phase, O&M issues will be reduced.					
6	Adaptability/Flexibility			If adaptability and flexibility are considered in the early phases, the project can have more enhanced O&M.					
7	Authority			Giving authority to O&M stakeholders as early as possible will reduce the number of O&M issues that can arise later on.					
8	O&M Available Resources			Both the technology choice during the pre-construction phases and the skillset of the O&M team must match.					
9	Clean ability			O&M can be improved if cleanability is addressed in this phase.					
10	Engineering Methodology			The design must address O&M considerations.					
11	Functionality/Fit for Purpose			O&M will be useful if the design has considered whether or not asset will serve the purpose its meant for.					
12	O&M Knowledge			The conceptual and detailed design must incorporate the input of O&M staff and their experience.					
13	Specifications			The development of specifications should take O&M into consideration in order to enhance the efficacy of the O&M phase.					
14	Technical Leaders/ (technical staff as a leader)			Including technical leaders instead of architects during the early phases can help the improved implementation of O&M principles.					

5.21 Operability and Maintainability Principles

III	FOR CONSTRUCTION STAGE					
15	Authority				Giving authority to O&M stakeholders during the construction phase can help enhance the O&M.	
16	Handover of Documentations				Construction teams must handover all necessary documentation to the O&M teams.	
I V	FOR O&M STAGES					
17	O&M Innovation and Consistent Computerization					Adoption of innovative technology and computerization can enhance the implementation of O&M.
18	O&M Feedback					A comprehensive O&M review can allow for experiences to be shared across projects.

6. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Based on the results the following conclusions are extracted. The Executive decision makers in the public organization have inadequate operability and maintainability awareness and they do not have much experience on in initiating new infrastructure projects. Because, the public Directors and General Managers reflected that the infrastructure projects are initiated at some point in the higher official levels such as ministry level in which they were assigned to execute the progress of the construction projects following political decisions have been made to launch a project, often after it is publicly announced.

Even though the interview participant Executive managers are at least aware of Constructability problems. Project activities are out sourced in to different stakeholders from the start of the infrastructure conceptualization that is many of the Infrastructure projects start through political decisions. Then it will be followed by procurement committees to select the consulting, designing and supervising firm, which will be followed by bidding and awarding the contractor for the immediate construction procedures. This will leave unorganized number of executives to consider and make O&M the focus area during the planning and construction phase, exactly as it has to be done for the concept of constructability currently does for construction.

Therefore, firmly applying the Operability and maintainability principles developed on this paper will reduce life time cost infrastructures and enable them provide their intended services with less break down time which will lead to higher customer satisfaction.

7.2 Recommendation

While this research has provided critical insights into the questions of operability and maintainability, there is ample room for further research in the future. In light of the research findings, and conclusions, the following recommendations are made in order to improve the practice of maintenance management in infrastructure constructions

- a. Interviews conducted for the research showed that there is a significant link between the choice of contract type and how the ideas of different stakeholders can be integrated into the different phases of the project. Therefore, it is recommended that the effect of contract type is studied in the future, with a focus on how it can improve the COM Ability Model.
- b. Government institution such as the Ethiopian construction project management institute and The Ethiopian construction authority shall study by selecting specific but large infrastructure organizations to enhance the model developed.

Hence, government authorities such as the Ministry of urban development and construction have to consider the following six points in to the construction policy and building regulations in order to provide maintainability in to infrastructure constructions

1. Contracts should be designed to ensure that the views of stakeholders involved in all phases of the construction project are incorporated, with emphasis on the perspective of the O&M professionals. This can lead to a more complete and comprehensive design.
2. Trainings for all stakeholders should be held, with a focus on the implementation of operability and maintainability.
3. An environment that is conducive for O&M staff to share their views and participate in multidisciplinary consultations should be created.
4. Feedback should be a continual, long-term process.
5. COM Ability Model principles that are based on data collected on infrastructure projects, and O&M concerns should be applied.
6. O&M professionals should be involved as early as possible, and the strategies to encourage this are as follows:
 - a. Identify and communicate the roles, responsibilities and expectations of all O&M stakeholders early.
 - b. The scope of the project should be clearly identified before budget allocation by the client.

- c. Designs must be a correct fit for the project's specifications and should match with the available personnels background and resources.
- d. Projects should be designed with the future in mind and with be flexible enough to accommodate changes in the future.
- e. The communication, inter-personal and professional skills of O&M personnel should be evaluated and improved continually.
- f. O&M professionals should be involved in the handover process, including training and preparation of guides.
- g. Design teams must include technical leaders and O&M professionals.
- h. Technological innovations should be integrated with the project, including computerizations/digitization, equipment management and project administration.
- i. A SWOT analysis should be performed and events that could affect the project during the planning and design stages should be identified.

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AN OVERVIEW OF CASE STUDY

Case study objectives: The case study method is used to:

1. Identify current O&M issues of construction projects.
2. Find existing practices regarding O&M during the delivery phases.
3. Identify what leads to effective implementation of O&M.

To Identify O&M Issues:

1. What issues did you encounter during Operation & Maintenance implementation?

To Address O&M Issues / To Identify the Approaches:

2. How did you work to address these problems?
3. What specific tools do you use to issues?
4. What difficulties have you experienced with your tools?
5. Do you know any alternatives?
6. Justify why you would recommend it?
7. How can your methodology solve these problems?

To Consider O&M Issues in Planning and Design Phases:

8. Can these approaches be achieved by feeding the O&M info into planning and design phases?
9. Who should be involved in planning and design? (You or anyone else?)
10. How can such involvement in planning and design satisfy these approaches?
11. To what extent can such involvement cause achievement of these approaches?
12. How can such involvement in planning and design phases be facilitated?
13. What do you estimate the benefits of this involvement?

APPENDIX A

Questionnaire for Executives, Directors, and Heads of Departments.

Research topic

IMPROVING FACILITY MANAGEMENT BY INTEGRATING OPERABILITY AND MAINTAINABILITY PRINCIPLES EARLY TO THE START OF INFRASTRUCTURE PROJECTS

Questionnaire

Dear /Sir

I kindly request your participation and support on the above-mentioned topic study by responding to the following questionnaire. The information you can provide would be greatly valued.

General information

The primary goal of the research is to identify the gaps of corporate managers in considering facility management requirements at the early design stage and to indicate possible solutions.

The intention of the survey

This survey is proposed to gain the required data for the consumption of research papers in Executive Business Administration. Every data which will be driven from the survey will be kept, and only used for academic effort.

The following questionnaires are prepared based on different literature assessment. You are required to tick, write in words, or rank when it is indicated on the space on condition that at your convince to the questionnaire.

The discretion of the respondents shall be well-kept closed and will not be disclosed. I am grateful for your kindness and for taking your appreciated time to reply to this questionnaire.

Thank you!

S/N	Level of implementation	Very low	Low	Medium	High	Very high
1	Influencing an Infrastructure project Initiations					
2	Participation in project conceptualization decisions					
3	Concept Design influencing mandate					
4	Availability of integrating Maintainability issues at the project conceptualization period					
5	Decisive power on the project Initiation phase					
6	Decisive power on the Design phase					
7	Decisive power on the Construction phase					
8	Building Operation and Maintenance					

Thank you!

APPENDIX B

Questionnaire for Managing Directors and Service Administration Director of Directorates

No.	Principles	Statement	Strongly Disagree	Disagree	Satisfied	Agree	Strongly Agree
P1	Integration	1	Operability and Maintainability must be a core component of the project plan, as well as constructability practice.				
		2	Participation of Construction and O&M stakeholders in the master plan preparation or review helps to adopt suitable national guidelines.				
		3	Integration of Constructability, Operability and Maintainability concepts in the design phases user sessions eases COM disparities.				
P3	Program	4	An Overall COM- sensitive program enables government/owner funding support				
		5	An Overall COM- sensitive program enables clearer future needs of the infrastructures/ facilities.				
P4	Team Skills	6	Multi discipliner consultations allows the incorporation COM skills in to the design and planning phases.				
		7	Consideration of different technical Construction, Operation and maintenance skills with in the planning phase enhances the planning process.				
		8	Collecting information from Construction, O&M staffs in local infrastructure projects provides up to date O&M considerations in the planning and design phases.				
P5	Accessibility	9	Operational activates of the facility can be kept on if O&M issues are considered in designing the infrastructure.				
		10	Having an O&M oriented business solution design provides a better accessibility for O&M staffs.				
P8	Available Resources	11	Technology of design solutions should be matched with the available materials, equipment's and resources.				
		12	Understanding of latest technologies and materials used in O&M of infrastructures facilitates better design.				
P10	Engineering Methodology	13	Having a cost effective engineering design facilitates achieving the projects with a lower O&M costs.				
			Having a comprehensive guideline covering all engineering methodology aspects of O&M helps designers to design for the right engineering method.				
P12	O&M knowledge	14	O&M knowledge transfer into early design phase causes widening of business solution designs.				
		15	O&M knowledge transfer into early design phases prevents poor trainings and as the result stops under-engineered maintenance process.				
P13	Specifications	16	Proper identification of projects' specifications plays an important role in correct locationing, building and delivering infrastructure projects.				
		17	Unless you have defined right specifications for your project, you won't achieve the right materials.				
P16	Innovation & Consistent Computerisati on	18	Use of technology and computerization along the construction, operation and maintenance phases should be maximized in order to improve patients' care system.				
		19	A consistent maintenance management system results in a cheaper and more systematic maintenance processes.				

		20	Use of alternative innovative methods along the construction, operation and maintenance phase results in significant savings in total project life cycle costs.					
P17	Feedback	21	O&M feedbacks should frequently be given to the designers in order to make facilities and designs more customer focused.					
		22	Feedbacks should not only be taken after finishing the construction phase, however there is significant need to trace the feedbacks in longer periods because several services will mostly be out of warranty after liability period of the contractor.					
P2	Standards Definition	23	Definition of minimum standards during the planning phases prevents unnecessary future changes in the managements of facilities/infrastructures.					
		24	Standardization of project documentations during designing phases balances O&M costs vs construction costs...					
		25	Defining the minimum standards during the designing phase eases O&M professional's tasks during project delivery process and O&M manuals.					
P6	Adaptability/ Flexibility	26	Infrastructure projects should consider future changes to minimize adaptation costs.					
		27	Involvement of construction, O&M staffs in the user group sessions minimize the number of inflexible designs					
		28	If a project is designed flexible enough, it will prevent many periodical services and facility changes in response to vast technological changes.					
P7	Authority	29	Involvement of O&M staffs with enough authority at the design or construction phases allows useful imputes from the O&M perspectives.					
		30	Use of experienced Maintenance Managers in project design and management offices can prevent future Maintenance issues.					
P9	Clean ability	31	Participation of actual facility cleaners in to user group sessions helps designers to have a better understanding of ongoing clean ability problems.					
		32	Right selection of materials and resources during the design plays a significant role in proper clean ability of facilities.					
P11	Functionality/ Fit for Purpose	33	Understanding project purpose should be clear right from the beginning of the planning phase.					
		34	Making the design to be based on actual project needs proposing a functional planning and design briefs necessary.					
P14	Technical Leaders	35	If an infrastructure project is fully led ONLY by the architects, it will cause many technical problems for O&M staff.					
		36	It is important to make the project leading process like a team approach including both technical and architectural professionals rather than having a project fully led by the architect only.					
P15	Handover of Documents and Trainings	37	Doing a proper final check up by an experienced maintenance staff just after the construction phase helps to have an appropriate hand over of documentation, and manuals.					
		38	Doing a proper final check up by an experienced maintenance staff just after the construction phase prevents poor construction phase implementation, and results in fit for purpose projects.					