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**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION TECHNOLOGY AND MANAGEMENT STREAM**

**DEVELOPMENT OF MAINTENANCE
PRIORITIZATION GUIDELINE FOR HISTORICAL
PUBLIC INSTITUTION BUILDINGS IN ADDIS ABABA**

**A Thesis submitted to School of Graduate Studies of Addis Ababa University
in partial fulfillment of the requirements of the Degree of Master of Science
in Civil Engineering (Construction Technology and Management)**

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Addis Ababa



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

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DECLARATION

I, the undersigned, declare that this thesis entitled “**Development of Maintenance Prioritization Guideline for historical public institution buildings in Addis Ababa**” is my original work. This thesis has not been presented for any other university for a degree, and that all sources of material used for the thesis have been duly acknowledged.

.....
Meresa Mekonnen

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ABSTRACT

This research deals with preparation of maintenance guidelines that enables the prioritization of one historical building over the other. It also deals with identifying the optimal maintenance type appropriate for historical buildings of public institutions in Addis Ababa. The objectives of the research were to prepare maintenance inspection checklist, to inspect and evaluate the maintenance condition of selected buildings and to develop maintenance optimization model for one of the inspected historical buildings, i.e., Menelik II School.

Different literatures were reviewed to prepare the inspection checklist and understand trends of developed countries to record maintenance condition of buildings. Visual inspections in conjunction with the developed condition inspection checklist were used to evaluate the maintenance condition of eight historical buildings of public institutions. The research found that six out of the eight selected historical buildings were under ‘moderate’ maintenance condition while the rest two buildings are in ‘good’ condition.

Moreover, the best possible maintenance decision was identified for one of the selected historical buildings, namely, Menelik II School. The maintenance decision was chosen by developing Markov decision process through prescribing appropriate maintenance alternatives along with their detailed engineering cost estimates and by estimating deterioration probabilities from Monte Carlo simulations for the different maintenance decision alternatives. Linear programming was formulated for the decision process to get the optimal maintenance alternative at different conditions of the historical building under budget and time constraints.

The maintenance decision model, developed for Menelik II School, suggested to ‘do-nothing’ when a building component is found in an excellent state; to do activities prescribed under ‘preventive maintenance’ for building components that are found under good maintenance condition; to execute specified items of work for ‘repairing defects’ and ‘preventive maintenance’ when building components are classified under moderate condition.

Lastly, the decision model recommends to ‘replace building components’ based on the developed specification for building components that are in ‘poor and failed condition.

Keywords: PRIORITIZATION, MAINTENANCE, INSPECTION, MARKOV, LINEAR PROGRAMMING,

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ABBREVIATIONS

AAUHDB	Addis Ababa Urban Heritage Data Base
Dia.	Diameter
DL	Daily Labor
EARCCH	Ethiopian Authority for Research and Conservation of Cultural Heritage
ETB	Ethiopian Birr
Lm	Linear meter
Ls	Lump sum
MC	Monte Carlo
Pcs	Pieces
Pkt	Packet
PPC	Portland Pozzolan Cement
Qt	Quintal
Qty	Quantity
S/n	Number Series
TPM	Transition Probability Matrix
UF	Utilization Factor
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America

CHAPTER 1

INTRODUCTION

1.1. Background of the Study

The first scientific approaches to maintenance management date from the 1950's and 1960's. At that time, preventive maintenance was encouraged as a means to reduce failures and unplanned downtime. First operations research models for maintenance appeared in the nineteen sixties, attempting to optimize maintenance cost (Ferran, 2009).

In the 1970's condition monitoring came forward, focusing on techniques, which predict failures using information on the actual state of the asset. Detailed studies by manufacturers about the failures of their products resulted in better designs, with fewer failures as a result (Kelly, 1989).

Building maintenance is a major activity in most countries. Any reduction in resources applied to building maintenance could have a visible effect on the economy. All buildings are subjected to agents that eventually cause deterioration and structural failure, and therefore buildings require periodic preventive maintenance to reduce costly repairs, to maintain the functions of the buildings that they are intended for.

Buildings in disrepair or unsanitary conditions, unauthorized building works and dilapidated signboards are potential hazards to the public. Timely maintenance and proper management of buildings prevent their deterioration, keep them safe and tidy, provide a pleasant and comfortable living environment, and uphold their value (Chinman, 2002) . No building is maintenance-free, so every structure, heritage or new, requires care to limit deterioration.

There are structural and architectural elements in several historical public buildings in Ethiopia that are in a state of disrepair and fast deterioration. However, these problems are controlled through planned and optimized periodic maintenance in developed countries.

In addition to historical significance and tourist attraction, heritage-building infrastructures take significant share of the government budget for their existence.

Therefore, it is important to preserve and maintain the building systems especially in developing countries like Ethiopia where scarcity of resources is common.

Setting up a building maintenance schedule helps to facilitate inspections or work that needs to be done. It is also important to prioritize maintenance among several actions and preventing avoidable, costly, future repairs (Heritage Buildings Manual. Canada, Historic Resources Branch, 2008).

Any constructed facility that can be considered as an asset or investment needs to be maintained to ensure its long life cycle. Inspecting and evaluating building maintenance condition is vital process to understand the maintenance of historical buildings and to determine appropriate maintenance at the right time.

In Ethiopia the trend of maintenance in most of heritage buildings are often neglected. According to thesis conducted by Selam (2011), maintenance and future prospects of historic buildings were analyzed and the findings showed that the majority of responsible owners are not aware of rules and regulations that they should follow during the maintenance. As the result, most of the buildings are not well maintained.

Justifying the need for maintenance for historic buildings in a scientific and quantifiable method is important to show clients and facility managers how to choose better maintenance policy and alternatives.

The contribution and scope of this research is expected to prepare inspection guideline that can be used to conduct survey on the conditions of the historical buildings and their elements for the public institution buildings registered as heritage building by EARCCCH and Addis Ababa city administration culture and tourism bureau and incorporated in the master plan of the city.

Optimization of alternative maintenance policies considering maintenance cost estimation for one of the selected buildings will be conducted and evaluated using Markov decision process. Linear programming tool will also be implemented to solve the formulation of Markov decision process. The decision procedure is expected to guide maintenance decision makers to choose the best possible alternatives.

1.2 Statement of the Problem

Many historical buildings of public institutions are often inadequately maintained. Building elements and facilities frequently show evidence of lack of maintenance and repair. Some of the proofs of non-maintenance are cracks in structural members, damaged ceilings and roofs, leakage and mold growth, problems on fittings, dust, and dirty surfaces.

The intention of this research is to create awareness so that the gradual loss of cultural value and nation's economy because of lack of scientific maintenance guidelines is controlled. Building elements deterioration eventually leads to extra expense due to emergency and corrective maintenance.

There is lack of clear maintenance policy and guideline yet in practice by Government authorities currently in our country.

In view of these, it has been considered necessary to study the maintenance of historical buildings of public institutions.

1.2. Research Questions

- 1.2.1. What are the current procedures used to inspect and identify the state/ level of maintenance of historical buildings of public institutions in Addis Ababa?
- 1.2.2. How can concerned bodies and authorities for historical buildings of public institutions, logically and quantitatively, prioritize heritage buildings among each other in order to retain their current condition as well as improve on their state and choose the optimal maintenance alternative policy to ensure such heritages are preserved?

1.3. Thesis Hypothesis

The research assumes that maintenance of public historical buildings has a positive effect on the efficiency of the building performance, its overall condition, and the total costs savings of the building and contributes to the nation's economy and heritage conservation. Moreover, the quantitative approach gives better understanding for choosing optimal maintenance policy among different alternatives under budget constraints, specifically, for prioritizing historic buildings for maintenance.

1.4. Research Objectives

1.4.1. General Objective

The general objective of the study is to develop guideline for maintenance prioritization based on building condition evaluation and maintenance cost optimization for historical buildings of public institutions in Addis Ababa.

1.4.2. Specific Objectives of the study

1.4.2.1. To develop inspection checklists and methods to quantify relative degree of deterioration for elements of buildings

1.4.2.2. To inspect and evaluate the current condition of selected historical buildings of public institutions in Addis Ababa

1.4.2.3. To develop maintenance optimization model for one of the historical building of public institutions in Addis Ababa using Markov decision process and linear programming tools that can be used as a guideline for prioritizing and selecting alternative maintenance policies.

1.5. Significance of the Study

The procedures and findings of the study benefit the Ethiopian authority for research and conservation of cultural heritage and Addis Ababa City Administration Culture and Tourism Bureau. As tried in the investigation to explore the current maintenance prioritization being followed through an interview with maintenance staff, it is found that subjective judgment after team inspection is used.

Therefore, scientific guideline that lets one historical building prioritized from the other and identifying the appropriate maintenance type suitable for a building is important that should be adopted.

In addition, the study is useful for researchers trying to solve similar problems all over the country, as Ethiopia is rich in ancient and historic monuments and building structures.

1.6. Scope and Limitation of the research

The scope of this research is limited to methods used to prioritize maintenance decisions using visual condition inspection and Markov decision tool, which is one of the stochastic decision-making processes.

In the maintenance condition inspection checklist, the values assigned to the condition category to rate the condition of building components is prone to subjectivity though it was presented in pictures to compare similar components of different historical buildings.

The probability of building component deterioration transition from one condition state to other maintenance condition states is dependent on judgment of ‘most likely’ values. Thus, it is probabilistic in nature.

Equipment and labor crew productivity rates are basic assumptions in the cost breakdown process to estimate unit costs of items prescribed for alternative maintenance decisions. These assumptions are taken after reviewing productivity rates recorded by three local contractors and comparing with cost of items specified to maintain historical buildings that are preserved recently.

1.7. Organization of the Research

This thesis work contains six chapters as described below

- ◆ Chapter one: Is an introductory part containing discussions on background, research problems, aim and objective of the research, significance of the research, scope and limitation of the research and organization or layout of the research.
- ◆ Chapter Two: Presents literature review with general descriptions by different researchers on quantitative maintenance condition ratings and trends of maintenance procedures regarding historical buildings.
- ◆ Chapter Three: Discusses about research design and methodology.
- ◆ Chapter Four: Deals with development of historical building condition inspection checklist. It also presents maintenance condition evaluation results and discussions for selected historical buildings.
- ◆ Chapter Five: Presents the development of Markov maintenance decision process.
- ◆ Chapter Six: Contains conclusions and recommendations based on discussions in the previous chapters.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

2.1.1. Definitions of Maintenance and Building Maintenance

Based on Oxford Dictionary; The word maintain is defined as Cause or enable a condition or situation to continue, Keep at the same level or rate. It is originated from Old French “maintenir”, from Latin “manu tenere” with equivalent English meaning 'hold in the hand'.

Business dictionary gives the following list of definitions: -

- Activities required or undertaken to conserve as nearly and as long as possible, the original condition of an asset or resource while compensating for normal wear and tear
- Actions necessary for retaining or restoring a piece of equipment or system to the specified operable condition to achieve its maximum useful life, in addition, it includes corrective maintenance and preventive maintenance.
- Maintenance is a combination of any action carried out to restore an item/machine/equipment/system/plant to acceptable workings Condition.
- Building maintenance is work undertaken in order to keep, restore or improve every facility i.e. every part of a building, its services and surrounds, to a currently accepted standard and to sustain the utility and value of facility.

“A group of tasks and steps that should be performed in order to keep the building or one of its parts in an acceptable state, increase its lifetime, improve it, prevent the fast deterioration of the building and assure safety of the users. The maintenance process includes all the processes of repair, innovation, improvement and for all parts of the buildings both inner and outer parts” (Khodeir, 2009). “Maintenance is synonymous

with controlling the condition of a building so that its pattern lies within specified regions” (Shear, 1983).

2.1.2. Definition of heritage

Different writers define the concept of heritage. The following section provides what heritage means and what should be considered for an item to be considered as a heritage. As Herbert cited in (Amanuel, 2007), heritage is a word with many meanings most relating to its general interpretation "which is inherited from the past” the term ‘heritage’ has been used in relation to the natural world, referring to mountains and rivers, buildings and monuments, arts and social customs and tradition.

According to the oxford English dictionary (2005) and Cambridge international dictionary (1995), Heritage, as derived from inheritance, and is defined as that which has been or may be inherited’, such as traditions, languages or historical buildings, which still exists from the past which have a historical importance.

As stated by the proclamation of Ethiopia 209/2000:

“Heritage means anything tangible or intangible which is the product of creativity and labor of man in pre- historical and history times, That describes and witness to the evolution of nature, and which has major value in its scientific, historical, cultural, artistic and handicraft content, a human work or a place that gives evidence of human activity or a place that has spiritual or cultural meaning. And that has been determined to be of historical value to the province, a community, or an aboriginal people”.

The World Bank as well tried to define it in a broad sense of physical cultural resources: “Movable or immovable objects, sites, structures, groups of structures, and natural feature and landscapes that have archeological, paleontological, historical, architectural, religious, aesthetic, or other cultural significance”.

2.2. Preservation and conservation theories

There are different thoughts concerned to maintenance of historic structures. Some say a heritage structure has to be maintained to keep safe from environmental degradation and aging, others say one has no right to alter the works of our forefathers, because it destroys the feelings and memories of events. Some theories

support the idea of partial or component replacement for historic building structures but some are against.

2.2.1. Theories of Viollet, Ruskin, and Morris

Concerning restoration, (Ruskin, 1989) stated that few men really knew what it meant. He termed restoration as “the most total destruction which a building can suffer: a destruction out of which no remnants can be gathered; a destruction accompanied with false description of the thing destroyed.” He deemed restoration wrong because it is impossible to recreate the original buildings since the restorers did not possess the feelings behind the original creation. Thus, any restoration destroys the building and its integrity. This idea of feelings or spirit is a key component to Ruskin’s theory of architecture. He believed that only moral men could create moral architecture and only happy men could create good architecture.

Viollet in (Hearn, 1990) wanted to highlight the best representations of each period in the building, thus maintaining the history and feeling of the building. In contrast, Ruskin and Morris viewed restoration as the destruction of a building because it removed the original spirit and beauty and replaced it with a modern falsification. Ruskin and Morris thought that modern man could neither think like those of the past, nor possess the same spirit or craftsmanship. For this reason, restoration was never an acceptable option because it destroyed the historic integrity of the building and detached the connection with those who built it.

Regarding preservation, Viollet also differed from Ruskin and Morris. Preservation, for Viollet, only applied to buildings that served no purpose other than their historical significance. If a building was to serve a contemporary purpose, then both restoration and preservation should occur. Areas of the building that needed support should be “propped up, strengthened, and conserved,” or preserved, but they should also be restored to return the original character of the building for modern man. To Viollet, the best way to preserve a building was to have a compatible use for it so changes were not necessary. However, for Ruskin, people should not wait until buildings fell into disrepair before becoming concerned. Instead, people should actively engage in preservation by supporting buildings, making the support obvious, and conducting routine maintenance and thus become stewards of the buildings. Ruskin defined preservation as taking ‘proper care’ of buildings. Morris viewed preservation as the

means for protecting the integrity of the building and preserving it for future generations. He thought architects and the public should be keepers of historic buildings to ensure their continuation; all levels of society should promote preservation because a loss of historical architecture was a loss to society.

In summation, Viollet, Ruskin, and Morris all thought that restoration could result in the destruction of buildings. However, for Ruskin and Morris destruction accompanied all restorations, and for Viollet it occurred only to those not based on research or done in the spirit of the builders. Additionally, Ruskin and Morris viewed preservation as the only option because modern man did not have the right to touch buildings as they did not belong to modern man. For Viollet, preservation only applied to ruins, buildings that did not serve a modern function, and strengthening the buildings. Viollet also promoted the idea of adaptive use to preserve buildings while Ruskin and Morris thought buildings should be preserved whether they were being used or not.

2.3. General Principles to register Buildings as Historical Structure

2.3.1. International heritage structure registration trends

According to (Kalman, 1980), Criteria for listing and selecting historic buildings that should be included in conservation master plan shall be established by Heritage Advisory Committee whose members are architects, historians, and architectural historians familiar with the buildings of the area.

- i) As organized in table 2.1, the list contains five basic criteria; there are different points under the basic grading criteria along with their description below.

Table 2.1: (Kalman, 1980) criteria for a building to register in a historic structure list

Basic criteria	Grading Parameter	Description
Architecture	Style	Notable, rare, unique, or early example of a particular architectural style, type, or convention
	Construction	Notable, rare, unique, or early example of a particular material or method of construction
	Age	Comparatively old in the context of its region

Basic Criteria	Grading Parameter	Description
Architecture	Architect	Designed or built by an architect or builder who has made a significant contribution to the community, province, or nation.
	Design	A particularly attractive or unique building because of the excellence, artistic merit, or uniqueness of its design, composition, crafts man, or details
	Interior	Interior arrangement, finish, crafts man, and detail that is particularly attractive or unique.
History	Person	Associated with the life or activities of a person, group, organization, or institution that has made a significant contribution to the community, province, or nation
	Event	Associated with an event that has made a significant contribution to the community, province, or nation
	Context	Related with, and effectively illustrative of, broad patterns of cultural, social, political, military, economic, or industrial history
Environment	Continuity	Contributes to the continuity or character of the street, Neighborhood, or area
	Setting	Setting and landscaping that contributes to the continuity or character of the street, neighborhood, or area.
	Landmark	A particularly important visual landmark
Usability	Compatibility	Present use is compatible with the current land use or zoning of the site, street, or neighborhood.
	Adaptability	Potentially adaptable to compatible re-use without harm to the architectural elements which contribute to its significance

	Grading Parameter	Description
Usability	Public	Capacity for needed public, educational, or museum use
	Services	Adequately serviced and protected for contemporary use.
	Cost	Reasonable cost of preservation, restoration, maintenance, and interpretation
Integrity	Site	Occupies its original site
	Alterations	Has suffered little alteration, and retains most of its original materials and design features
	Condition	Building is in good structural condition.

World Heritage Convention (<http://whc.unesco.org/en/guidelines,2017>) an organization operating under UNESCO outlined important attributes to register a building as heritage structure; these are integrity of the structure, authenticity, and outstanding universal value as discussed here under.

1) Outstanding Universal Value

Outstanding Universal Value means cultural and natural significance, which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity.

Criteria for the assessment of Outstanding Universal Value

The World Heritage Committee considers a property as having Outstanding Universal Value if the property meets one or more of the following criteria:

- 1) Represent a masterpiece of human creative genius
- 2) Exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design
- 3) Bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared
- 4) Be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates significant stage(s) in human history

- 5) Be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change
- 6) Be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria)
- 7) Contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance
- 8) Be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features
- 9) Be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals
- 10) Contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of Outstanding Universal Value from the point of view of science or conservation.

2) Authenticity

Properties nominated under criteria (1) to (6) must meet the conditions of authenticity. Depending on the type of cultural heritage, and its cultural context, properties may be understood to meet the conditions of authenticity if their cultural values are truthfully and credibly expressed through a variety of attributes including:-

- a. Form and design
- b. Materials and substance
- c. Use and function
- d. Traditions, techniques and management systems

- e. Location and setting
- f. Language, and other forms of intangible heritage
- g. Spirit and feeling; and
- h. Other internal and external factors

3) Integrity

All properties nominated for inscription on the World Heritage List shall satisfy the conditions of integrity. Integrity is a measure of the wholeness and intactness of the natural or cultural heritage and its attributes.

Examining the conditions of integrity therefore requires assessing the extent to which the property:

1. includes all elements necessary to express its Outstanding Universal Value
2. is of adequate size to ensure the complete representation of the features and processes which convey the property's significance
3. Suffers from adverse effects of development or neglect, this should be presented in a statement of integrity.

For properties nominated under criteria (1) to (6), the physical fabric of the property and/or its significant features should be in good condition, and the impact of deterioration processes controlled. A significant proportion of the elements necessary to convey the totality of the value conveyed by the property should be included. Relationships and dynamic functions present in cultural landscapes, historic towns or other living properties essential to their distinctive character should also be maintained.

The United Kingdom Conservation of historic buildings and monuments advisory board set the following criteria to identify whether a building is of special interest to add to the historic building list.

1) Architectural Interest

To be of special architectural interest, a building must be of importance in its architectural design, decoration, or craftsmanship; special interest may also apply to nationally important examples of particular building types and techniques and significant plan forms.

2) **Historic Interest**

To consider a building as a special historic interest a building must illustrate important aspects of the nation's social, economic, cultural, or military history and have close historical associations with nationally important people. There should normally be some quality of interest in the physical fabric of the building itself.

- When making a listing decision, the heritage advisory committee or Secretary of State may take into account the extent to which the exterior contributes to the architectural or historic interest.
- When considering whether a building is of special architectural or historic interest, the Secretary of State may take into account the desirability of preserving, on the grounds of its architectural or historic interest. Any feature of the building containing a man-made object or structure fixed to the building or forming part of the land and comprised within the curtilage of the building is of special interest.

Moreover, the advisory board sets four general principles. one has to consider these criteria to list buildings as historic structures.

- i. **Age and rarity:** The older a building is, and the fewer the surviving examples of its kind, the more likely it is to have special interest.
- ii. **Aesthetic merits:** The appearance of a building – both its intrinsic architectural merit and any group value – is a key consideration in judging listing proposals, but the special interest of a building will not always be reflected in obvious external visual quality. Buildings that are important for reasons of technological innovation, or as illustrating particular aspects of social or economic history, may have little external visual quality.
- iii. **Selectivity:** Where a building qualifies for listing primarily on the strength of its special architectural interest, the fact that there are other buildings of similar quality elsewhere is not likely to be a major consideration. However, a building may be listed primarily because it represents a particular historical type in order to ensure that examples of such a type are preserved.
- iv. **National interest:** The emphasis in these criteria is to establish consistency of selection to ensure that not only are all buildings of strong intrinsic architectural interest included on the list, but also the most significant or

distinctive regional buildings that together make a major contribution to the national historic stock.

2.3.2. Criteria Set by EARCCH for Registering Historical Buildings

According to municipal level, criteria used by Ethiopian authority for research and conservation of cultural heritage for selecting historical structures, a building is listed as heritage when at least one of the following criteria are satisfied.

1. Importance of the building for history and cultural researches
2. Unique in its architectural value
3. Old aged structures which shows the history and culture of a particular time.
4. Aesthetics, uniqueness and construction materials which are expensive.
5. A building which has a great role and importance for farther study and scientific research.

2.4. Trends and History of Building Scientific Maintenance

Public buildings in developed countries were considered valuable assets that should be reserved and maintained. To achieve this aim, efficient maintenance management systems are required. However, fulfilling this need for efficient maintenance management systems is becoming more and more difficult in developing countries. This is due to restricted budgets, lack of qualified labor, moreover, lack of methodology. Stimulated by these factors, interest in setting out a methodology for accomplishing an efficient maintenance management system in developing countries has increased (Khodeir, 2009).

Although public buildings are considered a national treasure that should be reserved and maintained, developing countries neglect maintenance and lower its share in their budgets. Maintenance work is usually delayed in these buildings until severe deterioration and fast failure occurs.

The life of a building can be categorized into structural life and economic life. The structural or physical life is the period which expires when it ceases to be an economic proposition to maintain the building, while economic life is concerned with earning power and it is that period of effective life before replacement. The actual

physical life of a building is frequently much greater than its economic life (Seeley, 1976).

Maintenance assists retaining economic life of buildings. Moreover, it is a productive activity at both the private and the national levels. At the private level, proper maintenance leads to lower depreciation costs and consequently leads to higher profitability. While at the national level, proper maintenance leads to lower expenditures on replacement. Thus, allowing more expenditure on expansion into new productive investment (Ikwan, 1996).

In the early nineties, (Neely, 1976) developed data bases of tasks that cover all maintenance work required over buildings. The databases include the entire component that could be found in buildings constructed by private industry and government agencies. The results of Neely identification include:

- All tasks that had to be performed to maintain the components in the standard operating order
- All possible components that could exist in any building
- Resource information was developed for each task to record labor and materials resources.
- The labor productivity

In 1993, Al-Shiha conducted a research discussing the effect of faulty design and construction factors on building maintenance. As a result, the most severe factors, which affect the maintenance works and cause the high maintenance cost are determined as:

- Inadequate structural design such as foundation
- Hiring unqualified designers
- Not complying with specification
- Failing for relating exterior materials selection to climate conditions

- inadequate waterproofing and drainage

- Unqualified workplace, inability to read the drawing

The criteria affecting the priority rating of public building maintenance works were studied in the late nineties. Standards were identified. These criteria were classified into two major groups as follows:

- Building performance group: criteria which emphasize on the building
- Managerial group: criteria, which deal with decision-making process and behavior of decision maker

(Ikwan, 1996) Proposed some concrete measures that can lead to the improvement of maintenance status along the following dimension:

- Developing and enforcing suitable maintenance practices
- Supporting researches in maintenance management systems

These measures are

- Study and assessment of maintenance status
- Development of adequate maintenance management

As part of construction process, maintenance has an important role to ensure the long life of the constructed building. .

2.5. Quantitative Scientific Research for Infrastructure Maintenance

One of the quantitative methods used to predict the deterioration of infrastructures is Markov model. Markov model is a special type of dynamic model with which the probabilistic evolution of a system can be modeled in time. The main assumption underlying such a model is that all information about the future behavior is captured in the state description. In other words, the present state provides all relevant information about the future behavior and knowledge about previous states is not necessary. Markov chain is a discrete time process governed by a discrete state space and deterioration transition probability matrix.

The Markov decision process is used in infrastructures rehabilitation problems for selecting the optimal maintenance and rehabilitation decision policy. It provides a set of rules that specifies how each decision is chosen from group of possible actions for

each state of infrastructure by considering the initial and subsequent costs (Winston, 2004). Markov decision process utilizes an infinite horizon probabilistic dynamic programming to solve problems in which the life cycle cost is performed based on long-term behavior of infrastructure.

In maintenance cost optimization, the Markov decision process is used for finding the optimal decision for each condition state, knowing the possible alternatives, their costs and their related transition probability matrices. The Markov decision process is described in four elements (Winston, 2004).

1. State space: the state (i) where the Markov decision process is found at the beginning of each period.
2. Decision set: for each state i , there is finite set of allowable or feasible alternatives and decisions $D(i)$ that can be considered.
3. Transition probabilities: denoted $p(j/i,d)$ where the next period's state (j) depends only on the current period's state (i) and on the chosen decision during the current period $d \in D(i)$
4. Expected reward or incurred costs: during a period in which the state is (i) and decision $d \in D(i)$ is chosen, an expected reward (r_{id}) or an expected costs (c_{id}) is incurred.

In Markov decision process, a policy is defined as a rule that specifies how each period's decision is chosen, a policy δ is stationary policy if whenever the state is (i) , the policy chooses the same decision $\delta(i)$ independently of the period (t) " (Winston, 2004). An optimal policy is the one that maximizes the total expected return for each state (i) and total number of periods (n) or minimizes the total expected cost..

2.6. Building Deterioration Prediction Techniques

In some industries, the transient probabilities of the Markov chain for deterioration prediction have been calibrated using expert judgments. Where not enough data are available for calibration, engineering judgment on the definition of Markov matrices would be the best guess for forecasting the future condition of an element. However,

when sets of inspection data are available, the calibration process determines the elements of the transition matrices using the data sets and mathematical approaches.

A well-considered prediction model is essential in enabling a decision-making model to deliver reliable and planned action. Moreover, an appropriate deterioration prediction method should be applied, depending on not only the data availability but also the data collection practicability of the case. Some of the deterioration prediction techniques are listed in the table 2.2 below.

Table 2.2: Mathematical model categorization for deterioration prediction

Modeling Category:	Deterministic models	Stochastic/statistical models
Technique	<ul style="list-style-type: none"> ➤ Regression ➤ Exponential ➤ Percentage Prediction 	<ul style="list-style-type: none"> ➤ Simulations and Probability distributions ➤ Poisson regressions

2.6.1. Deterministic methods

Deterministic models are techniques through which condition is predicted as a precise value based on mathematical functions of observed or measured deterioration. While deterministic methods of condition prediction are the most used techniques to date, the simplicity of the method may affect the outcome of predictions. The simplicity of deterministic methods is an advantage that can be easily deployed in asset management strategies for a wide variety of buildings or other asset types (Mohseni, 2012).

Straight-line extrapolation, regression-based or exponential deterioration model curves are often used for phenomena where relationships between components are certain. Exponential methods have been used for infrastructure deterioration prediction. The deterioration trend is faster for older assets than the newer one (NAMS, 2009). The total useful life is the sum of the remaining life and the age of the infrastructure as estimated in literatures the variable (x) is the remaining life in percent.

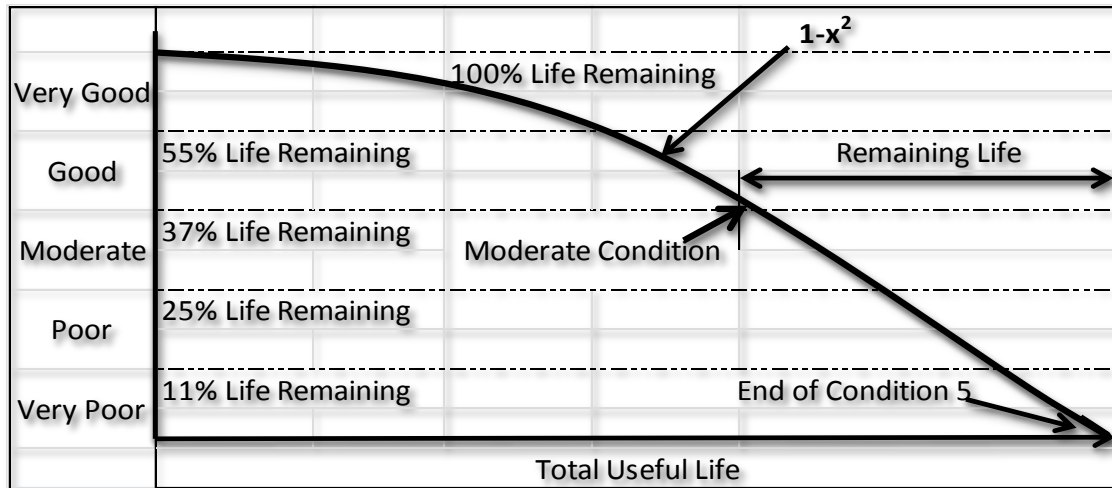


Figure 2.1: Exponential deterioration model for building components life cycle (NAMS, 2009)

2.6.1.1. Percentage Prediction Method

The percentage prediction method is the first method used for calibration of transition matrices using condition inspection data sets. The percentage prediction method is a straightforward method and can be easily obtained from the condition data.

(JIANG, 1989) estimates the probability ‘ P_{ij} ’ of transition in bridge element condition from state ‘ i ’ to state ‘ j ’ using the following formula:-

$$P_{ij} = n_{ij} / n_i \text{ -----Equation 2.5}$$

Where;

‘ n_{ij} ’ is the number of transitions from state ‘ i ’ to state ‘ j ’ within a given time period;

‘ n_i ’ is the total number of elements in state ‘ i ’ before the transition.

2.6.2. Probabilistic methods

Probabilistic models, on the other hand, predict the condition as the probability of occurrence of a range of possible outcomes. In prediction of deterioration, there are uncertainties due to the difficulties associated with isolating individual random variables.

2.6.2.1. Poisson Regression Model

The Poisson regression model can be used to describe events that occur both randomly and independently over time. Different incremental deterioration models are estimated for different condition states to realize the different mechanistic deterioration processes by many researchers.

2.7. Absolute and N-step transition Probabilities of Markov chain

A probabilistic process $\{X_t\}$ is said to have Markovian property when the conditional probability of any future event, given any past event and present state $X_t = i$, is independent of the past event and depends only upon the present state.

The conditional probabilities $P\{X_{t+1} = j / X_t = i\}$ for a markov chain are called one-step transition probabilities. If, for each i and j ,

$$P\{X_{t+1} = j / X_t = i\} = P\{X_1 = j / X_0 = i\}, \text{ for all } t = 1, 2, \dots, T$$

The one-step transition probabilities are said to be stationary. Thus, having (absolute) stationary transition probabilities imply that the transition probabilities do not change over time.

(Taha, 2007) described that, given the initial probabilities $a^{(0)} = \{a_j^{(0)}\}$ of starting in state j and the transition matrix P of markov chain, the absolute probabilities $a^{(n)} = \{a_j^{(n)}\}$ of being in state j after n transitions ($n > 0$) are computed as below:

$$a^{(1)} = a^{(0)}P$$

$$a^{(2)} = a^{(1)}P = a^{(0)}PP = a^{(0)}P^2$$

$$a^{(3)} = a^{(2)}P = a^{(0)}P^2P = a^{(0)}P^3$$

Continuing in the same way, it is found

$$a^{(n)} = a^{(0)}P^n, n = 1, 2, \dots$$

The matrix P^n is known as the n -step transition matrix. From the above calculations, one can see that

$$a^n = a^{n-1}P$$

Or $P^n = P^{n-m}P^m, 0 < m < n$, these are known as Chapman-Kolmogorov equations.

2.8. Appropriate Procedures to Carry Out Maintenance on Historical Buildings

Based on USA National Materials Advisory Board, (1982) intervention for historical buildings practically involve some loss of a value in cultural property, however, it is justified in order to preserve the buildings for the future before they are completely ruined. Conservation involves making interventions at various scales and levels of intensity that are determined by the physical condition, the causes of deterioration, and the probable future environment of the cultural property under treatment.

Following principles and rules of conservation, seven degrees of intervention can be identified. However, in any individual conservation treatment, several degrees may take place simultaneously in various parts of the whole. The seven degrees according to (USA National Materials Advisory Board, 1982) are:

- i. Prevention of Deterioration
- ii. Rehabilitation
- iii. Preservation
- iv. Reproduction
- v. Consolidation
- vi. Reconstruction
- vii. Restoration

2.8.1. Prevention of deterioration

Prevention involves protecting cultural property by controlling its environment, thus keeping agents of decay and damage from becoming active. Therefore, prevention includes control of humidity, temperature, and light, as well as measures for preventing fire ignition, theft, and vandalism. In the industrial and urban environment, it includes measures for reducing atmospheric pollution, traffic vibrations, and ground subsidence from many causes, particularly intrusion of water.

2.8.2. Preservation

The objective of preservation is to keep the structure in the same state. Damage and destruction caused by humidity, chemical agents, and all types of pests and microorganisms need to be stopped in order to preserve structure. Maintenance, cleaning schedules, good housekeeping, and good management aid preservation. A repair has to be carried out when it is necessary to prevent further decay and to keep cultural property in the same state. Regular inspections of cultural property are the basis of prevention.

2.8.3. Consolidation

Consolidation is the physical addition or application of adhesive or supportive materials into the actual fabric of cultural property in order to ensure its continued durability or structural integrity, for instance, the injection of adhesives to secure a detached mural painting to the wall.

With buildings, when the strength of structural elements has been so reduced that it is no longer sufficient to meet future hazards, the consolidation of the existing material is necessary, and new material may have to be added. However, the integrity of the structural system must be respected and its form preserved. No historical evidence should be destroyed.

2.8.4. Restoration

The objective of restoration is to revive the original concept of the object. Restoration and reintegration of details and features occur frequently and are based upon respect for original material, original design, and authentic documents. Replacement of missing or decayed parts must integrate harmoniously with the whole, but on close inspection, it must be distinguishable from the original so that the restoration does not falsify artistic or historical evidence. Contributions from all periods must be respected. All later additions that can be considered as historical documents, rather than merely previous restorations, must be preserved.

2.8.5. Rehabilitation

The best way of preserving buildings is to keep them in use, a practice that may involve modernization and adaptive alteration.

2.8.6. Reproduction

Reproduction entails copying an extant artifact, often in order to replace some missing or decayed, generally decorative, parts to maintain its aesthetic harmony. If valuable cultural property is being damaged irreversibly or is threatened by its environment, it may have to be moved to a more suitable environment. A reproduction is thus often substituted in order to maintain the unity of a site or building.

2.8.7. Reconstruction

Reconstruction of historic buildings using new materials may be required by disasters such as fire, earthquake, or war, but reconstructions cannot have the staining of age. As in restoration, reconstruction must be based upon accurate documentation and evidence.

2.9. Defects, Causes and Remedial Measures for building components

According to (DULING, 2006) the origin of external degradation agents is either the atmosphere or ground, which mostly involves complicated chemical and physical processes governed by a great number of degradation agents while occupancy, design

and installations are the main sources of internal degradation agents. It is also possible that a design consequence could result in an agent acting externally.

Table 2.3: Degradation agents affecting the service life of building materials and components ((DULING, 2006) in Jernberg, 2004)

Nature of degradation agents	Class
Mechanical agents	Gravitation forces and imposed deformations, kinetic energy, vibrations and noises
Electromagnetic agents	Radiation, electricity, magnetism
Thermal agents	Extreme levels or fast alterations of temperature
Chemical agents	Water and solvents, oxidizing and reducing agents, acids, bases and salts
Biological agents	Vegetable, microbial and animal

Chemical and physical incompatibility between dissimilar components is another important issue that should be considered. Incompatibility includes, for instance, corrosion caused by contact between dissimilar metals or stress caused by different thermal expansion coefficients of rigidly connected dissimilar components (Jernberg, 2004 in (DULING, 2006).

2.9.1. Building Components Built of Stone Masonry

Stone is one of the most used construction materials employed in historic structures. The exterior walls and some of the structural members for historical buildings selected for this research are made of stone.

There are visible deteriorations and defects on stone elements of buildings. Types of deterioration such as chipping, cracking, delamination, detachment, weathering, efflorescence and rising dampness are common defects observed in stone members. These defects are result of different stone deterioration natural agents as presented in table 2.4.

There are different mechanisms and causes of stone damage. The dominant factors in deterioration of stone and masonry structures are listed below;

- a. The available moisture from precipitation, fog, and humidity: Almost all decay mechanisms require some water, although heavy rainfall can wash away or dilute impurities and slow their attack on the stone.
- b. The temperature of the air: Most chemical reactions proceed more rapidly as the temperature increases.
- c. Solar insolation: Radioactive cooling of stone at night can result in condensation of water. Dry surface and cooling or heating of the stone relative to the air affects deposition rates, as do evaporation and condensation.
- d. Wind: The kinetic energy of abrasive particles and the degree of inertial impaction of particles or droplets onto the stone are dependent on the wind.
- e. Air constituents and contaminants: Constituents in the air determine the rates of some forms of chemical attack and are often a necessary originator of physical or chemical decay mechanisms.

Different type of stone deterioration exists, caused by diverse factors. Some of the stone Deterioration problems outlined by (Grimmer, 1984) are tabulated along with their possible causes and remedial measures in table 2.4 below.

Table 2.4: Stone deterioration and possible causes

Type	Definition	Possible Cause	Remedy/ Solution
chipping	Small pieces or larger fragments of masonry separating from the masonry unit, often at corners or mortar joints	Later alterations or repairs, such as use of hard mortar, or by accident	Replacing a small area of damaged stone with a new unit
cracking	Narrow fissures in a block of masonry	Structural settlement of a building, hard repointing mortar, or it may be an inherent characteristic of the masonry itself	Reinforcement pinning, and grouting methods

Type	Definition	Possible Cause	Remedy/Solution
Delamination	Splitting apart into thin layers and peels off the face of the stone.	Natural condition of sedimentary stones	Patching selected areas of deteriorating masonry with cementitious material
Detachment	Complete break or failure of an original construction joint in which the detached portion of masonry survives intact.	Natural deterioration	Reinforcement pinning, and grouting methods
Efflorescence	A whitish smoke of soluble salts on masonry	Excessive pulling of soluble salts into the masonry and capillary action may pull soluble salts which result in efflorescence from the ground into the masonry, such as chlorides, carbonates from lime mortar and air-borne or water-deposited pollutants in the atmosphere	Water washing and use of cleaning agents
Rising damp	Moisture is drawn up into the building walls and released at the interior and exterior surfaces where a horizontal wet stain or tidemark is left.	Suction of water into the base of masonry walls through capillary action	Use of damp proof materials
weathering	Granular and rounded surfaces particularly pronounced on sharp corners, or highly carved or projecting architectural details.	Wind and Rain	Replacement/patching with like or compatible substitute materials

Stone decay can come about for a variety of reasons. It can be the natural decay caused by the exposure of soft or vulnerable stone to the elements. It can also exist because of poor, or misguided, original craftsmanship, such as bedding the stone incorrectly, or the use of iron cramps to hold the stones in place. Sometimes the

original stone was of inferior quality or is porous. Stonework can also decay from environmental conditions such as pollution (Ireland Maintenance Publication, 2007).

2.9.2. Timber structures

Wood is widely used as structural member, exterior cladding, roofing, interior finishes, and decorative features in historic and older buildings. Therefore, it is important to protect and maintain wood features by providing proper drainage so that water is not allowed to stand on flat, horizontal surfaces or accumulate in decorative features.

Failing to identify, evaluate, and treat the causes of wood deterioration, including faulty flashing, leaking gutters, cracks and holes in siding, deteriorated caulking in joints and seams, plant material growing too close to wood surfaces, or insect or fungus infestation is failing to preserve the historic building.

(U.S. Secretary of the Interior's Standard's for Rehabilitation, 1997) Advises Retaining coatings such as paint that help protect the wood from moisture and ultraviolet light is helpful. Paint removal should be considered only where there is paint surface deterioration and as part of an overall maintenance program, which involves repainting or applying other appropriate protective coatings.

2.9.3. Doors and windows

Windows, like all building elements, require routine maintenance. Nothing can continue giving service over decades or centuries unless it is maintained, especially if it is exposed to the weather externally and central heating internally, as well as suffering the constant demands of opening and closing. Maintenance works can be done by enthusiastic and skilled householders or handymen with knowledge of windows or joinery. Maintenance works can lead on to repair, if parts or joints need cutting out and new ones require fitting. (Ireland, 2007).

Old Windows and doors can be repaired or restored. The most important consideration is one has to follow recommended preservation and restoration principles, specialized contractor or skilled workers. In the view of (National trust partners network, the Repair Retrofit and Replacement of Historic Windows, 2016) Traditional windows are made from individual parts, which are pieced together to make the window. Each piece of the window can be individually repaired or even

replaced. If the glass is broken, you can replace it. If the bottom rail or sill is rotted, you can repair or replace them. As all of its parts is not lost, because the condition of a window is poor does not mean that it needs to be replaced. It also recommends window-repairing techniques listed under:

1. Disassemble window/door unit and remove window frame: remove the seal that holds the window frame in, and then disconnect the frame.
2. Remove existing paint and sealant: remove the existing paint and glazing sealant. Most professionals seem to prefer using steam because it makes relatively quick work of the paint removal without negatively affecting the window frame.
3. Conduct repairs: Once the paint and glazing compound have been removed, take the glass out then conduct any necessary repairs, such as gluing and fixing joints, replacing damaged rails, or replacing broken glass, In the hands of a qualified carpenter or contractor.
4. Apply oil-based primer with a brush: After the repairs have been made and the frame has been sanded, prepare the wood for primer. This involves the application of a combination of linseed oil, often several layers. Once the surface is ready, apply one coat of oil-based primer with a brush, and allow it to dry.
5. Replace the glass and paint: When the primer has dried, create a bed of glazing sealant to set the glass in, and then install glazing points to hold the glass in place. The window will then be sealed with additional glazing sealant. Once the sealant has cured, prime it using oil-based primer, and then apply two coats of high-quality paint.
6. Reinstall the windows/door. Before reinstalling the windows, the contractor shall make any necessary repairs or modifications to the window frame. They can repair or replace rotted sills or pieces of the frame.

2.10. Summary

In conclusion, many researchers highlighted the importance of planned and preventive building maintenance due to the advantages it has on reducing building lifecycle cost, preventing, and limiting further deterioration of building elements, aesthetics, and health and safety issues

Several researches employed Markov decision process technique on infrastructure systems. As stated in (Ferran, 2009), Golabi. (1982) used it to develop pavement management system for the state of Arizona to produce optimal maintenance policies. Zayed (2002) used it to analyze the problem of steel bridge paint system. Wrahad ikusmah (1999) used it to study the sewer management problem, and guigner and madanat (1999) used it for managing a network of infrastructure facilities, such as high way pavements and bridges.

2.11. Identified Gap

In view of the existing principles employed on the quantitative and scientific maintenance of historical buildings, many researchers have done much to choose optimal maintenance alternatives based on formulating Markov decision processes.

Historical Building assessment is one of the requirements to estimate building deterioration probabilities, which is vital element, to develop Markov decision tool. In most developed countries, building inspection data is recorded for a long period to understand and better estimate the maintenance condition as well as the deterioration trends by concerned bodies.

Standard building inspection checklists, scientific maintenance prioritization methodologies and tools should be introduced to fill the gap that discourages decision makers to implement the optimal maintenance alternative at the right time. Components of historical structures require comprehensive procedures and guidelines in order to preserve their cultural values and existence.

The purpose of this research work is to inspire maintenance decision makers, especially, Addis Ababa City Administration Culture and Tourism Bureau and the Ethiopian Authority for Research, and conservation of cultural heritage that modern and scientific principles are helpful to choose the best possible maintenance alternatives. Maintenance of historical buildings requires periodic condition inspection. Moreover, maintenance prioritization and decision tools should be identified before components of historical buildings deteriorate through time, as it is clearly understood from experiences of developed countries and scientific principles of heritage conservation presented in this chapter.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. INTRODUCTION

3.1.1. Development of maintenance prioritization framework

As a result of the literature review, development of conceptual framework for prioritizing a historic building to maintenance schedule and finding the optimal maintenance alternative, is found essential.

The main stages required to develop maintenance prioritization are

- i. Developing inspection checklist
- ii. Building components categorization
- iii. Building condition assessment and evaluation
- iv. calibrating the Markov deterioration process
- v. formulating alternative maintenance and rehabilitation policies

3.2. Development of inspection checklists

To predict deterioration of infrastructure, condition inspection data collected over long period is required. The infrastructure condition data recorded periodically needs to be consistent and standardized. Hence standard condition inspection format needs to be formulated before one goes to inspect maintenance condition of a building. Those inspection formats are helpful to observe the increment of deterioration on components of a building.

Condition inspection is the most important milestone on preservation of historic buildings. Different Authors, organizations and journals outlined guidelines and checklists to identify condition of building components. However, identifying specified defect type on a building component is not enough to understand the condition level of a building. The defect has to be quantified, rated on predefined condition category and the urgency or level of seriousness of the defect has to be defined.

3.3. Building Condition Assessment

3.3.1. Establishing Building Condition Scale

An important factor affecting the cost of each maintenance and rehabilitation policies is the condition state of the infrastructure. The figure below presents a condition scale from 1 to 5 where 1 is the best possible state like new and 5 is the worst condition. It should be noted that the condition scale that is going to be used in this research is discrete time rating. Management decision policy represents which action could be undertaken at each state. For instance, no repair is required at State 1 and a rehabilitation action must be undertaken when the infrastructure reaches an advanced deterioration state.

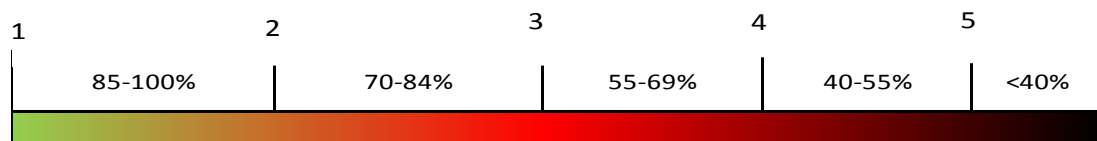


Figure 3.1: Building condition deterioration rating scale

To facilitate the representation of the stochastic deterioration process, a building/building element is assumed to gradually depart from one condition state to the next lower one. For instance, a ceiling deteriorates gradually from a Good to Fair condition state, and then, from Fair to Poor. Table 3.1 illuminates it more

Table 3.1: Building condition descriptions

Condition Rating	Description	Action	Range of % defect
1 - Excellent	Asset is new	May be No additional maintenance is required	0-15%
2 –Good	Asset is functional and displays superficial defects only	Minor maintenance intervention required. No component replacement required.	16-30%
3 - Average	Asset is functional but shows signs of moderate wear & tear	Minor maintenance intervention and/or minor component replacement required	31-45%
4 – Poor	Asset functionality is reduced. Asset has significant defects affecting major components	Significant ongoing maintenance intervention or major component or asset replacement required	46-60%
5 – Failed	Asset is not functional	Asset requires replacement	< 60%

For a five-point condition rating system, with Condition 1 the initial best or as new condition, progressively worsening towards Condition 5, where the material or component has failed and needs to be replaced, the transitional probability matrix is defined in Table 3.2 as shown below:

Table 3.2: Transition probability matrix

Condition	[1]	[2]	[3]	[4]	[5]	Probability
[1]	(1 → 1)	(1 → 2)	(1 → 3)	(1 → 4)	(1 → 5)	$\sum P(1j) = 1$
[2]	(2 → 1)	(2 → 2)	(2 → 3)	(2 → 4)	(2 → 5)	$\sum P(2j) = 1$
[3]	(3 → 1)	(3 → 2)	(3 → 3)	(3 → 4)	(3 → 5)	$\sum P(3j) = 1$
[4]	(4 → 1)	(4 → 2)	(4 → 3)	(4 → 4)	(4 → 5)	$\sum P(4j) = 1$
[5]	(5 → 1)	(5 → 2)	(5 → 3)	(5 → 4)	(5 → 5)	$\sum P(5j) = 1$

It is assumed, that under normal circumstances the condition will only deteriorate and not improve, in other words, it can only change from Condition 1 to Condition 2 to Condition 3 to Condition 4 to Condition 5, and not in the other direction. It is also assumed that the change in condition will only happen one step at a time, in other words; it is assumed that a two-year interval is short enough to ensure that the change in condition will not jump more than one condition rating.

$P(1 \rightarrow 1) + P(1 \rightarrow 2) = 1 \rightarrow P(1 \rightarrow 1) = 1 - P(1 \rightarrow 2)$, where $P(1 \rightarrow 2)$ = degradation rate

This means that $P_{ij} = 0$ when $i < j$ and $j < i - 1$, and the transitional probability matrix is represented as below:

Table 3.3: Simplified transition probability matrix

Condition	[1]	[2]	[3]	[4]	[5]	Probability
[1]	(1 → 1)	(1 → 2)	0	0	0	$\sum P(1j) = 1$
[2]	0	(2 → 2)	(2 → 3)	0	0	$\sum P(2j) = 1$
[3]	0	0	(3 → 3)	(3 → 4)	0	$\sum P(3j) = 1$
[4]	0	0	0	(4 → 4)	(4 → 5)	$\sum P(4j) = 1$
[5]	0	0	0	0	1	$\sum P(5j) = 1$

3.3.2. Priority Assessment for Seriousness of Defects on Buildings

The priority or seriousness of the defect on a building component is rated as shown on table 3.4. As the objective of this research is to prioritize maintenance of one building or component from the other, the priority rate considered for a defect description on a building component is the same for all historical buildings under the study population. The rate given to classify the condition of a historical building is described in figure

3.1 and table 3.1 above. These rates show the extent of component deterioration. A defect on building component can fall under condition category 5 and priority rate 1. These rates shall be understood as ‘the building condition is failed but it does not seriously affect the existence of the historic building. For instance, the condition of paint on internal wall can fail, but it may not affect the structure or other character defining elements.

It is the responsibility of well-trained building condition inspector to rate the specified defect on historic building component. In the inspection format, attachment of photographs of the most deteriorated element is required to reduce the subjectivity of the inspector while rating the condition of the defect. In addition, the overall condition of the building can be obtained from the product of the two rates.

Different approaches can be used in aggregation of conditions for building element’s defects. The simplest method is using an arithmetic mean of the condition of the components. Although this method can be easily applied, the reliability of the outcome is questionable. This concern is a result of averaging the conditions of different components which may not have the same importance. For example, if the condition of the paint on a building is 5 (on a scale of 1 to 5, 1 being as new and 5 being very poor condition) and the condition of the structural wall is 1, the average condition is 3. In this case, condition 3 may not be an appropriate aggregated condition for a maintenance or asset manager to make a decision about the building.

Therefore, a method used by (COBRA, 2010) is used in this paper for considering the importance of components in the view of their value on defining the historical building, cost of replacement and safety issues, and each recorded defect is assigned a condition and priority rating. Each priority rating is then multiplied by the condition rating to determine the total score for each defect.

Table 3.4: Priority assessment category

Priority	Scale Value	Description
1	Very Low	Functional; not argent
2	Low	Minor defect; cosmetic defects
3	Medium	Average; but could become serious if left unattended
4	High	Serious defect
5	Very high	doesn’t function; failed

Therefore, a range needs to be defined to rate the overall condition of a historic building based on the current defect condition and seriousness of the deterioration.

Table 3.5: Building condition aggregation

scale	Priority Assessment					Score Range	Building Condition
	5	4	3	2	1		
Condition Assessment	5	25	20	15	10	5	(1--5) Excellent
	4	20	16	12	8	4	[5--10) Good
	3	15	12	9	6	3	[10--15) Moderate
	2	10	8	6	4	2	[15--20) Poor
	1	5	4	3	2	1	[20--25] Failed

3.4. Calibrating Markov chain deterioration probability matrix

3.4.1. Markov Chain Degradation Transition

Deterioration or degradation rate is defined as that percentage of the building or component that will transit or change to a condition of worse degradation in one-time interval. In the case of historical buildings, this time interval is considered to be not less than two years, but could be months, weeks or even days. Due to the influence of the degradation and durability factors on the building, the transition to a condition of worse degradation is probabilistic with the transitional probabilities depending on the current condition of the building. Therefore, degradation rate is defined as the transition from condition (*i*) to the next worse condition (*j*) in one-time interval.

Degradation rate = transitional probability (P_{ij}) -----Equation 3.4
 (Probability of *j* knowing probability of *i*)

There are different methods of determining the probability of transition to the next poorest condition of a building component. The transition probability due to natural environmental factors can be estimated based on various procedures as discussed in the literature review part. Figure 3.2 presents methods to establish deterioration probability matrix.

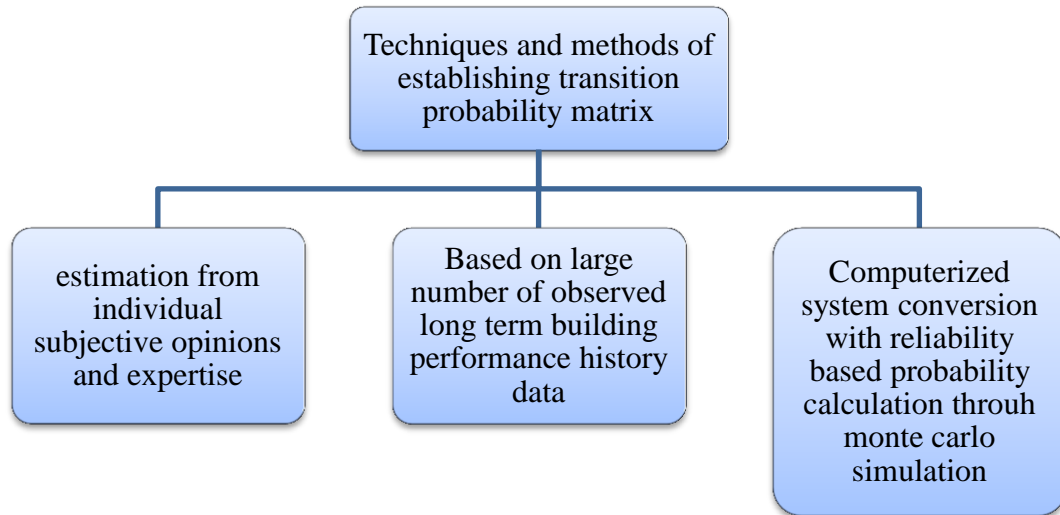


Figure 3.2: Techniques and methods of establishing transition probability matrix (Mohseni, 2012)

3.4.2. Establishing Transition Probability Using Simulation

Markov chain has been chosen in this project to predict the deterioration process of building components and Monte Carlo simulation to predict the transition probability matrix.

3.4.2.1. Monte Carlo simulation

An effective way to deal with uncertainties is through simulation, which can provide more accurate estimates using a large number of what if scenarios. The Monte Carlo simulation is a stochastic technique that randomly generates values for uncertain variables, over and over, to simulate a model. This technique can be used to evaluate the condition rating and transition probabilities by using random numbers for each condition state. A range is defined to represent the remaining element value in each condition state and a probability distribution can be assigned for each range to represent the variable frequency. For each iteration, the simulation selects random values from the defined ranges and calculates the transition probabilities. After running several iterations, the simulation will develop a distribution for the estimated values. Monte Carlo simulation is a wide-ranging method to compute statistical characteristics of an output function utilizing a large number of iterations for its random variables. As stated in (Mohseni, 2012) Monte Carlo simulation has been successfully used for parameter estimation by many researchers, including Zhang and Guay (2002); Marshall, (2003); Aggarwal and Carrayrou, (2006).

Monte Carlo simulation is a technique which can be used to numerically represent a physical problem based on deterministic and probabilistic models. This is achievable by utilizing random numbers generated on the basis of the probable distribution of parameters as inputs. Monte Carlo sampling relies on repeated random numbers (runs) generated according to the defined statistical characteristic of the input variables. Monte Carlo sampling uses randomization across the whole defined probability density function.

3.4. Alternative Maintenance Policies

The available maintenance and rehabilitation alternatives to be used in this research are as follows:

Alternative A: Replacing the ruined components

This alternative is undertaken when the deterioration of the structure is very advanced and the damages attained in the building or element are of major scale. The existing building element is demolished and replaced by new element. This solution ensures the best rehabilitation option in terms of quality but May remains very costly and the intervention decreases the heritage value of the building.

Alternative B: Repair the Most Defective components

The repair method depends on the deterioration level of the building element and the probability of the degradation. It mainly consists of removing loose non-structural elements, and repairing. Also, cracks are repaired by epoxy injections and joints are sealed.

Alternative C: Preventive Maintenance

Preventative maintenance program for infrastructures are cost-effective treatments that allows preserving the condition of the infrastructure and extending their useful life. The preventive maintenance activities include: periodic inspection and cleaning activities, such program could be appealing due to its low costs and temporary aesthetic improvement. Some of its measures will definitely improve the performance and the appearance of the building element, and prolong its useful life.

Alternative D: Do Nothing

In this alternative, the building component is kept without any maintenance action. Even though this alternative causes the infrastructure to deteriorate more rapidly, it remains appealing as it has no effect on the heritage value and from the monetary perspective since it practically incurs no costs.

3.5. Building Components Categorization and Grouping

According to (MORCOUS, 2002) categorizing the hierarchical decomposition of facilities as one of the requirements of asset management is important, since infrastructure facilities are complex structures that are made up of many components and sub-components, including sections, systems, assemblies, and elements.

(Mohseni, 2012), Categorized building elements and components, which are grouped into 4 component types: building interior, building exterior, building structure and building services.

The following table shows the building component categorization to be followed in the research.

Table 3.6: Building component categorization

building interior	building exterior	building structure	Building services
Internal Walls	External Walls	Roof-Structural Elements	Drainage
Floors	External Windows	Structural Frame	Drainage System
Ceilings	External Doors	External Walls	
	Roofs		
	Balconies/porches and stairs		

The components of building infrastructure also need to be clearly defined. Acquiring a comprehensive list of building elements is important so that individual elements can be recorded, inspected and monitored according to the organization's asset management plan. The information on these components can be processed with the deterioration prediction method and incorporated into the cost- forecasting and decision-making models.

Under to categorized building components, elements of the historical buildings are prescribed in order to identify and evaluate maintenance condition of components of the structure and implement suitable maintenance decisions.

3.6. Study Population

The Historical Buildings Registered by the Addis Ababa city administration culture and Tourism Bureau and included in the master plan of the city are listed in the table 3.7 below.

Table 3.7: Structures registered as historical and heritage buildings in Addis Ababa

S/N	Name of historical Institution	Year of Construction	Address	
			Kifle Ketema	Woreda
1	Etege menen school	1923-1930 E.C	Gulele	2
2	Genet luel palace (6 killo university campus)	1926 E.C	Gulele	2
3	Tafari Mekonnen School	1920 G.C	Gulele	2
4	Medhanialem school	1930 E.C	Gulele	8
5	Ras Desta hosipita	1932 G.C	Gulele	
6	Shieh Hojele palace	1890 E.C	Gulele	0/9
7	Commander Teref W/Gebriel house	1910 E.C	Gulele	7
8	Minilik II palace (Enteto)	1930-40 E.C	Gulele	2
9	Tax authority head quarter (Gumruk)	1930 E.C	Kirkos	
10	Finfine Restaurant	1890 E.C	Kirkos	
11	Ethio- Djubuti railway Enterprise /La Gare	1924 G.C	Kirkos	7
12	Ras Biru W/gebriel House	1880 E.C	Kirkos	9
13	Elias Hotel/martik kirkov	1910s G.C	Arada	01
14	King Minilik II prision	1884 E.C	Arada	04/05
15	saitan House	1900 E.C	Arada	15/16
16	Etege Taitu Hotel	1907 G.C	Arada	01
17	Abysinya Bank	1907 G.C	Arada	01
18	Son Ford school	1915 E.C	Arada	03/09
19	Merha Tibeb Printing press Building	around 1920 G.C	Arada	05
20	Arada post office	1908 G.C	Arada	01
21	Negdras H/giyorgs W/mikeal	1906 G.C	Arada	10
22	Africa Andnet School	1913 G.C	Arada	01
23	Cinema ethiopia building	1908 G.C	Arada	01
24	Bete Saida Hospital (yekatit 12)	1924 G.C	Arada	06
25	Minilik II school	1908 G.C	Arada	7
26	House of the parlament	1923 E.C	Arada	09
27	King Mickael 'Gbr Bet'	1900 G.C	Gulele	
28	Health Research Institute		Gulele	10/11/12
29	Minilik II Hospital	1909 G.C	Yeka	

3.7. Sampling Techniques

By assuming the attribute variability (P), value appropriate to the percent confidence level (z) and error margin (e) a formula showed below is used to calculate a sample size.

P=10%. As the materials and age of the historical building are not different by far, that are mainly made of stone, timber and aged more than 70 years.

Z=1.96, for 95% confidence level, E= 18%, Level of precision (sampling Error)

$$p=1-p$$

n_o = Sample size

N = total Population

$$\frac{n_o=z^2pq}{e^2} \text{ ----- Equation [3.1]}$$

(Runger, 2003) and (Soong, 2004)

$$n_o = \frac{1.96^2 * .10 * .90}{.18^2}$$

$$n_o = 10.56$$

However, for finite study population, which are 29 historic buildings in this case the formula needs to be modified as: -

$$n = \frac{n_o}{1 + (\frac{n_o-1}{N})} \text{ ----- Equation [3.2]}$$

$$n = \frac{10.56}{1 + (\frac{10.56-1}{29})} = 7.94 \approx 8$$

8 historic buildings need to be considered. These counts about 27% of the total population but Based on percentage distribution of the area the historical buildings are located, proportionate stratified sampling and Simple random sampling techniques are used in this research. Therefore, the sample size is adjusted as below:

Table 3.8: Sampling study population

C ₁	C ₂	C ₃	C ₄
		C ₄ =27%*C ₂	C ₅ =Approx C ₃
Sub –city	Number of Historical buildings	Sample taken	Approximated sample
yeka	1	0.27	1
Gulele	10	2.70	2
Kirkos	4	1.08	1
Arada	14	3.78	4
Total	29		8 (27%)

List of historic buildings randomly drawn by random probabilistic sampling are:-

1. Minilik II Preparatory School
2. Bete Saida Hospital
3. Etege Menen School
4. Tafari Mekonnen School
5. Menelik II Hospital
6. Taitu Hotel
7. Merha Tibebe Printing Press
8. La Gare

CHAPTER 4

EVALUATING CURRENT CONDITION OF HISTORICAL BUILDINGS

4.1. Background of historical buildings under the study population

1. Menelik II Secondary school



Figure 4.1: Front view picture of Menelik II School

General background

The building is mainly built of stone as structural system with timber flooring in some of the rooms. It has two wings of building blocks functioning as class rooms separated by a gateway serving as a main entrance. The building is designed by German architect and constructed in 1908. The building is documented in the Addis Ababa urban heritage data base as the first state school established in Addis Ababa and the place where king Haile -Selassie was one of the first students.

Location

The building is located in Arada sub city, kebele 13, at King George VI St, with northing = 99 85 76 and Easting= 47 39 03 coordinates.



Figure 4.2: Position of Menelik II School in Addis Ababa master plan

2. Tafari Mekonnen School/Entoto Poly Technique College/



Figure 4.3: Front view picture of Tafari Mekonnen School

General background

The building consists of fourteen class rooms and seven office rooms. Stone is the main structural construction material and there is timber flooring in both courtyards found around the two groups of class rooms. It is the third school in the history of our country, which was constructed in 1925. Tafari Mekonen School was funded by the private treasury of Ras Tafari to improve the school situation in Addis Ababa.

Location

Teferi mekonnen School is located in Gulele sub city, kebele 02, 11040 Street. with northing = 100 03 41 and Easting = 47 41 26 coordinates.

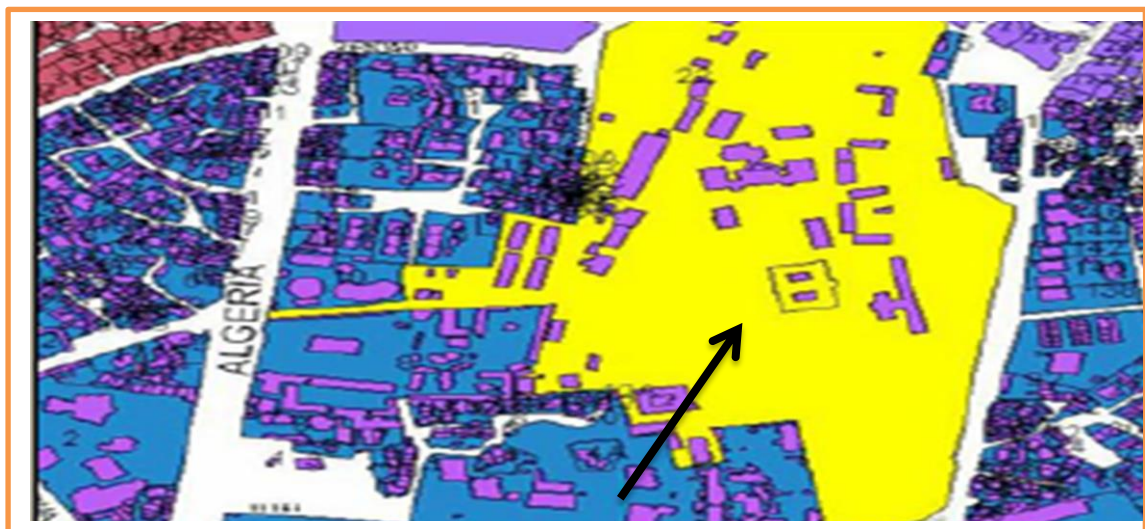


Figure 4.4: Location of Tafari Mekonnen in Addis Ababa master plan

3. TAITU HOTEL



Figure 4.5: Front view picture of Taitu Hotel

General background

It is the first hotel building in Ethiopia. Timber and ‘chika’ are the main construction materials of the building. It has two stories with approximate ground floor area of 1500 square meters. According to Addis Ababa urban heritage data base This building was the first hotel in Addis Ababa and accommodated mostly Ethiopian dignitaries, diplomats and foreigners. Constructed by the order of Empress Taitu and Designed by Minas Kerbekian in 1907.

Location

Taitu Hotel is located in Arada Sub city kebele 02, Wingate Street. with northing = 99 80 53 and Easting= 47 29 16 coordinates.



Figure 4.6: Map location of Taitu hotel in in Addis Ababa master plan

4. ETEGE MENEN /YEKATIT 12/ PREPARATORY SCHOOL



Figure 4.7: Picture of Etege Menen School

General background

It consists of three building blocks built of stone. Etege Menen School, Which is currently known as ‘Yekatit 12’ preparatory school, is the first girl’s school in Ethiopia. Based on the Addis Ababa urban heritage data base the school is built in obedience to "Etege", Empress Menen' s wish. It has Complex buildings. Designed by the Greek architect Balanos. Built in 1930 to 1938.

Location

Located in Gulele sub city kebele 02, Algeria Street. with northing = 100 02 58 and Easting = 47 34 37 coordinates.



Figure 4.8: Location of Etege Menen School in Addis Ababa master plan

5. BERHANENA SELAM/MERHA TIBEB/ PRINTING ENTERPRISE BUILDING



Figure 4.9: Picture taken for Merha Tibeb printing press building

General background

The building, built of Stone masonry with semicircular window arches, was a former place for Berhanena Selam Printing Enterprise, which is the first printing press in Ethiopia, before the enterprise relocated its head to ‘Arat killo’ area. Currently the building is serving as branch office.

Location

The building is located in Arada sub-city kebele 9, Benin Street. With northing = 99 90 18 and Easting= 47 27 51 coordinates.



Figure 4.10: Map location of Merha Tibeb printing press building

6. CHEMIN DE FER DJIBOUTO ETHIOPIAN/ ETHIO- DJIBOUTI RAILWAY ENTERPRISE



Figure 4.11: Front view picture of La Gare building

General background

The building is listed in Addis Ababa urban heritage data base with background information “*Railway Station for the Franco-Ethiopian railway line from Djibouti to Addis Ababa, which was constructed 1897-1917. Functioned in addition as a rest house for travelers. Designed by the French architect Paul Barrias. Built in 1928-1929.*”

Location

The building is located in Kirkos sub-city kebele15, 21124 Street. With northing = 99 57 01 and Easting= 47 28 20 coordinates.



Figure 4.12: Location of La Gare building in Addis Ababa master plan

7. BETE SAIDA /YEKATIT 12/ HOSPITAL



Figure 4.13: Picture of Bete Saida hospital building

General background

Bete Saida is one of the oldest public hospital buildings in Addis Ababa constructed in 1924 E.C. The Hospital is currently known by the name ‘Yekatit 12’ hospital. It comprises of three building blocks. Based on the information from Addis Ababa urban heritage database, it was enlarged during the Italian occupation and called Vittorio Emanuel after the King of Italy. It was designed by Balanos, and presently a number of the buildings is being renovated.

Location

The building is located in Arada sub-city kebele 11, Tewodros Street. with northing = 99 94 80 and Easting= 47 36 18 coordinates.



Figure 4-14: Location of Bete Saida on map

8. Minilik II Hospital



Figure 4-15: Picture of Menelik II Hospital

General background

The Menelik II Hospital was the first Ethiopian hospital in Addis Ababa. Established in 1910. It has fourteen blocks in hilly landscapes.

Location

The building is located in Yeka sub-city kebele 05, 13003 Street. With northing = 99 88 52 and Easting= 47 51 85 coordinates.



Figure 4.16: Map location of Menelik II Hospital

4.2. Development of Historic Building Inspection Checklist

As stated in COBRA, (2010 building inspection is one of the key components of building maintenance. The primary purpose of performing a building inspection is to evaluate the building's condition. Without inspection, it is difficult to determine a building's current condition, so failure to inspect can contribute to the asset's eventual detriment.

Heritage structures require periodic inspection in accordance with standardized building condition inspection checklists and guideline. Building condition data recorded annually for a long period of time is helpful to predict the future trends of deterioration and saves the heritage building value in addition to repair and replacement cost.

Different literatures and publications such as (Heritage Buildings Manual. Canada, Historic Resources Branch, 2008), (Ireland Maintenance Publication, 2007) and (Preservation Alliance of West Virginia, 2012) recommend several heritage building condition assessment checklists for different building components. These references are used as point of departure to develop the inspection checklists to be implemented for heritage buildings of public institutions in Addis Ababa.

The historical building condition inspection checklist adopted for this study assigns condition and priority ratings for the above mentioned categories of building components by evaluating five-point defect assessment statements given for each building sub-components.

Weighted average value is considered to account the effect of less condition rates and low priority records. To account the weights of priority as well as condition ratings, a factor (δ) is introduced. This factor prevents the consideration of minor defects in the score of the condition matrix calculated in table 4.1 from being counted as major defect in the total number of defects on components. When a maintenance condition inspector records minor defects, then the result of arithmetic mean lowers leading to good condition matrix. Therefore, factored arithmetic mean is used. This

factor (δ) is calculated as:-
$$(\delta) = \frac{1}{\left(1-\frac{a}{10}\right)+\left(1-\frac{b}{10}\right)}$$
 ----- Equation 4.1

Where, (a) is condition category rating and (b) is priority category.

Table 4.1: Building inspection checklist prepared to evaluate the condition for buildings of public intuitions

HISTORIC BUILDING NAME: <u>MENELIK II PREPARATORY SCHOOL BUILDING</u>						DATE OF INSPECTION: <u>MARCH 6, 2017</u>						
CURRENT NAME: _____						WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.
Component	Sub-component	Material type	S / n	Description	Yes	No			{a}	{b}	c=δ*a*b	
Building Interior	Internal Wall	plastered and painted stone	1	Stains or damp spots on Walls		x	m ²			4		
			2	Paint Peeling or cracked	x		m ²	63.4	4	2	5.71	1
			3	Plaster on walls cracked	x		m ²	37.8	4	3	9.23	2
			4	Signs of structural movement such as cracking		x	Lm			5		
			5	Signs of fungal or insect attack in timber walls		x	m ²			4		
	Floor	Terrazzo	1	Rise and Fall on timber floors	x		m ²	60.5	5	4	18.18	3
			2	Wear and tear on floor finishes	x		m ²	59.6	5	3	12.5	4
			3	Unclean floors	x		m ²	86.4	4	2	5.71	5
			4	Defect on joints	x		Lm	53.6	5	3	12.5	6
			5	Damage to floor surfaces	x		m ²	0.99	4	2	5.71	7
	Ceiling	Chip wood	1	Sagging in ceilings		x	m ²			3		
			2	Cracked plaster on ceiling		x	m ²			3		
			3	Paint Peeling	x		m ²	28.6	5	2	7.69	8
			4	Signs of water leakage on Ceilings	x		m ²	9.5	5	5	25	9
			5	Hairline cracks in ceilings	x		m ²	13.6	3	1	1.87	10
















HISTORIC BUILDING NAME: <u>MENELIK II PREPARATORY SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>MARCH 6, 2017</u>					
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>					
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____					
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.
Component	Sub-component	Material type	S / n	Description	Yes	No			{a}	{b}	c=δ*a*b	
Building Exterior	External Wall	Stone wall	1	Evidence of mortar pointing deterioration in masonry walls	x		Lm	345	5	4	18.18	11
			2	Cracks in walls	x		Lm	0.015	4	5	18.18	12
			3	Signs of decay or deterioration in stone walls	x		m ²	39	5	4	18.18	13
			4	Unclean walls	x		m ²	51.4	4	3	9.23	14
			5	Cracked paint and loose plaster with hairline cracks		x	m ²			2		
	Doors	Timber	1	Paint or protective coating damaged.	x		Pcs	44	5	3	12.5	15
			2	Decaying exterior seal, or corrosion on steel / wood frames	x		Pcs	10	5	5	25	16
			3	Loose or damaged seals	x		Pcs	25	5	4	18.18	17
			4	Signs of decay on Door frames	x		Pcs	38	5	4	18.18	18
			5	Sticking or jamming doors	x		Pcs	4	5	3	12.5	19
	Windows	Timber	1	Paint or protective coating damaged, blistered.	x		Pcs	76	5	3	12.5	20
			2	Decaying exterior sill, or window frame	x		Pcs	65	5	4	18.18	21

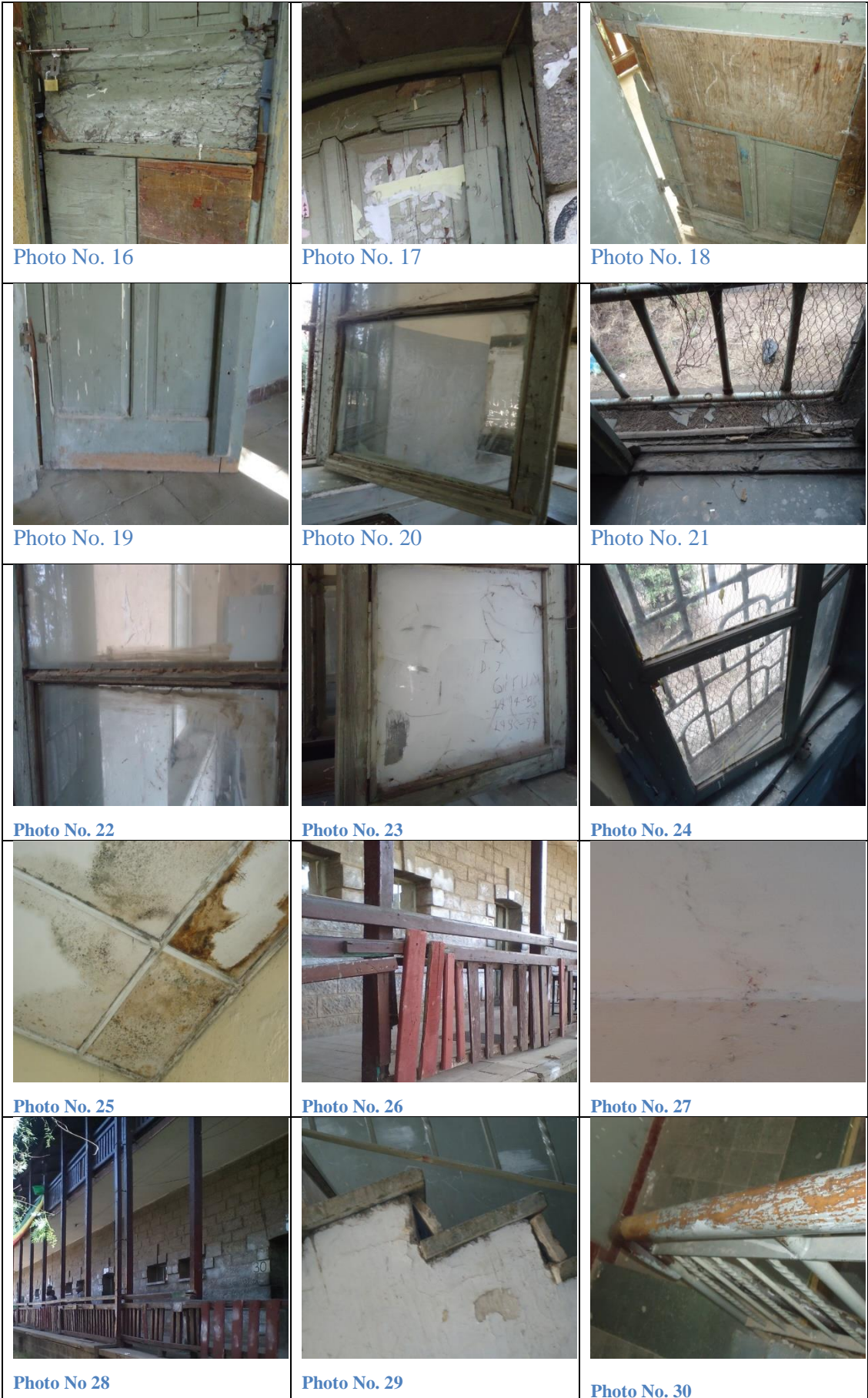
HISTORIC BUILDING NAME: <u>MENELIK II PREPARATORY SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>MARCH 6, 2017</u>					
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>					
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____					
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.
Component	Sub-component	Material type	S / n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Windows	Timber	3	Loose or damaged seals	x		Pcs	42	5	3	12.5	22
			4	Signs of decay on Window Frames	x		Pcs	51	5	5	25	23
			5	Sticking or jamming windows	x		Pcs	26	5	3	12.5	24
	Roof	corrugated iron sheet	1	Severe wear, or rusting on roof		x	m ²			5		
			2	Corrosion on the underside of metal sheeted roofs		x	No.			5		
			3	Joint problems leading to leakage on metal sheets	x		No.	7	4	4	13.33	25
			4	Evidence of decay in the rafter		x	No.			4		
			5	Loose, missing or broken roofing materials		x	m ²			4		
	Balcony/porches	wood	1	Loose or deteriorated components	x		Ls	-	5	4		26
			2	Cracked paint	x		m ²	126	5	2	7.69	27
			3	Railings decayed or rusting and deteriorated	x		Ls	-	3	5		28
			4	Plaster on walls loose or cracked		x	m ²			3		
5			Dust and accumulation of Debris		x	m ²			3			

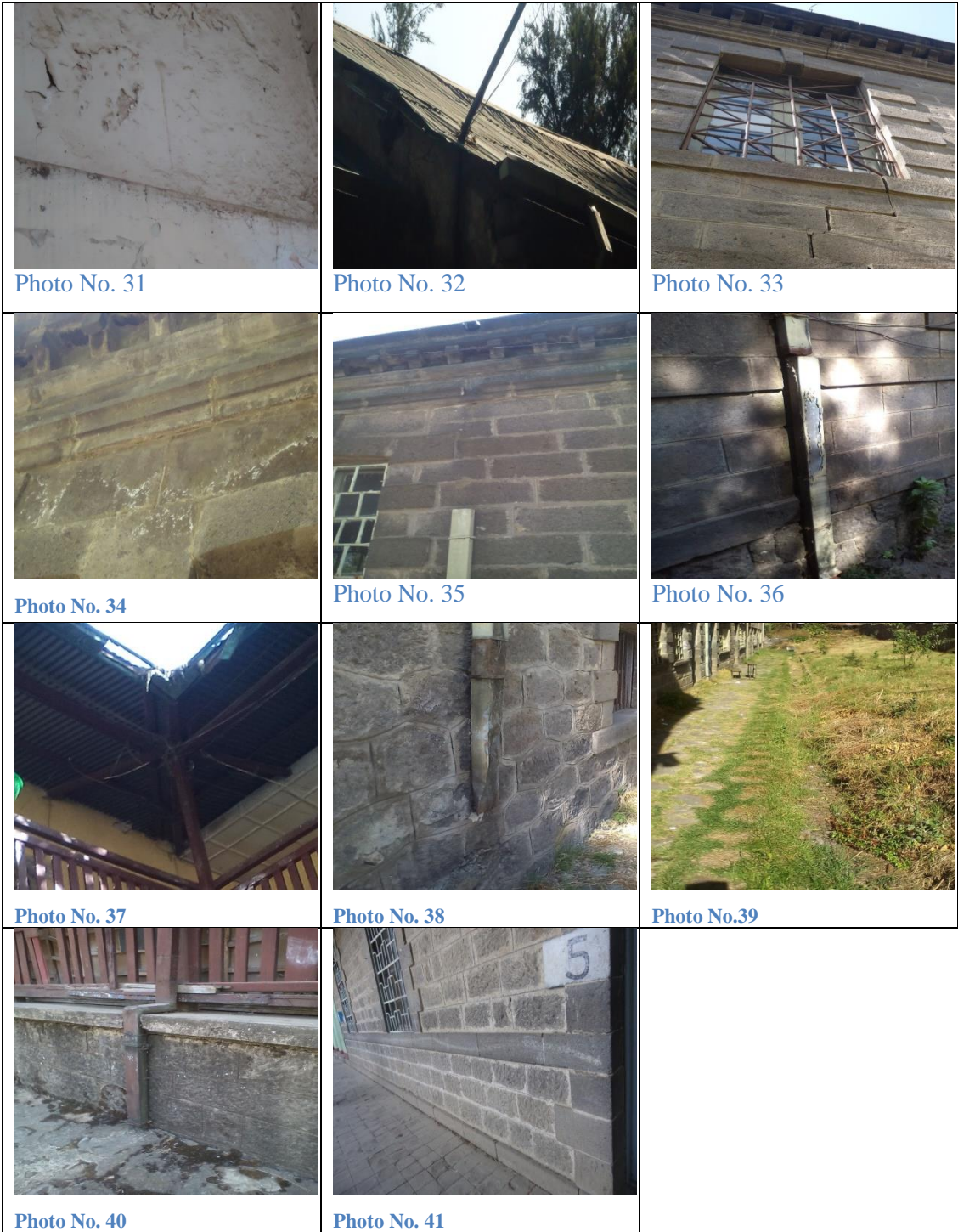
HISTORIC BUILDING NAME: <u>MENELIK II PREPARATORY SCHOOL BUILDING</u>						DATE OF INSPECTION: <u>MARCH 6, 2017</u>						
CURRENT NAME: _____						WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description			Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S / n	Description	Yes	No		{a}	{b}	c=δ*a*b		
Building Exterior	External Stair	Stone masonry	1	Visible cracks on steps		x	Lm			4		
			2	Damage to staircase		x	m ²			5		
			3	Railings rotting or rusting leading to deterioration	x		Lm	23	5	4	18.18	29
			4	Paint cracked	x		m ²	41.8	5	2	7.69	30
			5	Plaster on walls loose or cracked		x	m ²			3		
Building Structure	Roof structural Element	Wood truss	1	Deflections in the overall profile of the roof	x		Lm	18	4	4	13.33	32
			2	Sagging ridge of the roof		x	Lm		2	4		32
			3	Decaying on elements of truss system		x	m ²			5		
			4	Fascia boards and soffits loose, unsecured to structure		x	Lm			3		
			5	Sagging purlins		x	m ²			5		
	Structural Wall	Stone	1	Major cracks in stone masonry	x		Lm	0.018	5	5	25	33
			2	Stone masonry units missing, loose or deteriorating		x	m ²			4		
			3	Water stained walls, or mold grown on the wall surface	x		m ²	21	4	4	13.33	34

HISTORIC BUILDING NAME: <u>MENELIK II PREPARATORY SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>MARCH 6, 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>ARADA SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.		
Component	Sub-component	Material type	S / n	Description	Yes	No	Unit	{a}	{b}	c=δ*a*b			
			4	Wood elements that are not firmly attached and painted		x	m ²		4				
			5	Signs of decay on structural wall		x	m ²		4				
Building Services	Gutters and Down Pipes	Sheet metals	1	Loose, or missing gutters or Down Pipes	x		Pcs	6	5	5	25	35	
			2	Gutters and Down Pipes that are blocked with leaves and debris	x		Lm	43	5	4	18.18	36	
			3	Joints in Down Pipes not secured from leaks	x		Pcs	5	5	5	25	35	
			4	Sagging gutters or gutters sloping the wrong way	x		Lm	18	4	5	18.18	37	
			5	Outlets from Down Pipes have not extensions to ditch	x		Pcs	15	5	3	12.5	38	
	Drainage			1	Rainwater ponds around the base of the buildings	x		Ls	-	4	4		39
				2	Rainwater gullies not draining properly		x	Pcs			3		
				3	Rising dampness visible	x		m ²	45.6	4	3	9.23	40
				4	Manholes blocked with sedimentation and debris		x	Pcs			3		
				5	Wet stains, or efflorescence on exterior surfaces	x		m ²	36.5	4	3	9.23	41
TOTAL					38	27				550.84			

Table 4.2: Pictures for defects on Menelik II School

		
Photo No. 01	Photo No. 02	Photo No. 03
		
Photo No. 04	Photo No. 05	Photo No. 06
		
Photo No. 07	Photo No. 08	Photo No. 09
		
Photo No. 10	Photo No. 11	Photo No. 12
		
Photo No. 13	Photo No. 14	Photo No. 15





4.3. Maintenance Condition of historical buildings under the study

Using the developed building inspection checklist, data is collected from field visual inspection for the sampled eight historical buildings. To classify the condition of an element or a building, the only situation that is considered is the deterioration due to natural phenomena. Conditions of buildings caused by accidents such as fire, flood, etc. are not reflected under any of the historical buildings evaluated.

4.3.1. Conditions of buildings' interior

The condition of building interior is the aggregate maintenance level of the internal wall, floor and ceiling. The conditions of these three building components were inspected as per the developed inspection checklist for eight historical buildings. As the condition of the building component along with its sub-component is based on visual inspection, and hence pictures of defects were found vital to help better compare the condition of one historical building to the other.

The inspection checklist in line with the visual field assessment is evaluated and the result of maintenance condition for building interior for the study population is described in table 4.3 and shown in figure 4.17.

Table 4.3: Interior Condition Score and maintenance level of selected historic buildings

S/n	Name of Heritage Building	Condition of Building Interior						
		Condition Matrix			Interior Condition summary			
		Internal Wall	Floor	Ceiling	Defect No.	condition matrix	Score	Condition
1	Menelik II Preparatory School	14.95	54.61	34.57	10.00	104.12	10.41	Moderate
2	Bete Saida Hospital	5.71	16.14	6.07	5.00	27.93	5.59	Good
3	3. Etege Menen School	15.83	10.80	25.00	5.00	51.64	10.33	Moderate
4	Tafari Mekonnen School	-	56.67	23.93	6.00	80.60	13.43	Moderate
5	Menelik II Hospital	5.71	12.50	32.69	4.00	50.91	12.73	Moderate
6	Taitu Hotel	14.95	34.71	20.88	9.00	70.53	7.84	Good
7	Merha Tibebe Printing Press	30.26	28.50	30.71	7.00	89.47	12.78	Moderate
8	La Gare	4.00	8.93	0.00	3.00	12.93	4.31	Excellent

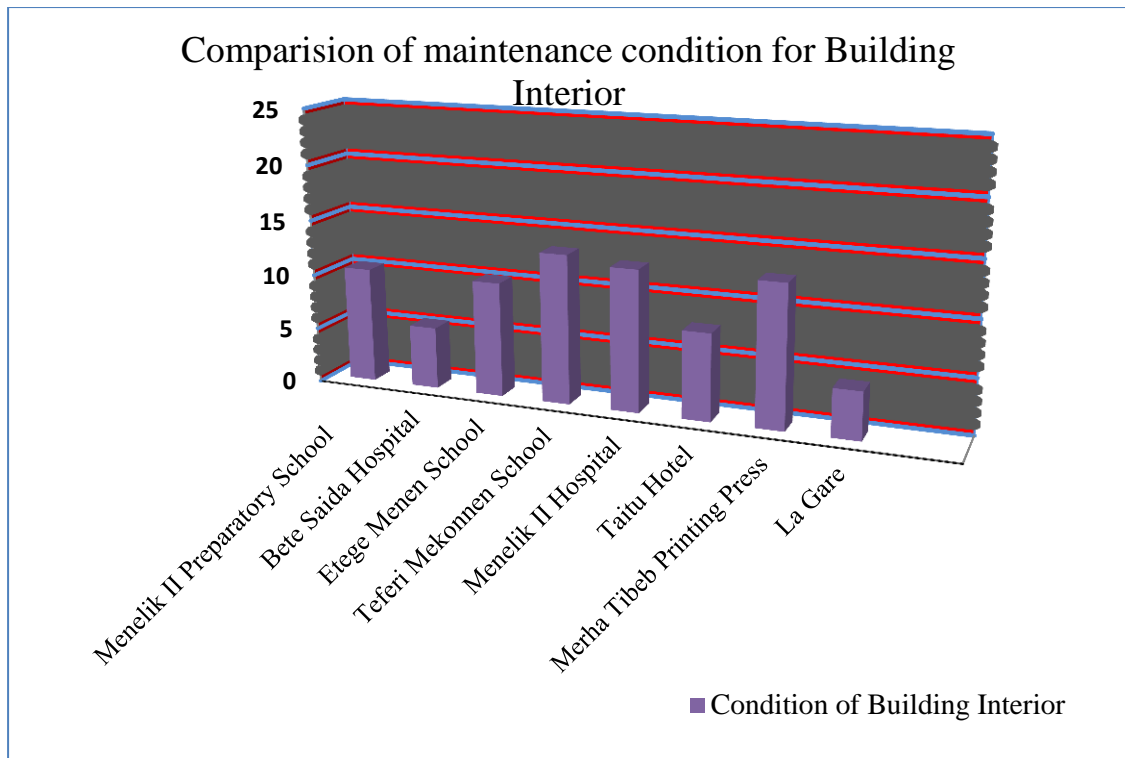


Figure 4-17: Interior condition for buildings under the study

4.3.2. Conditions of buildings' exterior

The outer envelope of a building is classified as roof, exterior walls, windows, doors, balcony, porches and stairs. The extent of deterioration observed on component of each historical building has been measured based on the result of the condition and priority category range. Components of building exterior are found in reasonably fair condition in some buildings and highly deteriorated for other historical buildings.

All of the buildings being evaluated under this thesis work are functional and they are serving as public institutions. The responsibility to maintain, respecting the historical significance of the historical building, is left for the Ethiopian authority for research, and conservation of cultural heritage. However, lack of maintenance and proper care for components showing major deterioration is clearly seen in the inspection checklist.

The evaluation result of building condition assessment for the above-mentioned components of historical buildings is presented in figure 4.18. Table 4.4 shows the exterior condition of La Gare building and Bete-Saida hospital building are 'good' and the exterior maintenance condition for the rest six buildings is 'moderate'.

Table 4.4: Exterior condition score and maintenance level of selected historic buildings

S/n	Name of Heritage Building	Condition of Building Exterior									
		Condition Matrix						Exterior Condition summary			
		External Wall	Doors	Windows	Roof	Balcony/porches	External stair	Defect No.	condition matrix	Score	Condition
1	Menelik II Preparatory School	63.78	86.36	80.68	13.3	7.69	25.87	18.00	277.72	15.43	Poor
2.	Bete Saida Hospital	13.23	6.43	0.00	9.2	0.00	24.00	9.00	52.89	5.88	Good
3	Etege Menen School	25.37	24.61	37.94	18.2	9.23	0.00	11.00	115.34	10.49	moderate
4	Teferi Mekonnen School	48.57	37.14	52.86	43.8	7.50	0.00	13.00	189.88	14.61	Moderate
5	Menelik II Hospital	48.09	43.18	55.68	31.5	0.00	18.21	15.00	196.72	13.11	Moderate
6	Taitu Hotel	14.95	27.41	18.46	0.00	42.08	0.00	9.00	102.90	11.43	Moderate
7	Merha Tibebe Printing Press	26.56	35.06	55.68	21.7	0.00	43.00	14.00	182.04	13.00	Moderate
8	La Gare	15.28	0.00	24.61	5.7	9.71	0.00	8.00	55.32	6.92	Good

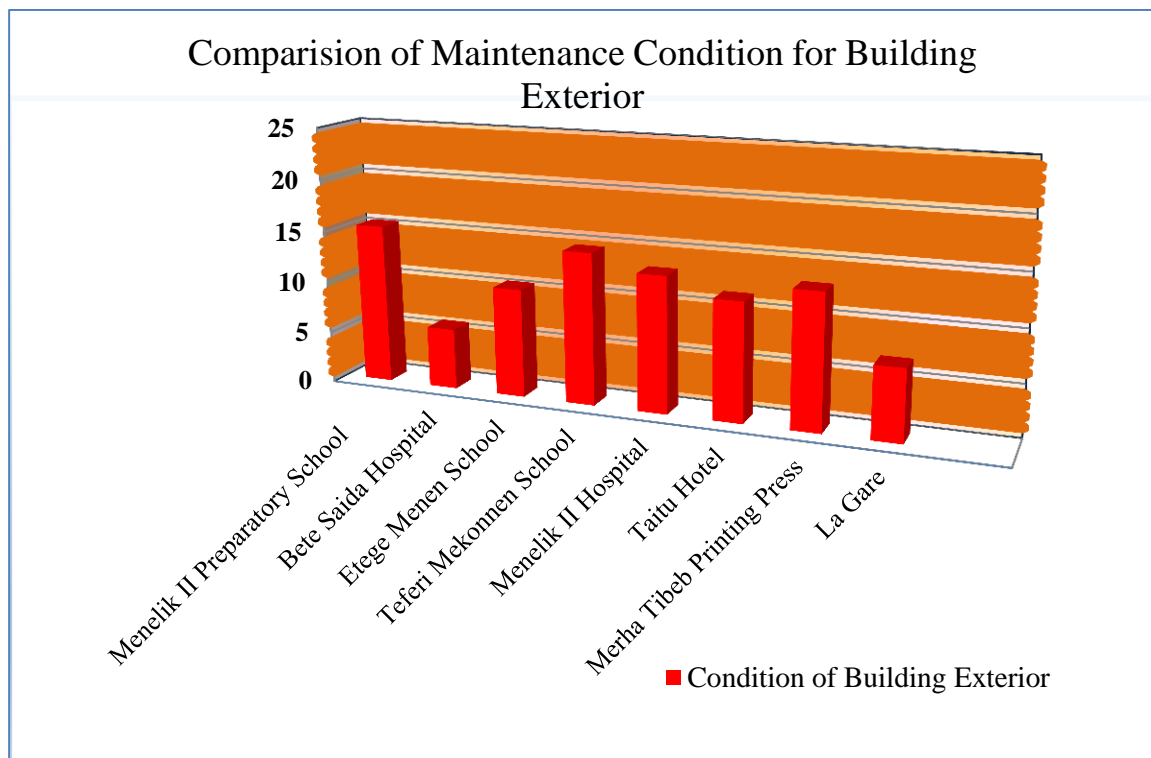


Figure 4.18: Exterior conditions for selected historic buildings

4.3.3. Condition of buildings' structural members

Building structural components are the most important elements that determine the existence of the structure. Structural elements presented in this study are structural walls, foundation and roof structural elements.

The condition evaluation process followed to inspect foundation based on visual inspection is comparably difficult to record and register in the inspection checklist. Yet, foundation structural issues such as partial settlement can be observed indirectly from the effects followed on walls. Moreover, lack of proper drainage systems could lead to poor foundation condition in addition to excessive loading due to change in the function of the historical building.

In roof truss structural systems, wood members are deteriorated and decayed in some buildings. Even though roof structural elements was difficult to assess as there was no access in most of the buildings.

The result of the structural condition of the historical buildings evaluated from the inspection checklists is summarized in table 4.5 and figure 4.19.

Table 4.5: Condition score and maintenance level of historic buildings' Structure

S/n	Name of Heritage Building	Condition of Building Structure					
		Condition Matrix		Exterior Condition summary			
		Roof structural Element	Foundation and Structural Wall	Defect No.	condition matrix	Score	Condition
1	Menelik II Preparatory School	13.3	38.3	3.0	51.7	17.2	Poor
2	Bete Saida Hospital	-	21.7	2.0	21.7	10.9	Moderate
3	Etege Menen School	21.73	20.7	5.0	42.4	8.5	Good
4	Teferi Mekonnen School	-	38.6	2.0	38.6	19.3	Poor
5	Menelik II Hospital	19.7	40.756	5.0	60.5	12.1	Moderate
6	Taitu Hotel	27.4	22.6	4.0	50.0	12.5	Moderate
7	Merha Tibeb Printing Press	-	31.5	2.0	31.5	15.8	Poor
8.	La Gare	12.5	19.1	4.0	31.6	7.9	Good

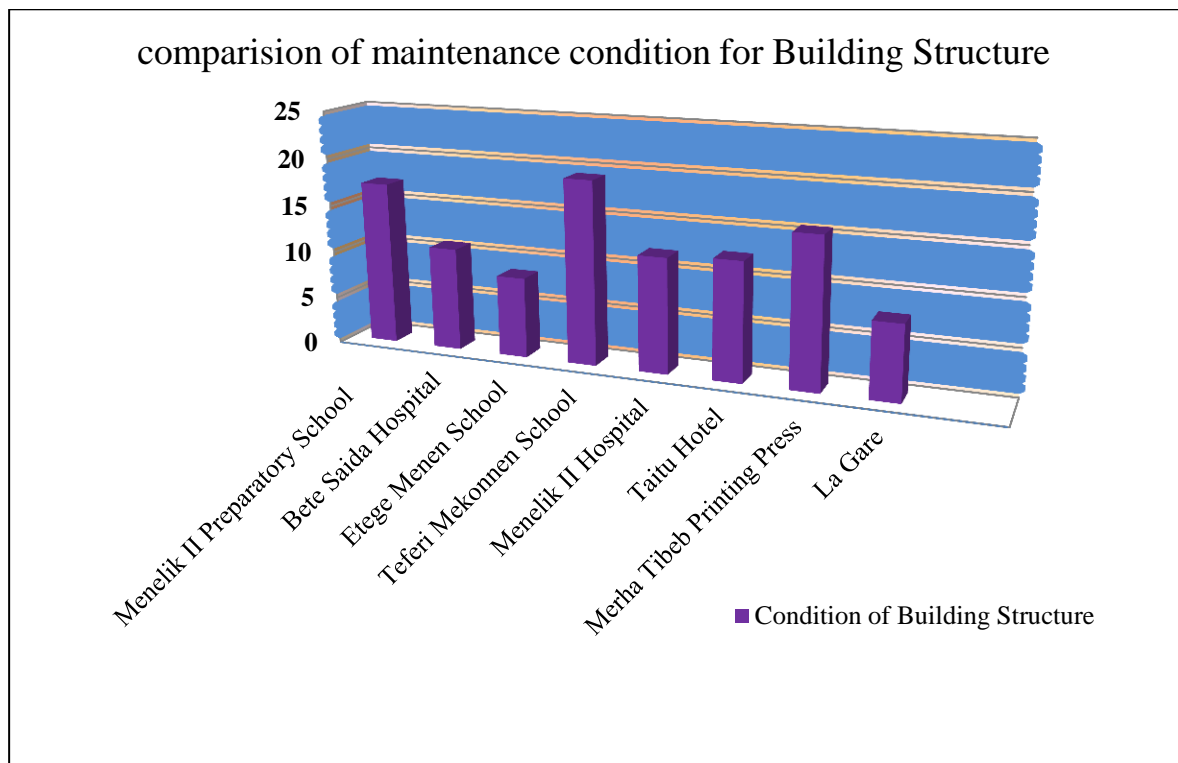


Figure 4.19: Condition of building structure for historical buildings

4.3.4. Condition of Buildings' services

Components classified under building services are gutters, downpipes and drainage works such as ditches. The cost of these components is low as compared to the structural elements. However, forgetting to maintain building services is a clue to failure and deterioration of other components, which require higher cost to rectify. Deterioration of building services has a great negative impact on foundation and wood members.

Most of the historical buildings evaluated has 'moderate' to 'poor' drainage systems. Table 4.6 shows building services of Menelik II Preparatory School, Merha Tibebe printing Press and Menelik II Hospital, which are 'poor', whereas the condition of building services for the other five institutions are moderate. The extent of deterioration for components of the evaluated historical buildings is plotted as shown in figure 4.20.

Table 4.6: Condition score and building service maintenance level

S/n	Name of Heritage Building	Condition of Building Services					
		Condition Matrix		Exterior Condition summary			
		Gutters and Downpipes	Drainage	Defect No.	Total condition matrix	Score	Condition
1	Menelik II School	98.9	18.5	7.0	117.3	16.76	Poor
2	Bete Saida Hospital	22.2	30.7	5.0	52.9	10.6	Moderate
3	Etege Menen School	48.9	15.7	5.0	64.5	12.9	Moderate
4	Teferi Mekonnen School	56.8	15.0	6.0	71.8	11.9	Moderate
5	Menelik II Hospital	73.9	9.2	5.0	83.1	16.6	Poor
6	Taitu Hotel	49.1	15.7	6.0	64.8	10.8	Moderate
7	Merha Tibebe Printing Press	74.7	22.6	6.0	97.3	16.2	Poor
8	La Gare	24.6	18.5	4.0	43.1	10.8	Moderate

Comparison of maintenance condition for Building Services

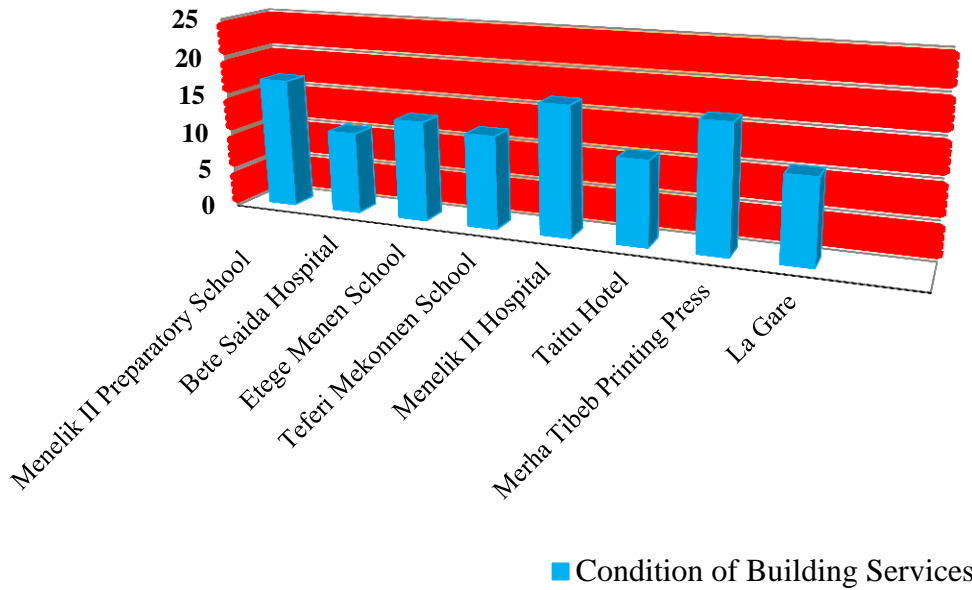


Figure 4.20: Condition of building services

The condition of building components can be aggregated to represent the overall condition of the selected historical buildings. Table 4.7 summarizes the component conditions to the overall maintenance condition of the building. The score is the result of factored arithmetic mean of the components condition matrix.

Table 4.7: Maintenance level of historic buildings under the study

S/n	Name of Heritage Building	Summary of Condition for selected historic Buildings			
		Condition Matrix	Defect No.	Score	Condition
1	Menelik II Preparatory School	550.8	38.0	14.5	Moderate
2	Bete Saida Hospital	155.4	21.0	7.4	Good
3	Etege Menen School	273.9	26.0	10.5	Moderate
4	Teferi Mekonnen School	380.8	27.0	14.1	Moderate
5	Menelik II Hospital	391.2	29.0	13.5	Moderate
6	Taitu Hotel	288.2	28.0	10.3	Moderate
7	Merha Tibebe Printing Press	400.3	29.0	13.8	Moderate
8	La Gare	142.9	19.0	7.5	Good

CHAPTER 5

DEVELOPMENT OF MARKOV DECISION PROCESS

5.1. Introduction

Various probability models exist for processes that evolve over time in a probabilistic manner. Such processes are called stochastic process. Markov chains are stochastic processes that have a special property that probabilities involving how the process will evolve in the future depend only on the present state of the process, and so are independent of events in the past.

This chapter focuses on how to design the operation of Markov chain to optimize its performance. Markov decision process is a useful tool to make maintenance decisions knowing alternative maintenance policies and corresponding transition probability matrices.

For each possible state of the Markov chain, we make a decision about which one of several alternative actions should be taken in that state. The action chosen affects the transition probabilities as well as both the immediate and subsequent costs from operating the system. The process of choosing the optimal actions for the respective states when considering both immediate and subsequent costs is referred to as a Markov decision process. (Hiller and Lieberman, 2001)

5.2. Maintenance Policy Specification

A decision maker can choose four maintenance policies when preserving and maintaining a building. These policies, as described in the research methodology session, are preventing maintenance, repairing defects, replacing failed components and doing nothing. However, these maintenance policies would not be easy to historic buildings. The reason is the fact that one has to follow a specific procedure of maintaining the structure by respecting the historic value, especially to the character defining components of the historic buildings.

Different literatures such as (U.S. Secretary of the Interior's Standard's for Rehabilitation, 1997) outlined guidelines to maintain deteriorated materials of historic elements. Even though recommending good practice for maintaining historic

buildings is beyond the scope of this research, specifying the way different building components are repaired or replaced is vital to determine the cost of maintenance.

Specifying procedures of repair and component replacements that could restore the deteriorated building element to its previous condition state is required. Without describing the detailed maintenance activities that should be undertaken, it would be difficult to proceed to engineering cost estimation.

Following recommended procedures and guidelines of the references reviewed in the literature chapter, detailed tasks that have less effect on reducing the historic value of heritage building are described in table 5.1, for preventive maintenance, repairing defects and replacing failed components.

Table 5.1: Maintenances activities specified under alternative decisions

Sub component	Preventive maintenance	Repairing defects	Replacing failed components
Internal Wall	Cleaning stone wall and providing protective coating for timber walls	Plastering and re-application of paints for walls	Replacing the entire wall
Floor	Periodic cleaning, providing protective mat	Correcting slopes and railings, and fixing joints, replacing damaged floor finishes	Replacing floor finish using similar material
Ceiling	Periodic cleaning	Removing water stained boards and replacing after treating water leakage, plastering and re-painting for concrete slab ceilings	Restoring the entire ceiling

Sub component	Preventive maintenance	Repairing defects	Replacing failed components
External Wall	Cleaning walls, oiling removing decayed elements	Re-pointing deteriorated mortar, cement mortar grouting for cracks in stone masonry	Restoring ruined components, plastering and re-painting, re-fabricating character defining elements
Windows and Doors	Periodic cleaning, varnishing, providing protection and paint coating to reduce deterioration due to moisture and ultraviolet ray	Scarifying decayed wood frames, splicing, repaired damaged elements.	Replacing the historic windows and doors respecting the historic value, with similar material and style
Roof	Painting anti-rust, Cyclical cleaning of roof gutters, fastening joints and fixing leaking openings.	Correcting roof slopes, replacing corrugated iron sheet and decayed wood truss elements.	Restoring the roof in accordance with the shape and stile of the original roof structure and material
Balcony/porches	Periodic cleaning of rust and debris, providing protective coating to railings	Scarifying and splicing deteriorated wood railings	Replacing ruined and deteriorated railings, plastering and re-painting loose components
Stair	Periodic cleaning, providing protective coating to railings, threads and risers	Fixing damaged components such as cracks and displaced risers	Reconstruction of all components

Sub component	Preventive maintenance	Repairing defects	Replacing failed components
Roof structural Element	Preventing leakage by identifying defects, rust and dust removal	Removing and replacing deteriorated truss elements, corrugated iron sheet and fixing joint problems.	Replacing the entire roof structure by the same style as the original
Structural Wall	Periodic cleaning and repairing gutters and downpipes, providing proper roof and surface drainage systems, stone wall cleaning using low pressure water spray	piecing-in, re-pointing mortar, and fixing cracks by mortar grouting	Replacing defective wall with similar material and style as the original

5.3. Cost Estimation for Building Components

5.3.1. Estimating Cost for Preventive Maintenance of Menelik II School

Cost of preventive maintenance is estimated based on the procedures and specifications described in table 5.1 and detailed cost estimation shown in appendix B. Moreover, the monthly payment payroll for maintenance crew shown for two years is brought to net present value to compare with the other costs estimated in the current time.

To calculate the present worth, knowledge of current market interest rate is required. Market interest rate accounts inflation rate and inflation free interest rate. To account for the effect of varying yearly inflation rates over a period of several Years, a single rate that represents an average inflation rate is computed based on data obtained from National Bank of Ethiopia shown in Table 5.2.

5.3.2. Estimation Cost for Repairing Defects of Menelik II School

Defects in historical buildings should be repaired by giving due respect to the historical values of the structures. Different literatures outlined procedures to maintain heritage structures. These rules are followed while prescribing specification in order to estimate the required costs when defected components of menelik II School building. This school is selected because it has the highest condition matrix score.

The detailed cost break down calculations and assumptions made to fix the unit rates for items specified under repairing deteriorated building components are presented in Appendix B. Table 5.4 presents the bill of quantities for repairing defects.

Table 5.4: Specified work items and bill of quantities for repairing defects

Building Component	Repairing defects				
	Item	Unit	Quantity	Unit cost	Amount (ETB)
Internal Wall	Two coats of plastering with lime based cement mortar	m ²	37.8	198.41	7,500.05
	Applying plastic emulsion paint to vertical plastered surfaces	m ²	63.4	61.62	3,906.83
Floor	Demolishing terrazzo tile	m ²	76.67	46.80	3,587.88
	Re-laying timber floor		60.5	95.27	5,764.05
	Re-laying terrazzo floor	m ²	53.6	212.23	11,375.35
Ceiling	Demolishing chip wood ceiling	m ²	9.5	50.39	
	Replacing the dilapidated chip wood	m ²	9.5	210.46	1,999.33
	Painting chip wood ceiling	m ²	9.5	61.62	585.41
External Wall	Cleaning and repointing mortar	m ²	26.5	197.45	5,232.45
	Lime Based Cement mortar Grouting	ml	23	476.19	10,952.42
Windows and Doors	Scarifying and varnishing	m ²	20.35	142.22	2,894.14
Roof works	Roof demolishing	m ²	2.75	50.39	138.58
	Truss and purlin works	m ²	2.75	706.46	1,942.77
	Replacing galvanized iron sheet	m ²	2.75	266.57	733.08
Balcony/porches	Painting	m ²	126	61.62	7,764.37

Building Component	Repairing defects				
	Item	Unit	Quantity	Unit cost	Amount (ETB)
Stair	Scarifying, varnishing and painting	m ²	41.8	203.84	8,520.51
Roof structural Element	Demolishing truss system and iron sheet	m ²	36	50.39	1,814.14
	Replacing truss and purlin elements and iron sheet recovering	m ²	36	443.80	15,976.78
Foundation and Structural Wall	Replacing Gutter	ml	42	329.53	13,840.27
	Ditch construction	ml	73	385.75	28,159.67
	Lime Based Cement mortar Grouting	ml	16	476.19	7,619.08
	Replacing downpipes	ml	37	304.45	11,264.60
Total					151,571.75

5.3.3. Cost of replacing failed components for Menelik II School

The detailed calculations used to determine the unit rates for activities prescribed to be performed for replacing components of Menelik II School are shown in Appendix B, and the bill of quantity is summarized in table 5.5 below

Table 5.5: Specified work items for replacing failed components

Building Component	Replacing failed components				
	Item	Unit	Quantity	Unit cost	Amount(ETB)
Floor	Demolishing work	m ²	121	46.80	5,662.36
	Terrazzo flooring	m ²	59.8	1266.22	75,719.90
	Timber flooring	m ²	60.5	1200.23	72,613.81
Ceiling	Demolishing work	m ²	28.6	46.80	1,338.38
	Painted chip wood ceiling	m ²	28.6	463.43	13,254.01
External Wall	Demolishing work	m ²	39	96.80	3,775.06

Building Component	Replacing failed components				
	Item	Unit	Quantity	Unit cost	Amount(ETB)
External Wall	Dressed stone work	m ²	39	1026.8513	40,047.20
Windows and Doors	Demolishing work	m ²	172	66.80	11,488.98
	Replacing wood windows and doors	m ²	173	2863.82	495,441.01
Roof	Demolishing work	m ²	72	50.39	3,628.28
	Roof work/truss system with galvanized iron sheet	m ²	72	266.57	19,193.30
	Demolishing work	m ²	70.00	20.39	1,427.50
Balcony/porches	Timber railing work	m ²	70.00	520.28	36,419.95
	Varnishing and painting	m ²	126	151.62	19,104.37
Stair	Varnishing Rails	m ²	42	90	3,780.00
	Demolishing work	m ²	42	50.39	2,116.50
	Painting walls	m ²	41.8	61.62	2,575.80
	Stone masonry stair case work				
Roof structural Element	Demolishing work	m ²	72	90.39	6,508.28
	Roof work/truss system with galvanized iron sheet	m ²	72	1258.96	90,644.83
Structural Wall	Demolishing work	m ²	21	96.80	2,032.72
	Replacing stone masonry wall(two sides dressed)	m ²	21	1026.8513	21,563.88
Total					928,336.10

5.3.4. Cost of Maintenance Alternatives at Different States

Cost of maintenance alternatives is different at various maintenance condition states. These costs can be better estimated from maintenance cost records and detailed cost break down. The cost of different maintenance decision at different states for Menelik

II School is distributed based on the condition rating scale defined in Table 3.5. A design and supervision cost of 15% is assumed, even though it does not have any effect on the Markov decision process. The resulting cost is presented in Table 5.6 shown below.

Table 5.6: Cost summary of maintenance alternatives at different states

Alternative state(i)	Replace ruined element	Repair defects	Preventive Maintenance	Do nothing
	(4)	(3)	(2)	(1)
1 (Excellent)	ND	ND	25,033.84	0
2 (Good)	ND	ND	50,067.68	0
3 (Moderate)	ND	174,307.51	75,101.52	0
4 (Poor)	1,423,448.68	232,410.01	100,135.36	ND
5 (Failed)	1,779,310.85	290,512.52	ND	ND

Note: ND = Not Desirable

5.4. Estimating Deterioration Probability Matrix

The Transition Probability Matrix (TPM) of each maintenance alternative is estimated based on personal judgment and on some data observation (Ferran, 2009). For the case of replacing failed components, the state goes back to 1 (excellent state) no matter what the current state is in. For the repairing defective components alternative, the TPM is improved by one state. It means portions with State 2 will switch to State 1, portions with State 3 will switch to State 2, portions with State 3 will switch to State 4, and finally portions with State 5 will switch to State 4. Based on this notion, the transition probability matrix for replacing failed components and repairing defects is presented in table 5.7 and table 5.8 respectively.

Table 5.7: Deterioration probability matrix for building elements under replacing failed components alternative

P_{ij} (replace Failed Components)	State	1	2	3	4	5
	1	1	0	0	0	0
2	1	0	0	0	0	
3	1	0	0	0	0	
4	1	0	0	0	0	
5	1	0	0	0	0	

Table 5.8: Deterioration probability matrix for building elements under repairing defective alternative

P_{ij} (repairing Defects)	State	1	2	3	4	5
	1	1	0	0	0	0
	2	1	0	0	0	0
	3	0	1	0	0	0
	4	0	0	1	0	0
	5	0	0	0	1	0

Without having condition inspection data collected for a long period, it would be difficult to estimate the TPM for the ‘do-nothing’ and ‘preventive maintenance’ alternatives. However, probability distribution and personal judgment in conjunction with Monte Carlo simulation can be used to estimate the TPM better. To present the probability distribution and Monte Carlo simulation, software named (Oracle Crystal ball V11) is used.

Crystal Ball uses Monte Carlo simulation to generate a range of values for defined assumptions. With Monte Carlo simulation, Crystal Ball displays results in a forecast chart that shows the entire range of possible outcomes and the likelihood of achieving each value. These forecast charts are used to estimate the probability.

For each uncertain variable in a simulation, possible values with a probability distribution are defined. A simulation calculates numerous scenarios of a model by repeatedly picking values from the probability distribution for the uncertain variables. The probability distribution used to run the crystal ball software is beta distribution.

Figure 5.1 to 5.4 and figure 5.5 to 5.8 presents assumption values and values from beta distribution. Assumption charts show trial values for the last simulation compared with the distribution selected for that assumption, Beta distribution in this case, after running simulations with Monte Carlo. 1000 run is chosen in this case.

From crystal ball-Monte Carlo simulation, the probability of a state to stay in its condition is estimated from forecast charts generated for each state under ‘do-nothing’ and ‘preventive maintenance’ alternatives by assigning most likely values from the researcher’s personal judgment. Table 5.10 and table 5.11 summarized the transition probability matrix for ‘preventive maintenance’ and ‘do-nothing’ actions respectively.

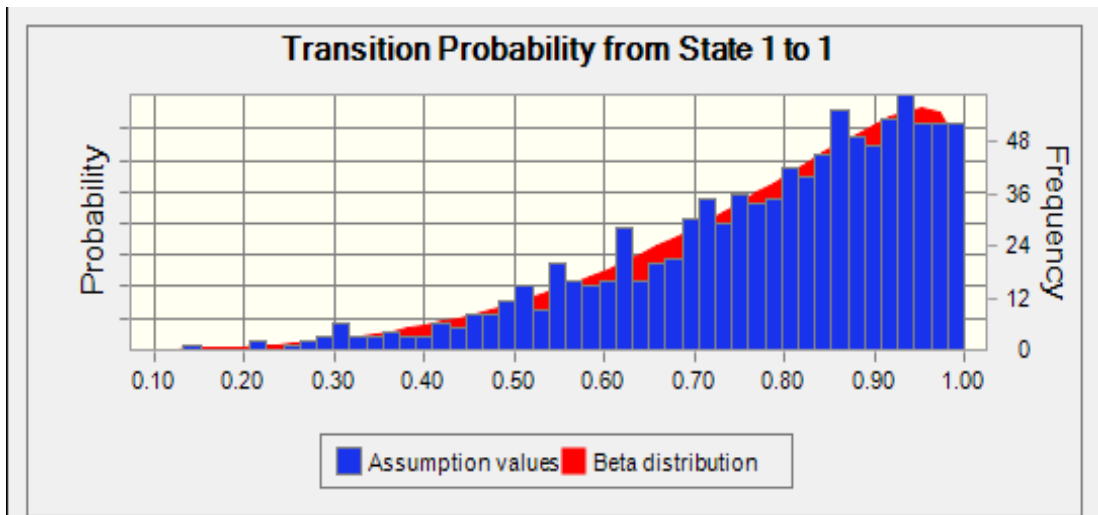


Figure 5.1: Transition probability from state 1 to state 1 under preventive maintenance

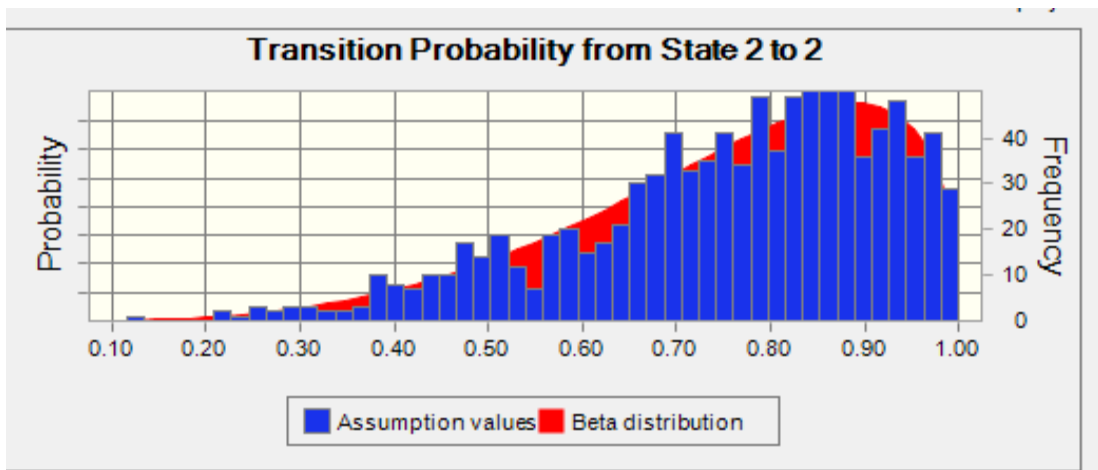


Figure 5.2: Transition probability from State 2 to state 2 under preventive maintenance

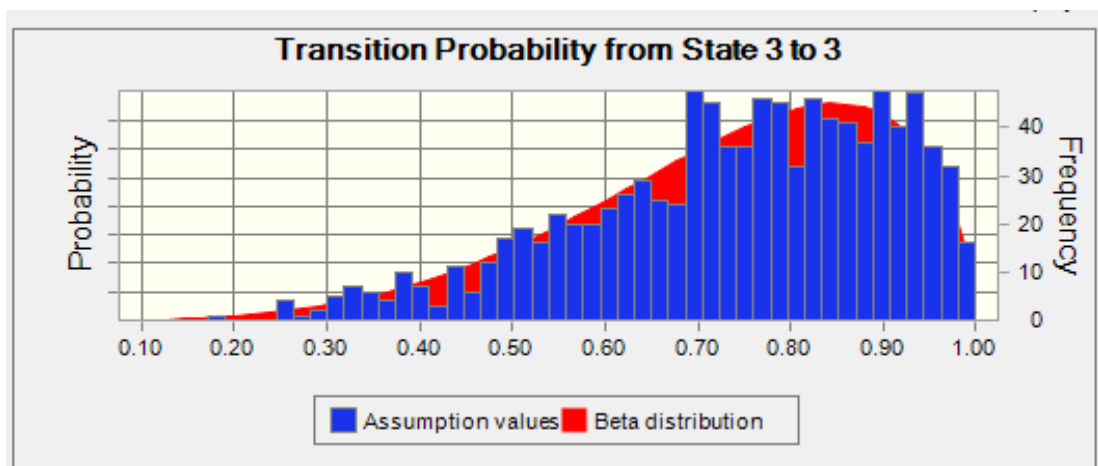


Figure 5.3: Transition probability from state 3 to state 3 under preventive maintenance

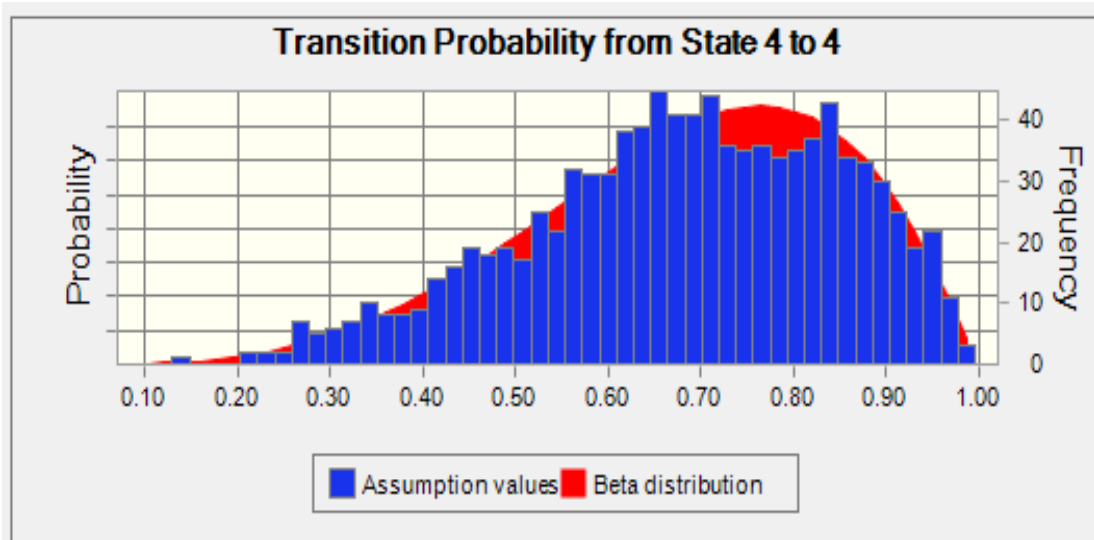


Figure 5.4: Transition probability from Sate 4 to state 4 under preventive maintenance

Table 5.9: Transition probability for preventive maintenance decision alternative

P_{ij} (preventive maintenance)	State	1	2	3	4	5
	1	0.92.	0.08	0	0	0
	2	0	0.88	0.12	0	0
	3	0	0	0.85	0.15	0
	4	0	0	0	0.78	0.22
	5	0	0	0	0	1

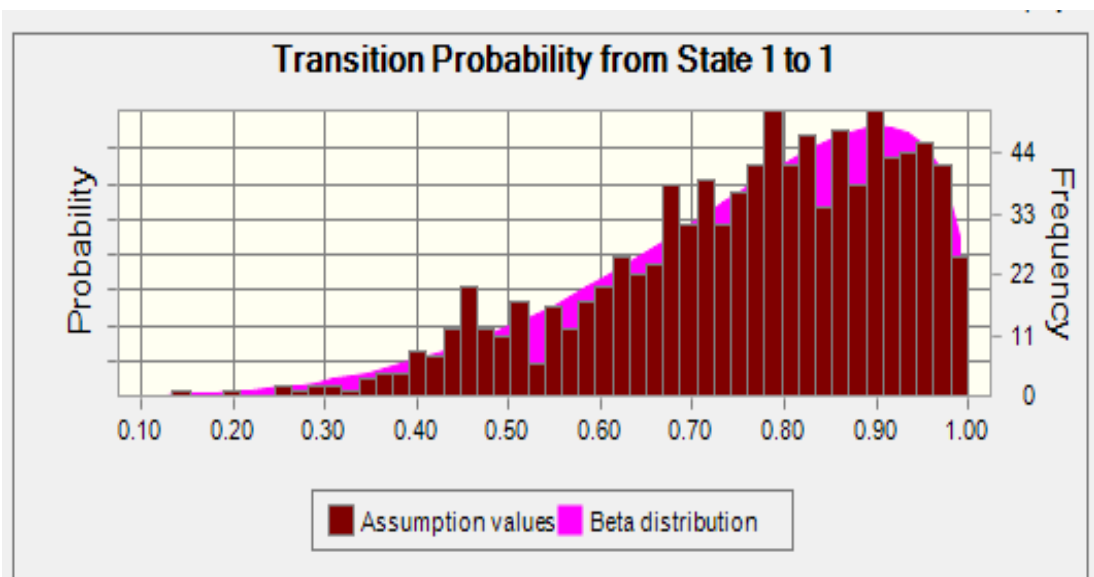


Figure 5.5: Transition probability from sate 1 to state 1 under Do-Nothing

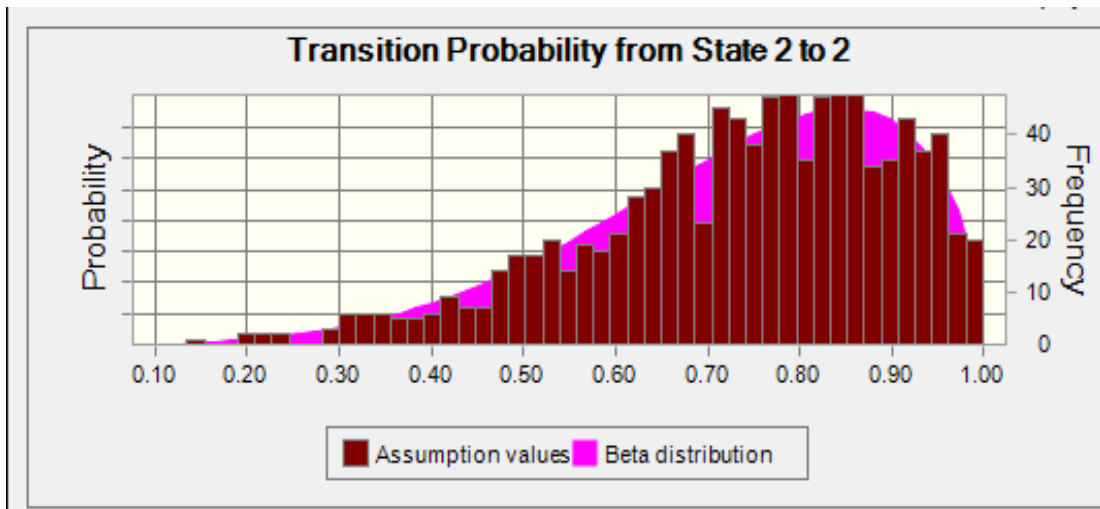


Figure 5.6: Transition probability from state 2 to state 2 under Do-Nothing

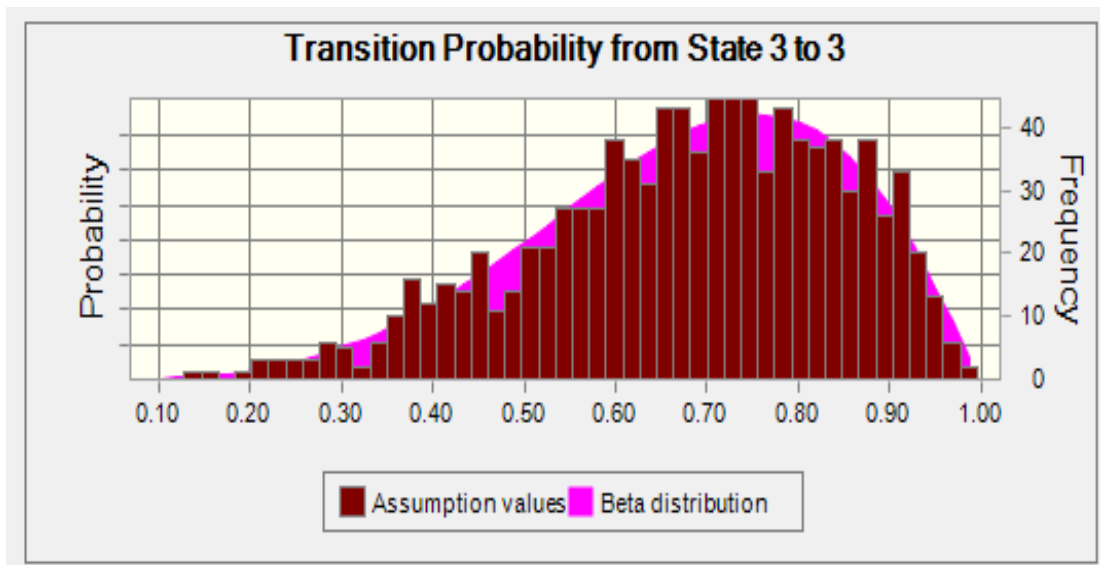


Figure 5.7: Transition probability from state 3 to state 3 under Do-Nothing

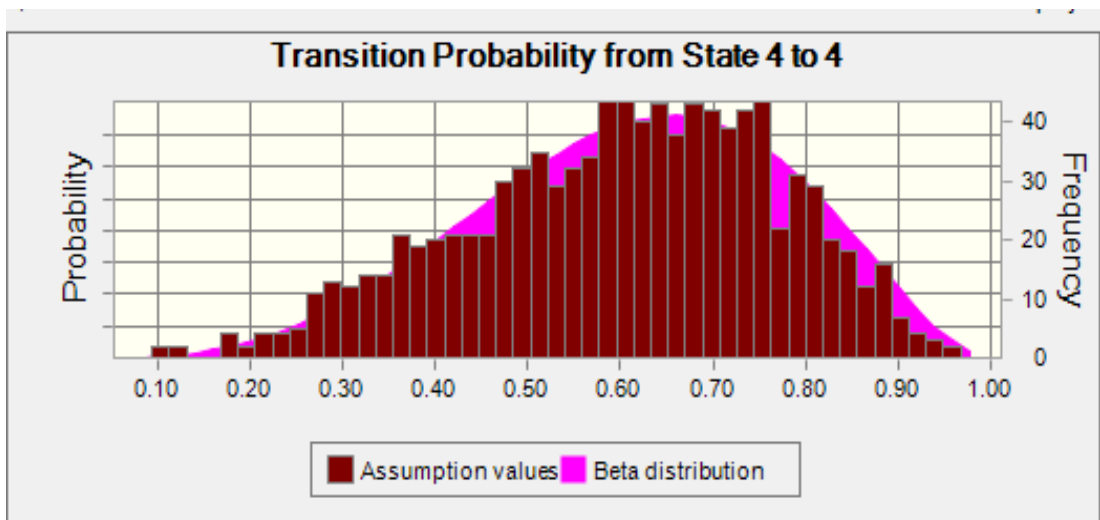


Figure 5.8: Transition probability from state 4 to state 4 under Do-Nothing

Table 5.10: Deterioration probability matrix for building elements under do Nothing decision alternative

	State	1	2	3	4	5
	$P_{ij}(\text{do nothing})$	1	0.89	0.11	0	0	0
2		0	0.86	0.14	0	0
3		0	0	0.77	0.23	0
4		0	0	0	0.67	0.33
5		0	0	0	0	1

5.5. Linear Programming Model for Markov Decision Process

Linear programming is a tool for solving optimization problems. Linear programming uses a mathematical model to describe the problem of concern. The adjective linear means that all the mathematical functions in this model are required to be linear functions.

The most common type of application involves the general problem of allocating limited resources among competing activities in a best possible (optimal) way. This problem involves selecting the level of certain activities that compete for scarce resources that are necessary to perform those activities.

As stated in (Winston, 2004) in 1947, George Dantzing developed an efficient method, the simplex algorithm, for solving linear programming problems. And since the development of the simplex algorithm, linear programming has been used to solve optimization problems in various industries.

(Hiller and Lieberman, 2001) summarized a model for Markov decision processes as follows.

1. The state (i) of a discrete time Markov chain is observed after each transition ($i = 0, 1, \dots, M$).
2. After each observation, a decision (action) (k) is chosen from a set of (K) possible decisions ($k = 1, 2, \dots, K$). (Some of the (K) decisions may not be relevant for some of the states.)
3. If decision d_{ik} is made in state (i), an immediate cost is incurred that has an expected value C_{ik} .

4. The decision d_{ik} in state i determines what the transition probability will be for the next transition from state i . These transition probabilities are denoted by p_{ij} (k), for $j = 0, 1, \dots, M$.
5. A specification of the decisions for the respective states (d_1, d_2, \dots, d_M) prescribes a policy for the Markov decision process.
6. The objective is to find an optimal policy according to some cost criterion which considers both immediate costs and subsequent costs that result from the future evolution of the process. One common criterion is to minimize the long-run expected average cost per unit time.

This general model qualifies to be a Markov decision process because it possesses the Markovian property that characterizes any Markov process. Given the current state and decision, any probabilistic statement about the future of the process is completely unaffected by providing any information about the history of the process. This property holds in this model since,

1. The new transition probabilities depend on only the current state and decision
2. The immediate expected cost also depends on only the current state and decision.

Table 5.11: Presentation of alternative decisions for various states

		Decision k			
		1	2	..	k
	1	D_{11}	D_{12}	..	D_{1k}
	2	D_{21}	D_{22}	..	D_{2k}
State	.....	.....	.....	.....	.....
	M	D_{m1}	D_{m1}	..	D_{mk}

Where each D_{ik} ($i = 1, 2, \dots, k$) is defined as

$$D_{ik} = \begin{cases} 1 & \text{if decision } k \text{ is to be made in state } i \\ 0 & \text{otherwise.} \end{cases}$$

5.5.1. Randomized Policies

As states in (Hiller and Lieberman, 2001) Introducing a related Variable (D_{ik}) which relates the rational numbers expected in the solution for a linear programming formulation to the integers are useful. It is anticipated that the expected cost of a policy can be expressed as a linear function of (D_{ik}) subject to linear constraints. But, the (D_{ik}) values are integers (0 or 1), and continuous variables are required for a linear programming formulation. This requirement can be handled by expanding the interpretation of a policy. The previous definition calls for making the same decision every time the system is in state i . The new interpretation of a policy will call for determining a probability distribution for the decision to be made when the system is in state (i).

With this new interpretation, the D_{ik} now need to be redefined as

$$D_{ik} = P \{ \text{decision} = k / \text{state} = i \}$$

In other words, given that the system is in state i , variable D_{ik} is the probability of choosing decision k as the decision to be made. Therefore, ($D_{i1}, D_{i2}, \dots, D_{ik}$) is the probability distribution for the decision to be made in state i .

This kind of policy using probability distributions is called a randomized policy, whereas the policy calling for $D_{ik} = 0$ or 1 is a deterministic policy. Randomized policies can again be characterized by the matrix.

Table 5.12: Presentation of alternative probability distribution of decisions for various states

		Decision k			
		1	2	. .	k
1		D_{11}	D_{12}	. .	D_{1k}
2		D_{21}	D_{22}	. .	D_{2k}
State	.....	.....	.....	.....	.....
M		D_{m1}	D_{m1}	. .	D_{mk}

Where each row sums to 1, and now

$$0 \leq D_{ik} \leq 1$$

The long -run expected average cost per unit time is given by:-

$$E(C) = \sum_{i=1}^m \sum_{k=1}^k \pi_i C_{ik} D_{ik} = \sum_{i=1}^m \sum_{k=1}^k C_{ik} y_{ik} \dots\dots\dots Equation 5.4$$

Hence the linear programming model is to choose the y_{ik} so as to

$$\text{Minimize } z = \sum_{i=1}^m \sum_{k=1}^k C_{ik} y_{ik}$$

Subject to the constraints

1. $\sum_{i=1}^m \sum_{k=1}^k y_{ik} = 1$
2. $\sum_{k=1}^K y_{jk} - \sum_{i=1}^m \sum_{k=1}^k y_{ik} p_{ij}(K) = 0$ for $j = 1, 2, \dots, M$
3. $y_{ik} \geq 0, \text{ for all } i = 1, 2, \dots, M \text{ and } k = 1, 2, \dots, K$

The above formulation is applied to the maintenance and rehabilitation prioritization under the objective of this thesis as described below.

$$\begin{aligned} \text{Minimize } Z = & 25033.84Y_{12} + 50067.68Y_{22} + 75101.52Y_{32} + 100135.36Y_{42} + \\ & 174307.51Y_{33} + 232410.01Y_{43} + 290512.52Y_{53} + 1423448.68Y_{44} + \\ & 1779310.85Y_{54} \end{aligned}$$

Subject to;

$$y_{11} + y_{21} + y_{31} + y_{12} + y_{22} + y_{32} + y_{42} + y_{33} + y_{43} + y_{53} + y_{44} + y_{54} = 1$$

$$y_{22} + y_{21} - (0.88y_{22} + 0.86y_{21} + 0.08y_{12} + 0.11y_{11}) = 0$$

$$y_{33} + y_{32} + y_{31} - (y_{43} + 0.14y_{21} + 0.12y_{22} + 0.85y_{32} + 0.77y_{31}) = 0$$

$$y_{44} + y_{43} + y_{42} - (y_{53} + 0.67y_{41} + 0.78y_{42} + 0.15y_{32} + 0.23y_{31}) = 0$$

$$y_{54} + y_{53} - (0.22y_{42} + 0.33y_{41}) = 0$$

$$\text{All } y_{ik} \geq 0$$

This linear programming equation is solved using a software (TORA) and the resulting optimal variables that minimizes the long run expected cost are found after fourteen iterations. Figure 5.9 shown below is the optimal policy generated from TORA linear programming optimization software.

Problem Title: **Cost Minimization**

Nbr. of Variables: **15**

No. of Constraints: **6**

INPUT GRID - LINEAR PROGRAMMING

	x1	x2	x3	x4	x5	x6	x7	x8	x9
Var. Name	y12	y22	y32	y42	y33	y43	y53	y44	y54
Minimize	25033.84	50067.68	75101.52	100135.36	174307.51	232410.01	290512.52	1423448.68	1779310.85
Constr 1	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00
Constr 2	0.08	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	-1.00
Constr 3	0.08	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Constr 4	0.00	-0.12	0.15	0.00	1.00	-1.00	0.00	0.00	0.00
Constr 5	0.00	0.00	-0.15	0.22	0.00	1.00	-1.00	1.00	0.00
Constr 6	0.00	0.00	0.00	-0.23	0.00	0.00	1.00	0.00	1.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n	n	n	n

Problem Title: **Cost Minimization**

Nbr. of Variables: **15**

No. of Constraints: **6**

INPUT GRID - LINEAR PROGRAMMING

	x7	x8	x9	x10	x11	x12	x13	x14	x15	Enter <, >, or =	R.H.S.
Var. Name	y53	y44	y54	y11	y21	y31	y41	y51	y52		
Minimize	290512.52	1423448.68	1779310.85	0.00	0.00	0.00	0.00	0.00	0.00		
Constr 1	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	=	1.00
Constr 2	0.00	-1.00	-1.00	0.11	0.00	0.00	0.00	0.00	0.00	=	0.00
Constr 3	0.00	0.00	0.00	-0.11	0.14	0.00	0.00	0.00	0.00	=	0.00
Constr 4	0.00	0.00	0.00	0.00	-0.14	0.23	0.00	0.00	0.00	=	0.00
Constr 5	-1.00	1.00	0.00	0.00	0.00	-0.23	-0.67	0.00	0.00	=	0.00
Constr 6	1.00	0.00	1.00	0.00	0.00	0.00	-0.33	-1.00	-1.00	=	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity	infinity	infinity	infinity		
Unrestr'd (y/n)?	n	n	n	n	n	n	n	n	n		

Phase 1 (Iter 1)	y12	y22	y32	y42	y33	y43			
Basic	x1	x2	x3	x4	x5	x6			
z (min)	1.16	1.00	1.00	-0.01	2.00	1.00			
Rx16	1.00	1.00	1.00	0.00	1.00	1.00			
Rx17	0.08	0.00	0.00	0.00	0.00	0.00			
Rx18	0.08	0.12	0.00	0.00	0.00	0.00			
Rx19	0.00	-0.12	0.15	0.00	1.00	-1.00			
Rx20	0.00	0.00	-0.15	0.22	0.00	1.00			
Rx21	0.00	0.00	0.00	-0.23	0.00	0.00			
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n	n	n	n			
Phase 1 (Iter 1)	y53	y44	y54	y11	y21	y31			
Basic	x7	x8	x9	x10	x11	x12			
z (min)	1.00	1.00	1.00	1.00	0.00	0.00			
Rx16	1.00	1.00	1.00	1.00	0.00	0.00			
Rx17	0.00	-1.00	-1.00	0.11	0.00	0.00			
Rx18	0.00	0.00	0.00	-0.11	0.14	0.00			
Rx19	0.00	0.00	0.00	0.00	-0.14	0.23			
Rx20	-1.00	1.00	0.00	0.00	0.00	-0.23			
Rx21	1.00	0.00	1.00	0.00	0.00	0.00			
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n	n	n	n			
Phase 1 (Iter 1)	y41	y51	y52						
Basic	x13	x14	x15	Rx16	Rx17	Rx18			
z (min)	-1.00	-1.00	-1.00	0.00	0.00	0.00			
Rx16	0.00	0.00	0.00	1.00	0.00	0.00			
Rx17	0.00	0.00	0.00	0.00	1.00	0.00			
Rx18	0.00	0.00	0.00	0.00	0.00	1.00			
Rx19	0.00	0.00	0.00	0.00	0.00	0.00			
Rx20	-0.67	0.00	0.00	0.00	0.00	0.00			
Rx21	-0.33	-1.00	-1.00	0.00	0.00	0.00			
Lower Bound	0.00	0.00	0.00						
Upper Bound	infinity	infinity	infinity						
Unrestr'd (y/n)?	n	n	n						
Phase 1 (Iter 1)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Rx16	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Rx17	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Rx18	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Rx19	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Rx20	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Rx21	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 1 (Iter 2)	y12	y22	y32	y42	y33	y43			
Basic	x1	x2	x3	x4	x5	x6			
z (min)	1.16	1.24	0.70	-0.01	0.00	3.00			
Rx16	1.00	1.12	0.85	0.00	0.00	2.00			
Rx17	0.08	0.00	0.00	0.00	0.00	0.00			
Rx18	0.08	0.12	0.00	0.00	0.00	0.00			
x5	0.00	-0.12	0.15	0.00	1.00	-1.00			
Rx20	0.00	0.00	-0.15	0.22	0.00	1.00			
Rx21	0.00	0.00	0.00	-0.23	0.00	0.00			
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n	n	n	n			
Phase 1 (Iter 2)	y53	y44	y54	y11	y21	y31			
Basic	x7	x8	x9	x10	x11	x12			
z (min)	1.00	1.00	1.00	1.00	0.28	-0.46			
Rx16	1.00	1.00	1.00	1.00	0.14	-0.23			
Rx17	0.00	-1.00	-1.00	0.11	0.00	0.00			
Rx18	0.00	0.00	0.00	-0.11	0.14	0.00			
x5	0.00	0.00	0.00	0.00	-0.14	0.23			
Rx20	-1.00	1.00	0.00	0.00	0.00	-0.23			
Rx21	1.00	0.00	1.00	0.00	0.00	0.00			
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n	n	n	n			
Phase 1 (Iter 2)	y41	y51	y52						
Basic	x13	x14	x15	Rx16	Rx17	Rx18			
z (min)	-1.00	-1.00	-1.00	0.00	0.00	0.00			
Rx16	0.00	0.00	0.00	1.00	0.00	0.00			
Rx17	0.00	0.00	0.00	0.00	1.00	0.00			
Rx18	0.00	0.00	0.00	0.00	0.00	1.00			
x5	0.00	0.00	0.00	0.00	0.00	0.00			
Rx20	-0.67	0.00	0.00	0.00	0.00	0.00			
Rx21	-0.33	-1.00	-1.00	0.00	0.00	0.00			
Lower Bound	0.00	0.00	0.00						
Upper Bound	infinity	infinity	infinity						
Unrestr'd (y/n)?	n	n	n						
Phase 1 (Iter 2)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	-1.00	-1.00	0.00	0.00	0.00	-2.00	0.00	0.00	1.00
Rx16	0.00	0.00	1.00	0.00	0.00	-1.00	0.00	0.00	1.00
Rx17	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Rx18	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
x5	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Rx20	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Rx21	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 1 (Iter 3)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	1.16	1.24	1.15	-0.67	0.00	0.00
Rx16	1.00	1.12	1.15	-0.44	0.00	0.00
Rx17	0.08	0.00	0.00	0.00	0.00	0.00
Rx18	0.08	0.12	0.00	0.00	0.00	0.00
x5	0.00	-0.12	0.00	0.22	1.00	0.00
x6	0.00	0.00	-0.15	0.22	0.00	1.00
Rx21	0.00	0.00	0.00	-0.23	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 3)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	4.00	-2.00	1.00	1.00	0.28	0.23
Rx16	3.00	-1.00	1.00	1.00	0.14	0.23
Rx17	0.00	-1.00	-1.00	0.11	0.00	0.00
Rx18	0.00	0.00	0.00	-0.11	0.14	0.00
x5	-1.00	1.00	0.00	0.00	-0.14	0.00
x6	-1.00	1.00	0.00	0.00	0.00	-0.23
Rx21	1.00	0.00	1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 3)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	1.01	-1.00	-1.00	0.00	0.00	0.00
Rx16	1.34	0.00	0.00	1.00	0.00	0.00
Rx17	0.00	0.00	0.00	0.00	1.00	0.00
Rx18	0.00	0.00	0.00	0.00	0.00	1.00
x5	-0.67	0.00	0.00	0.00	0.00	0.00
x6	-0.67	0.00	0.00	0.00	0.00	0.00
Rx21	-0.33	-1.00	-1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 1 (Iter 3)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	-1.00	-1.00	0.00	0.00	0.00	-2.00	-3.00	0.00	1.00
Rx16	0.00	0.00	1.00	0.00	0.00	-1.00	-2.00	0.00	1.00
Rx17	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Rx18	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
x5	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
x6	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Rx21	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 1 (Iter 4)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	1.16	1.24	1.15	0.25	0.00	0.00
Rx16	1.00	1.12	1.15	0.25	0.00	0.00
Rx17	0.08	0.00	0.00	0.00	0.00	0.00
Rx18	0.08	0.12	0.00	0.00	0.00	0.00
x5	0.00	-0.12	0.00	-0.01	1.00	0.00
x6	0.00	0.00	-0.15	-0.01	0.00	1.00
x7	0.00	0.00	0.00	-0.23	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 4)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	-2.00	-3.00	1.00	0.28	0.23
Rx16	0.00	-1.00	-2.00	1.00	0.14	0.23
Rx17	0.00	-1.00	-1.00	0.11	0.00	0.00
Rx18	0.00	0.00	0.00	-0.11	0.14	0.00
x5	0.00	1.00	1.00	0.00	-0.14	0.00
x6	0.00	1.00	1.00	0.00	0.00	-0.23
x7	1.00	0.00	1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 4)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	2.33	3.00	3.00	0.00	0.00	0.00
Rx16	2.33	3.00	3.00	1.00	0.00	0.00
Rx17	0.00	0.00	0.00	0.00	1.00	0.00
Rx18	0.00	0.00	0.00	0.00	0.00	1.00
x5	-1.00	-1.00	-1.00	0.00	0.00	0.00
x6	-1.00	-1.00	-1.00	0.00	0.00	0.00
x7	-0.33	-1.00	-1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 1 (Iter 4)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	3.00	3.00	0.00	0.00	0.00	-2.00	-3.00	-4.00	1.00
Rx16	3.00	3.00	1.00	0.00	0.00	-1.00	-2.00	-3.00	1.00
Rx17	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Rx18	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
x5	-1.00	-1.00	0.00	0.00	0.00	1.00	1.00	1.00	0.00
x6	-1.00	-1.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00
x7	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 1 (Iter 5)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	0.16	0.12	0.00	0.00	0.00	0.00
x14	0.33	0.37	0.38	0.08	0.00	0.00
Rx17	0.08	0.00	0.00	0.00	0.00	0.00
Rx18	0.08	0.12	0.00	0.00	0.00	0.00
x5	0.33	0.25	0.38	0.07	1.00	0.00
x6	0.33	0.37	0.23	0.07	0.00	1.00
x7	0.33	0.37	0.38	-0.15	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 5)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	-1.00	-1.00	0.00	0.14	0.00
x14	0.00	-0.33	-0.67	0.33	0.05	0.08
Rx17	0.00	-1.00	-1.00	0.11	0.00	0.00
Rx18	0.00	0.00	0.00	-0.11	0.14	0.00
x5	0.00	0.67	0.33	0.33	-0.09	0.08
x6	0.00	0.67	0.33	0.33	0.05	-0.15
x7	1.00	-0.33	0.33	0.33	0.05	0.08
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 5)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	0.00	0.00	0.00	-1.00	0.00	0.00
x14	0.78	1.00	1.00	0.33	0.00	0.00
Rx17	0.00	0.00	0.00	0.00	1.00	0.00
Rx18	0.00	0.00	0.00	0.00	0.00	1.00
x5	-0.22	0.00	0.00	0.33	0.00	0.00
x6	-0.22	0.00	0.00	0.33	0.00	0.00
x7	0.45	0.00	0.00	0.33	0.00	0.00
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 1 (Iter 5)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	0.00	0.00	-1.00	0.00	0.00	-1.00	-1.00	-1.00	0.00
x14	1.00	1.00	0.33	0.00	0.00	-0.33	-0.67	-1.00	0.33
Rx17	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Rx18	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
x5	0.00	0.00	0.33	0.00	0.00	0.67	0.33	0.00	0.33
x6	0.00	0.00	0.33	0.00	0.00	-0.33	0.33	0.00	0.33
x7	0.00	0.00	0.33	0.00	0.00	-0.33	-0.67	0.00	0.33
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 1 (Iter 6)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	0.00	0.12	0.00	0.00	0.00	0.00
x14	0.00	0.37	0.38	0.08	0.00	0.00
x1	1.00	0.00	0.00	0.00	0.00	0.00
Rx18	0.00	0.12	0.00	0.00	0.00	0.00
x5	0.00	0.25	0.38	0.07	1.00	0.00
x6	0.00	0.37	0.23	0.07	0.00	1.00
x7	0.00	0.37	0.38	-0.15	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 6)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	1.00	1.00	-0.22	0.14	0.00
x14	0.00	3.83	3.50	-0.13	0.05	0.08
x1	0.00	-12.50	-12.50	1.38	0.00	0.00
Rx18	0.00	1.00	1.00	-0.22	0.14	0.00
x5	0.00	4.83	4.50	-0.13	-0.09	0.08
x6	0.00	4.83	4.50	-0.13	0.05	-0.15
x7	1.00	3.83	4.50	-0.13	0.05	0.08
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 6)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	0.00	0.00	0.00	-1.00	-2.00	0.00
x14	0.78	1.00	1.00	0.33	-4.17	0.00
x1	0.00	0.00	0.00	0.00	12.50	0.00
Rx18	0.00	0.00	0.00	0.00	-1.00	1.00
x5	-0.22	0.00	0.00	0.33	-4.17	0.00
x6	-0.22	0.00	0.00	0.33	-4.17	0.00
x7	0.45	0.00	0.00	0.33	-4.17	0.00
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 1 (Iter 6)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	0.00	0.00	-1.00	-2.00	0.00	-1.00	-1.00	-1.00	0.00
x14	1.00	1.00	0.33	-4.17	0.00	-0.33	-0.67	-1.00	0.33
x1	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00
Rx18	0.00	0.00	0.00	-1.00	1.00	0.00	0.00	0.00	0.00
x5	0.00	0.00	0.33	-4.17	0.00	0.67	0.33	0.00	0.33
x6	0.00	0.00	0.33	-4.17	0.00	-0.33	0.33	0.00	0.33
x7	0.00	0.00	0.33	-4.17	0.00	-0.33	-0.67	0.00	0.33
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 1 (Iter 7)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	0.00	0.00	0.00	0.00	0.00	0.00
x14	0.00	-0.09	0.38	0.08	0.00	0.00
x1	1.00	1.50	0.00	0.00	0.00	0.00
x8	0.00	0.12	0.00	0.00	0.00	0.00
x5	0.00	-0.33	0.38	0.07	1.00	0.00
x6	0.00	-0.21	0.23	0.07	0.00	1.00
x7	0.00	-0.09	0.38	-0.15	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 7)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	0.00	0.00	0.00	0.00	0.00
x14	0.00	0.00	-0.33	0.72	-0.49	0.08
x1	0.00	0.00	0.00	-1.38	1.75	0.00
x8	0.00	1.00	1.00	-0.22	0.14	0.00
x5	0.00	0.00	-0.33	0.94	-0.77	0.08
x6	0.00	0.00	-0.33	0.94	-0.63	-0.15
x7	1.00	0.00	0.67	0.72	-0.49	0.08
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 1 (Iter 7)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	0.00	0.00	0.00	-1.00	-1.00	-1.00
x14	0.78	1.00	1.00	0.33	-0.33	-3.83
x1	0.00	0.00	0.00	0.00	0.00	12.50
x8	0.00	0.00	0.00	0.00	-1.00	1.00
x5	-0.22	0.00	0.00	0.33	0.67	-4.83
x6	-0.22	0.00	0.00	0.33	0.67	-4.83
x7	0.45	0.00	0.00	0.33	-0.33	-3.83
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 1 (Iter 7)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	0.00	0.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	0.00
x14	1.00	1.00	0.33	-0.33	-3.83	-0.33	-0.67	-1.00	0.33
x1	0.00	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00
x8	0.00	0.00	0.00	-1.00	1.00	0.00	0.00	0.00	0.00
x5	0.00	0.00	0.33	0.67	-4.83	0.67	0.33	0.00	0.33
x6	0.00	0.00	0.33	0.67	-4.83	-0.33	0.33	0.00	0.33
x7	0.00	0.00	0.33	-0.33	-3.83	-0.33	-0.67	0.00	0.33
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 2 (Iter 8)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	0.00	28147.31	157308.49	-112917.91	0.00	0.00
x14	0.00	-0.09	0.38	0.08	0.00	0.00
x1	1.00	1.50	0.00	0.00	0.00	0.00
x8	0.00	0.12	0.00	0.00	0.00	0.00
x5	0.00	-0.33	0.38	0.07	1.00	0.00
x6	0.00	-0.21	0.23	0.07	0.00	1.00
x7	0.00	-0.09	0.38	-0.15	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 8)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	0.00	-297759.66	242741.19	-179894.19	0.00
x14	0.00	0.00	-0.33	0.72	-0.49	0.08
x1	0.00	0.00	0.00	-1.38	1.75	0.00
x8	0.00	1.00	1.00	-0.22	0.14	0.00
x5	0.00	0.00	-0.33	0.94	-0.77	0.08
x6	0.00	0.00	-0.33	0.94	-0.63	-0.15
x7	1.00	0.00	0.67	0.72	-0.49	0.08
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 8)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	38928.68	0.00	0.00	blocked	blocked	blocked
x14	0.78	1.00	1.00	0.33	-0.33	-3.83
x1	0.00	0.00	0.00	0.00	0.00	12.50
x8	0.00	0.00	0.00	0.00	-1.00	1.00
x5	-0.22	0.00	0.00	0.33	0.67	-4.83
x6	-0.22	0.00	0.00	0.33	0.67	-4.83
x7	0.45	0.00	0.00	0.33	-0.33	-3.83
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 2 (Iter 8)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	0.00	0.00	blocked	blocked	blocked	blocked	blocked	blocked	232410.01
x14	1.00	1.00	0.33	-0.33	-3.83	-0.33	-0.67	-1.00	0.33
x1	0.00	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00
x8	0.00	0.00	0.00	-1.00	1.00	0.00	0.00	0.00	0.00
x5	0.00	0.00	0.33	0.67	-4.83	0.67	0.33	0.00	0.33
x6	0.00	0.00	0.33	0.67	-4.83	-0.33	0.33	0.00	0.33
x7	0.00	0.00	0.33	-0.33	-3.83	-0.33	-0.67	0.00	0.33
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 2 (Iter 9)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	0.00	112654.02	58142.46	-131888.80	-258693.99	0.00
x14	0.00	0.16	0.09	0.03	-0.77	0.00
x1	1.00	1.02	0.56	0.11	1.47	0.00
x8	0.00	0.04	0.09	0.02	0.23	0.00
x10	0.00	-0.35	0.41	0.08	1.07	0.00
x6	0.00	0.12	-0.15	0.00	-1.00	1.00
x7	0.00	0.16	0.09	-0.20	-0.77	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 9)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	0.00	-211528.33	0.00	19300.18	-19833.21
x14	0.00	0.00	-0.08	0.00	0.10	0.02
x1	0.00	0.00	-0.49	0.00	0.62	0.11
x8	0.00	1.00	0.92	0.00	-0.04	0.02
x10	0.00	0.00	-0.36	1.00	-0.82	0.08
x6	0.00	0.00	0.00	0.00	0.14	-0.23
x7	1.00	0.00	0.92	0.00	0.10	0.02
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 9)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	96703.67	0.00	0.00	blocked	blocked	blocked
x14	0.95	1.00	1.00	0.08	-0.84	-0.13
x1	-0.33	0.00	0.00	0.49	0.98	5.42
x8	-0.05	0.00	0.00	0.08	-0.84	-0.13
x10	-0.24	0.00	0.00	0.36	0.71	-5.15
x6	0.00	0.00	0.00	0.00	0.00	0.00
x7	0.62	0.00	0.00	0.08	-0.84	-0.13
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 2 (Iter 9)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	0.00	0.00	blocked	blocked	blocked	blocked	blocked	blocked	146178.68
x14	1.00	1.00	0.08	-0.84	-0.13	-0.84	-0.92	-1.00	0.08
x1	0.00	0.00	0.49	0.98	5.42	0.98	0.49	0.00	0.49
x8	0.00	0.00	0.08	-0.84	-0.13	0.16	0.08	0.00	0.08
x10	0.00	0.00	0.36	0.71	-5.15	0.71	0.36	0.00	0.36
x6	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00
x7	0.00	0.00	0.08	-0.84	-0.13	-0.84	-0.92	0.00	0.08
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 2 (Iter 10)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	0.00	0.00	198959.99	-131888.80	680089.49	-938783.48
x14	0.00	0.00	0.29	0.03	0.60	-1.36
x1	1.00	0.00	1.84	0.11	9.98	-8.51
x8	0.00	0.00	0.14	0.02	0.60	-0.36
x10	0.00	0.00	-0.03	0.08	-1.84	2.90
x2	0.00	1.00	-1.25	0.00	-8.33	8.33
x7	0.00	0.00	0.29	-0.20	0.60	-1.36
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 10)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	0.00	-211528.33	0.00	-112129.50	196087.00
x14	0.00	0.00	-0.08	0.00	-0.09	0.33
x1	0.00	0.00	-0.49	0.00	-0.57	2.07
x8	0.00	1.00	0.92	0.00	-0.09	0.10
x10	0.00	0.00	-0.36	1.00	-0.41	-0.59
x2	0.00	0.00	0.00	0.00	1.17	-1.92
x7	1.00	0.00	0.92	0.00	-0.09	0.33
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 10)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	96703.67	0.00	0.00	blocked	blocked	blocked
x14	0.95	1.00	1.00	0.08	-0.84	-0.13
x1	-0.33	0.00	0.00	0.49	0.98	5.42
x8	-0.05	0.00	0.00	0.08	-0.84	-0.13
x10	-0.24	0.00	0.00	0.36	0.71	-5.15
x2	0.00	0.00	0.00	0.00	0.00	0.00
x7	0.62	0.00	0.00	0.08	-0.84	-0.13
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 2 (Iter 10)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	0.00	0.00	blocked	blocked	blocked	blocked	blocked	blocked	146178.68
x14	1.00	1.00	0.08	-0.84	-0.13	0.52	-0.92	-1.00	0.08
x1	0.00	0.00	0.49	0.98	5.42	0.49	0.49	0.00	0.49
x8	0.00	0.00	0.08	-0.84	-0.13	0.52	0.08	0.00	0.08
x10	0.00	0.00	0.36	0.71	-5.15	-2.19	0.36	0.00	0.36
x2	0.00	0.00	0.00	0.00	0.00	-8.33	0.00	0.00	0.00
x7	0.00	0.00	0.08	-0.84	-0.13	0.52	-0.92	0.00	0.08
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 2 (Iter 11)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	-68170.39	0.00	73637.86	-139214.40	0.00	-358588.44
x14	-0.06	0.00	0.18	0.02	0.00	-0.85
x5	0.10	0.00	0.18	0.01	1.00	-0.85
x8	-0.06	0.00	0.03	0.01	0.00	0.15
x10	0.18	0.00	0.31	0.10	0.00	1.34
x2	0.84	1.00	0.29	0.09	0.00	1.22
x7	-0.06	0.00	0.18	-0.21	0.00	-0.85
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 11)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	0.00	-178230.18	0.00	-73281.66	54983.56
x14	0.00	0.00	-0.05	0.00	-0.06	0.21
x5	0.00	0.00	-0.05	0.00	-0.06	0.21
x8	0.00	1.00	0.95	0.00	-0.06	-0.02
x10	0.00	0.00	-0.45	1.00	-0.52	-0.20
x2	0.00	0.00	-0.41	0.00	0.69	-0.19
x7	1.00	0.00	0.95	0.00	-0.06	0.21
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 11)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	119013.43	0.00	0.00	blocked	blocked	blocked
x14	0.97	1.00	1.00	0.05	-0.90	-0.46
x5	-0.03	0.00	0.00	0.05	0.10	0.54
x8	-0.03	0.00	0.00	0.05	-0.90	-0.46
x10	-0.30	0.00	0.00	0.45	0.89	-4.15
x2	-0.27	0.00	0.00	0.41	0.82	4.53
x7	0.64	0.00	0.00	0.05	-0.90	-0.46
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 2 (Iter 11)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	0.00	0.00	blocked	blocked	blocked	blocked	blocked	blocked	112880.53
x14	1.00	1.00	0.05	-0.90	-0.46	-0.05	-0.95	-1.00	0.05
x5	0.00	0.00	0.05	0.10	0.54	0.95	0.05	0.00	0.05
x8	0.00	0.00	0.05	-0.90	-0.46	-0.05	0.05	0.00	0.05
x10	0.00	0.00	0.45	0.89	-4.15	-0.45	0.45	0.00	0.45
x2	0.00	0.00	0.41	0.82	4.53	-0.41	0.41	0.00	0.41
x7	0.00	0.00	0.05	-0.90	-0.46	-0.05	-0.95	0.00	0.05
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 2 (Iter 12)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	-60816.61	0.00	50963.07	-141770.33	0.00	-253612.57
x13	-0.06	0.00	0.19	0.02	0.00	-0.88
x5	0.10	0.00	0.19	0.01	1.00	-0.88
x8	-0.06	0.00	0.04	0.01	0.00	0.12
x10	0.17	0.00	0.37	0.10	0.00	1.07
x2	0.82	1.00	0.34	0.10	0.00	0.98
x7	-0.02	0.00	0.06	-0.22	0.00	-0.29
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 12)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	0.00	-172205.48	0.00	-66252.84	29453.43
x13	0.00	0.00	-0.05	0.00	-0.06	0.21
x5	0.00	0.00	-0.05	0.00	-0.06	0.21
x8	0.00	1.00	0.95	0.00	-0.06	-0.02
x10	0.00	0.00	-0.46	1.00	-0.54	-0.14
x2	0.00	0.00	-0.42	0.00	0.67	-0.13
x7	1.00	0.00	0.98	0.00	-0.02	0.07
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 12)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	0.00	-123049.98	-123049.98	blocked	blocked	blocked
x13	1.00	1.03	1.03	0.05	-0.33	-0.47
x5	0.00	0.03	0.03	0.05	0.07	0.53
x8	0.00	0.03	0.03	0.05	-0.93	-0.47
x10	0.00	0.31	0.31	0.46	0.61	-4.30
x2	0.00	0.28	0.28	0.42	0.56	4.40
x7	0.00	-0.66	-0.66	0.02	-0.31	-0.16
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 2 (Iter 12)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	-123049.98	-123049.98	blocked	blocked	blocked	blocked	blocked	blocked	106855.83
x13	1.03	1.03	0.05	-0.33	-0.47	-0.05	-0.30	-1.03	0.05
x5	0.03	0.03	0.05	0.07	0.53	0.95	0.02	-0.03	0.05
x8	0.03	0.03	0.05	-0.93	-0.47	-0.05	0.02	-0.03	0.05
x10	0.31	0.31	0.46	0.61	-4.30	-0.46	0.15	-0.31	0.46
x2	0.28	0.28	0.42	0.56	4.40	-0.42	0.14	-0.28	0.42
x7	-0.66	-0.66	0.02	-0.31	-0.16	-0.02	-0.32	0.66	0.02
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 2 (Iter 13)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	-44288.49	0.00	0.00	-147514.96	0.00	-17672.43
x3	-0.32	0.00	1.00	0.11	0.00	-4.63
x5	0.16	0.00	0.00	-0.01	1.00	0.00
x8	-0.05	0.00	0.00	0.01	0.00	0.31
x10	0.29	0.00	0.00	0.06	0.00	2.78
x2	0.93	1.00	0.00	0.06	0.00	2.55
x7	0.00	0.00	0.00	-0.23	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 13)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	0.00	0.00	-158664.57	0.00	-50455.11	-27927.21
x3	0.00	0.00	-0.27	0.00	-0.31	1.13
x5	0.00	0.00	0.00	0.00	0.00	0.00
x8	0.00	1.00	0.96	0.00	-0.05	-0.06
x10	0.00	0.00	-0.36	1.00	-0.42	-0.56
x2	0.00	0.00	-0.33	0.00	0.78	-0.51
x7	1.00	0.00	1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 2 (Iter 13)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	-267490.46	-399612.85	-399612.85	blocked	blocked	blocked
x3	5.25	5.43	5.43	0.27	-4.90	-2.48
x5	-1.00	-1.00	-1.00	0.00	1.00	1.00
x8	-0.21	-0.19	-0.19	0.04	-0.73	-0.37
x10	-1.93	-1.69	-1.69	0.36	2.42	-3.38
x2	-1.77	-1.55	-1.55	0.33	2.21	5.23
x7	-0.33	-1.00	-1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 2 (Iter 13)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	-399612.85	-399612.85	blocked	blocked	blocked	blocked	blocked	blocked	93314.92
x3	5.43	5.43	0.27	-4.90	-2.48	-0.27	-5.16	-5.43	0.27
x5	-1.00	-1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
x8	-0.19	-0.19	0.04	-0.73	-0.37	-0.04	0.23	0.19	0.04
x10	-1.69	-1.69	0.36	2.42	-3.38	-0.36	2.05	1.69	0.36
x2	-1.55	-1.55	0.33	2.21	5.23	-0.33	1.88	1.55	0.33
x7	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Phase 0 (Iter 14)	y12	y22	y32	y42	y33	y43
Basic	x1	x2	x3	x4	x5	x6
z (min)	-44288.49	0.00	0.00	-184007.81	0.00	-17672.43
x3	-0.32	0.00	1.00	0.05	0.00	-4.63
x5	0.16	0.00	0.00	-0.01	1.00	0.00
x8	-0.05	0.00	0.00	0.23	0.00	0.31
x10	0.29	0.00	0.00	-0.02	0.00	2.78
x2	0.93	1.00	0.00	-0.02	0.00	2.55
x9	0.00	0.00	0.00	-0.23	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 0 (Iter 14)	y53	y44	y54	y11	y21	y31
Basic	x7	x8	x9	x10	x11	x12
z (min)	158664.57	0.00	0.00	0.00	-50455.11	-27927.21
x3	0.27	0.00	0.00	0.00	-0.31	1.13
x5	0.00	0.00	0.00	0.00	0.00	0.00
x8	-0.96	1.00	0.00	0.00	-0.05	-0.06
x10	0.36	0.00	0.00	1.00	-0.42	-0.56
x2	0.33	0.00	0.00	0.00	0.78	-0.51
x9	1.00	0.00	1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00	0.00	0.00	0.00
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity
Unrestr'd (y/n)?	n	n	n	n	n	n

Phase 0 (Iter 14)	y41	y51	y52			
Basic	x13	x14	x15	Rx16	Rx17	Rx18
z (min)	-319849.77	-558277.42	-558277.42	93214.92	-1127818.51	-279501.07
x3	5.16	5.16	5.16	0.27	-4.90	-2.48
x5	-1.00	-1.00	-1.00	0.00	1.00	1.00
x8	0.10	0.77	0.77	0.04	-0.73	-0.37
x10	-2.05	-2.05	-2.05	0.36	2.42	-3.38
x2	-1.88	-1.88	-1.88	0.33	2.21	5.23
x9	-0.33	-1.00	-1.00	0.00	0.00	0.00
Lower Bound	0.00	0.00	0.00			
Upper Bound	infinity	infinity	infinity			
Unrestr'd (y/n)?	n	n	n			

Phase 0 (Iter 14)	y51	y52							
Basic	x14	x15	Rx16	Rx17	Rx18	Rx19	Rx20	Rx21	Solution
z (min)	-558277.42	-558277.42	93214.92	-1127818.51	-279501.07	80892.59	202315.25	558177.42	93314.92
x3	5.16	5.16	0.27	-4.90	-2.48	-0.27	-5.16	-5.16	0.27
x5	-1.00	-1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
x8	0.77	0.77	0.04	-0.73	-0.37	-0.04	0.23	-0.77	0.04
x10	-2.05	-2.05	0.36	2.42	-3.38	-0.36	2.05	2.05	0.36
x2	-1.88	-1.88	0.33	2.21	5.23	-0.33	1.88	1.88	0.33
x9	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Lower Bound	0.00	0.00							
Upper Bound	infinity	infinity							
Unrestr'd (y/n)?	n	n							

Figure 5.9: Iterations of the linear programming optimal solution

As shown in Figure 5.9 above, the last iteration result of the linear programming simplex tabulation calculated using TORA software, the optimal result is described below

Table 5.13: Linear programming optimal solution

Variable of objective function	TORA basic Variable	Description
Y_{11}	X_{10}	Do – Nothing at State 1
Y_{22}	X_2	Preventive Maintenance at state 2
$Y_{32}, Y_{33},$	X_3, X_5	Preventive Maintenance and Repairing Defects at State 3 Respectively
Y_{44}, Y_{54}	X_8, X_9	Replace Failed Components at State 4 and 5

The subscript number in the variable of the objective function ‘ Y_{32} ’, for instance, the number 3 stands for the condition state and 2 stands for decision alternative. Where 3 corresponds to ‘moderate’ condition and 2 represents ‘Preventive Maintenance’.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

This research had three main objectives, which were believed to guide the Ethiopian Authority for Research and Conservation of Cultural heritage (EARCCH) and the Addis Ababa City Administration Culture and Tourism bureau on how to prioritize historical buildings for maintenance under limited budget. Preparation of maintenance inspection checklist is important to evaluate and understand the prevalent condition of historic buildings. It also helps to better estimate the deterioration trends for building components from condition inspection data recorded over a long period of time.

As part of the study, maintenance conditions of eight selected historical buildings were identified after thorough inspection and evaluation. Then a Maintenance optimization model using Markov decision process was developed for Menelik II Preparatory School. The School was part of the originally selected historical buildings for inspection. After the inspection, a suitable maintenance scheme was selected by formulating four alternative maintenance decisions with estimated costs. The process also used building component deterioration probabilities generated using Monte Carlo simulation tool..

The result of the condition inspection of the selected historical buildings of public institutions was presented in the previous section. The outcome of the linear programming cost optimization for Markov decision process for Menelik II School was also discussed. In this chapter, the conclusions derived from the research findings and recommendations are presented.

6.1. Conclusions

1. The result of the evaluation of condition inspection data for Most of the selected Historical buildings of public institutions under the study of this research were found to lie between moderate and poor conditions for building services. The failure of gutters, downpipes, and Lack of proper drainage systems are Common problems for all the inspected historical buildings. The condition of structural components for three historical buildings, namely, Menelik II School, Tafari Mekonnen School and Merha Tibeb Printing press is poor, Even though the

aggregate maintenance condition is for each ranks between good and moderate. Buildings of bête saida hospital and La Gare scored relatively good maintenance condition. Table 6.1 presents component and aggregate maintenance conditions for the selected buildings.

Table 6.1: Summary of maintenance conditions for selected historical buildings

S/n	Historical Buildings	Interior	Exterior	structure	service	Aggregate condition
1	Menelik II Preparatory School	Moderate	Poor	Poor	Poor	Moderate
2	Bete Saida Hospital	Good	Good	Moderate	Moderate	Good
3	Etege Menen School	Moderate	moderate	Good	Moderate	Moderate
4	Tafari Mekonnen School	Moderate	Moderate	Poor	Moderate	Moderate
5	Menelik II Hospital	Moderate	Moderate	Moderate	Poor	Moderate
6	Taitu Hotel	Good	Moderate	Moderate	Moderate	Moderate
7	Merha Tibebe Printing Press	Moderate	Moderate	Poor	Poor	Moderate
8	La Gare	Excellent	Good	Good	Moderate	Good

- Based on the prescribed maintenance specifications for alternative decisions and their cost estimates, as well as the calibrated transition probability matrices presented in previous sessions, a Markov decision process was formulated and linear programming tool was used to find the optimal maintenance decision for Menelik II School. The best possible decision alternative for Menelik II School is described in table 6.2 below.

Table 6.2: Optimal decision policies for Menelik II School

State	Maintenance Condition	Optimal Decision
1	Excellent	Do -Nothing
2	Good	Preventive Maintenance
3	Moderate	Preventive Maintenance and Repairing defects
4	Poor	Replacing Failed Components
5	Failed	Replacing Failed Components

For the condition of Menenlik II School, the Markov decision process suggested to perform activities specified under ‘preventive maintenance’ for the interior components and implement work items presented under ‘replacing failed elements’ for the exterior, structure and building service components.

6.2. Recommendations

1. Attention should be given to follow up and maintain historical buildings of public institutions before sever deterioration and gradual failure. Concerned bodies, especially, Addis Ababa city administration culture and tourism bureau in collaboration with EARCCH should work diligently to preserve such historical buildings.
2. Skilled and trained employees should be assigned to record inspections, at least once a year, in order to accurately evaluate and document maintenance conditions of historical buildings.
3. Maintenance specification should be prescribed and prepared by team of experts favorably composed of Engineers, architects and historians. Maintenance of historic structures requires multi-disciplinary knowledge. Maintenance procedures are vital to protect character defining elements of historic buildings from destruction and loss of cultural value.
4. Designers and maintenance contractors should be provided opportunities as well as responsibilities to submit alternative design an methodologies to maintain historical structures during procurement process.
5. Decision makers and stakeholders should encourage modern and quantitative techniques for making decisions as literature review of experiences of developed countries encourages. These countries have achieved much better outcomes by utilizing such quantitative techniques and tools.

6.3. Directions for further research

- ◆ To make cost based decisions, defined frameworks for varies methodologies along with productivity rates should be set to better estimate cost and reduces subjectivity during estimating unit rates of maintenance task. Therefore, recording productivity rates is a good objective for future researchers in Ethiopia.
- ◆ Development of Maintenance decision model based on neural network

CHAPTER 7

REFERENCES

- 1) Addis Ababa Urban Heritage Data Base. (2017). AAUHDB, Addis Ababa
- 2) Al-Khatam, J. A. (2003). Building Maintenance Cost, Master of Engineering Report.
- 3) Al-Shiha, M. (1993). The Effect of Faulty Design and Construction on Building Maintenance, Master Thesis. Dhahran, Saudi Arabia.
- 4) Amanuel, W. (2007). Urban Heritage Management Challenges and Opportunities (In The Case Of Aksum) . Addis Ababa.
- 5) Bjarnason, J. H. (2013). Building Maintenance-and Energy Efficiency Renovation, Thesis Dissertation.
- 6) British Standard (3811:19740. (1986). Guide to Building Maintenance Management. London.
- 7) Bv Mak Kai Wah, M. D. (2006). Manangement and Maintenance of Buildings. Hong Kong.
- 8) Cambridge International Dictionary of English. (1995). Press Syndicate of the University of Cambridge.
- 9) Central Public Works Department Maintenance Manual, India. (2000).
- 10) Chin-Man, 8 L. (2002). Retrieved from Www.Info.Gov.Hk/Bd/,2002/26/06/2017.
- 11) Cobra, C. B. (2010). The Development of a Condition Survey Protocol Matrix. Cobra.
- 12) Department for Culture, M. &. (2010). Principles of Selection for Listing Buildings. London: Conservation of Historic Buildings and Monuments.
- 13) Duling, J. M. (2006). Towards The Development Of Transition Probability Matrices In The Markovian Model for The Predicted Service Life of Buildings. Phd Thesis.
- 14) Ferran, M. (2009, Sep/Oct). Comparative Analysis of Life-Cycle Costing for Rehabilitating Infrastructure Systems. Performance of Constructed Facilities.
- 15) Grimmer, A. E. (1984). A Glossary of Historic Masonry Deterioration Problems And Preservation Treatments (Vol. Ii). Washington D.C., Usa: Us Government Printing Office.
- 16) Hearn, M.F. (1990). *The Architectural Theory of Viollet-le-Duc*, Massachusetts Institute of Technology
- 17) Heritage Buildings Manual. Canada. (N.D.). Historic Resources Branch. Retrieved From Www.Manitoba.Ca/Heritage/2/06/2017.

- 18) Hiller And Lieberman, F. S. (2001). Introduction to Operations Research (7th Ed.). Mcgraw-Hill.
- 19) Hovde, P. J. (2004). Performance Based Methods for Service Life Prediction. State of The Art Reports, Cib Report.
- 20) [Http://Whc.Unesco.Org/En/Guidelines.24/06/2017](http://Whc.Unesco.Org/En/Guidelines.24/06/2017).
- 21) Ikwan, M. H. (1996). Maintenance Management In Saudi Arabia. Eng. Science, 4, 67-80.
- 22) Ireland Maintenance Publication. (2007). Maintenance Guide to The Care of Older Buildings. Dublin: Watermans Printers.
- 23) Ireland, G. O. (2007). A Guide to The Repair of, Historic Windows. Stationery Office.
- 24) Jiang, Y. (1989). Bridge Service Life Prediction Model Using The Markov Chain.
- 25) Kalman, H. (1980). The Evaluation of Historic Buildings. Ottawa, Canada.
- 26) Kelly, A. (1989). Maintenance and Its Management. Monks Hill, England.
- 27) Khodeir, L. M. (2009). Towards an Efficient Maintenance Management for Public Buildings In Egypt.
- 28) Legislative Auditor, S. O. (2000). Preventive Maintenance for Local Government Buildings, Best Practive Review.
- 29) Mohseni, H. (2012). Deterioration Prediction of Community Buildings In Australia, Phd Thesis.
- 30) Morcous. (2002). Modeling Bridge Deterioration Using Case-Based Reasoning. Journal Of Infrastructure Systems, 8,86-95.
- 31) Nams. (2009). International Infrastructure Management Manual. Version 4.0, 2011 (4th Ed.). New Zealand: New Zealand National Asset Managementsteering Group(Nams).
- 32) National Trust Partners Network, The Repair Retrofit and Replacement of Historic Windows. (2016). Retrieved From Preservation Pennsylvania: Www.Preservationpa.Org/26/06/2017.
- 33) Neely, E. (1976, June). Life Cycle Maintenance Costs By Facility Use. Journal of Construvtion Engineering And Management, 117 No.2.
- 34) Oracle, Crystal Ball(Computer Software),2013
- 35) Oxford Dictionary. 11th Edition.
- 36) Preservation Alliance Of West Virginia. (2012). Historic Building Assessment Checklist. Retrieved From [Http://Www.Nps.Gov/Hps/Tps/Briefs/Brief37.Htm./26/04/2017](http://Www.Nps.Gov/Hps/Tps/Briefs/Brief37.Htm./26/04/2017).

- 37) Prince Jude Cobbinah, B. (2010). Maintenance of Buildings of Public Institutions In Ghana. Case Study of Selected Institutions In The Ashanti Region Of Ghana. Ghana.
- 38) Queensland Public Works, D. O. (2012). Building Maintenance Policy, Standards and Strategy Development.
- 39) Research, M.-E. J. (2013). Building Maintenance Management Preliminary Findings of Case Study In Icym. Middle-East Journal of Scientific Research 17(9).
- 40) Ross, S. M. (2010). Introduction To Probability Models. California: Elsevier Inc.
- 41) Runger, D. C. (2003). Applied Statistics And Probability For Engineers. Arizona State University: John Wiley & Sons, Inc.
- 42) Ruskin, J. (1989). The Seven Lamps Of Architecture. New York: Dover Publications.
- 43) Seeley, H. (1976). Building Maintenance. London: Macmillan Press Ltd.
- 44) Selam, T. (2011). The Status of Historic Buildings In Addis Ababa And Their Contribution To The Urban Development. Addis Ababa.
- 45) Shear, M. (1983). Building Maintenance Management. Virginia: Reston Publishing Co.
- 46) Soong, T. (2004). Fundamentals of Probability And Statistics For Engineers. New York: John Wiley And Sons, Ltd.
- 47) Surveyors, H. K. (2009). General Specification for Building Maintenance Works In Residential Buildings (1st Ed.). Hong Kong Institute Of Surveyors.
- 48) Taha, H. A. (2007). Operations Research : An Introduction. (E. Edition, Ed.) New Jersey: Pearson Education, Inc.
- 49) Taha, H. A. .TORA (Computer Software),2002,New Jersey, Prentice Hall, Inc
- 50) U.K. Department For Culture, M. &. (2010). Conservation of Historic Buildings and Monuments.
- 51) U.S. Secretary of The Interior's Standard's For Rehabilitation. (1997). Illustrated Guidelines For Rehabilitating Historic Buildings. In W. B. Grimmer. Washington D.C.
- 52) UNESCO. Retrieved From [Http://Whc.Unesco.Org/En/Guidelines/24/06/2017](http://Whc.Unesco.Org/En/Guidelines/24/06/2017)
- 53) USA National Materials Advisory Board, U. (1982). Conservation of Historic Stone Buildings and Monuments. Washington D.C.: National Academy Pres S.
- 54) Winston, W. L. (2004). Operations Research Applications and Algorithms. Canada: Thomson Brooks.

APPENDICES

1) Appendix A

This appendix contains the condition inspection data collected for seven historical buildings. Pictures of defects, detailed condition assessment ratings and priority categories for elements of the remaining buildings, which are not included in the main body part, are presented under appendix A. The amount or quantity of the deteriorated components are also quantified so that future researchers can refer the data to predict deteriorations.

HISTORIC BUILDING NAME: <u>TAFARI MEKONNEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18,2016</u>						
CURRENT NAME: <u>ENTOTO POLY TECHNIQUE COLLEGE</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>GULELE SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Interior	Internal Wall		1	Stains or damp spots on Walls		x	m ²			4			
			2	Paint Peeling or cracked		x	m ²			2			
			3	Plaster on walls cracked		x	m ²			3			
			4	Signs of structural movement such as cracking		x	Lm			5			
			5	Signs of fungal or insect attack in timber walls		x	m ²			4			
	Floor			1	Rise and Fall on timber floors	x		m ²	84.2	4	4	26.67	1
				2	Wear and tear on Floors and floor finishes	x		m ²	54.6	3	3	12.86	2
				3	Unclean floors		x	m ²			2		
				4	Defect on joints	x		Lm	56.5	3	3	12.86	3
				5	Damage to floor surfaces	x		m ²	112.4	3	1	4.29	4

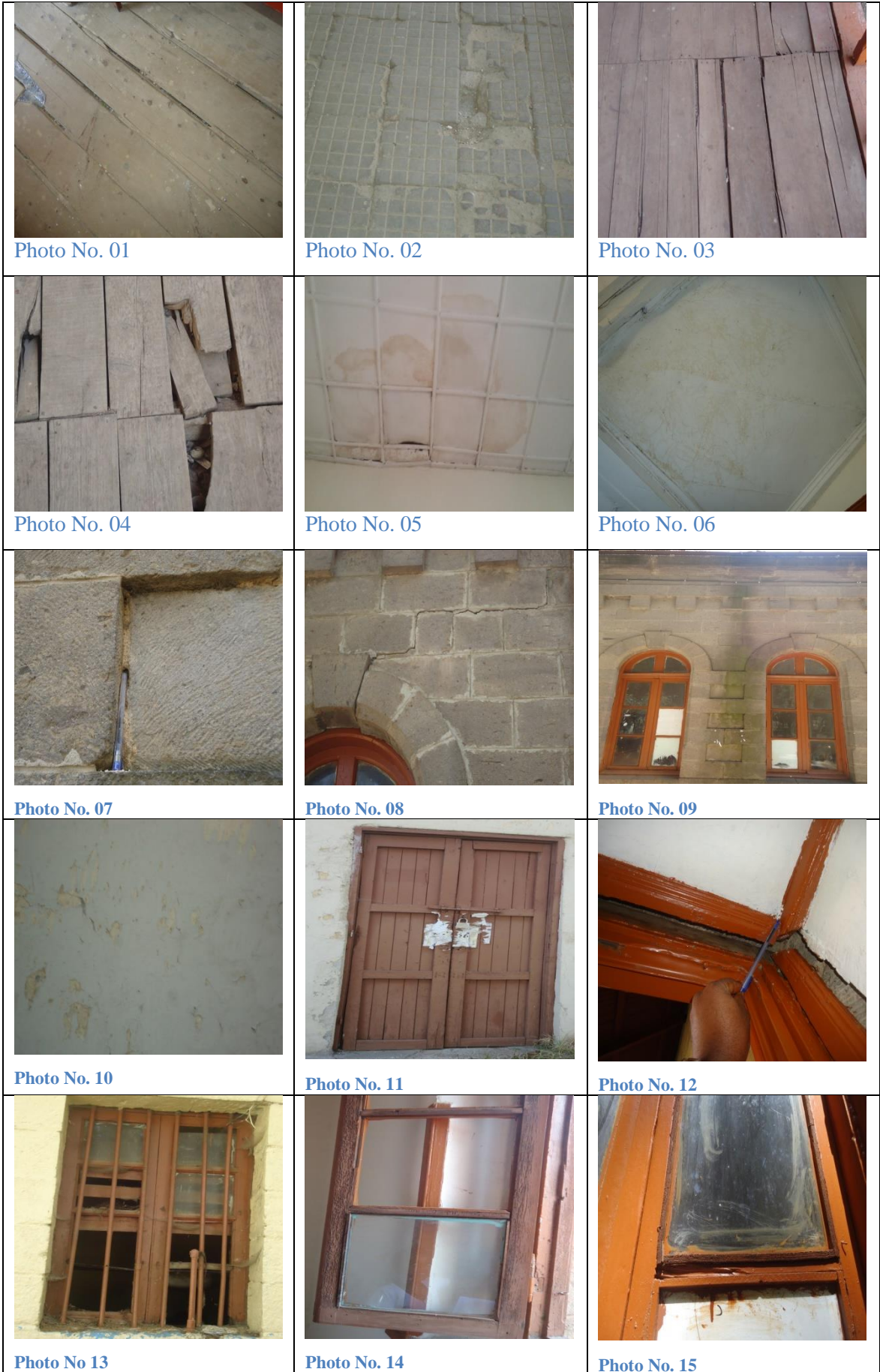
HISTORIC BUILDING NAME: <u>TAFARI MEKONNEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18,2016</u>					
CURRENT NAME: <u>ENTOTO POLY TECHNIQUE COLLEGE</u>							WEATHER: <u>SUNNY</u>					
OWNER NAME: <u>GOVERNMENT</u> ADDRESS: <u>GULELE SUB-CITY</u>							INSPECTED BY(NAME & ADDRESS): _____					
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Interior	Ceiling		1	Sagging in ceilings		x	m ²			3		
			2	Cracked plaster on ceiling		x	m ²			3		
			3	Paint Peeling		x	m ²			2		
			4	Signs of water leakage on Ceilings	x		m ²	13.9	3	5	21.43	5
			5	Hairline cracks in ceilings	x		m ²	29.1	2	1	2.50	6
Building Exterior	External Wall		1	Evidence of mortar pointing deterioration in masonry walls	x		Lm	16.8	3	4	17.14	7
			2	Cracks in walls		x	Lm			5		
			3	Signs of decay or deterioration in stone walls	x		m ²	46.8	2	4	10.00	8
			4	Unclean walls	x		m ²	28.86	3	3	12.86	9
			5	Cracked paint and loose plaster with hairline cracks	x		m ²	136.5	3	2	8.57	10

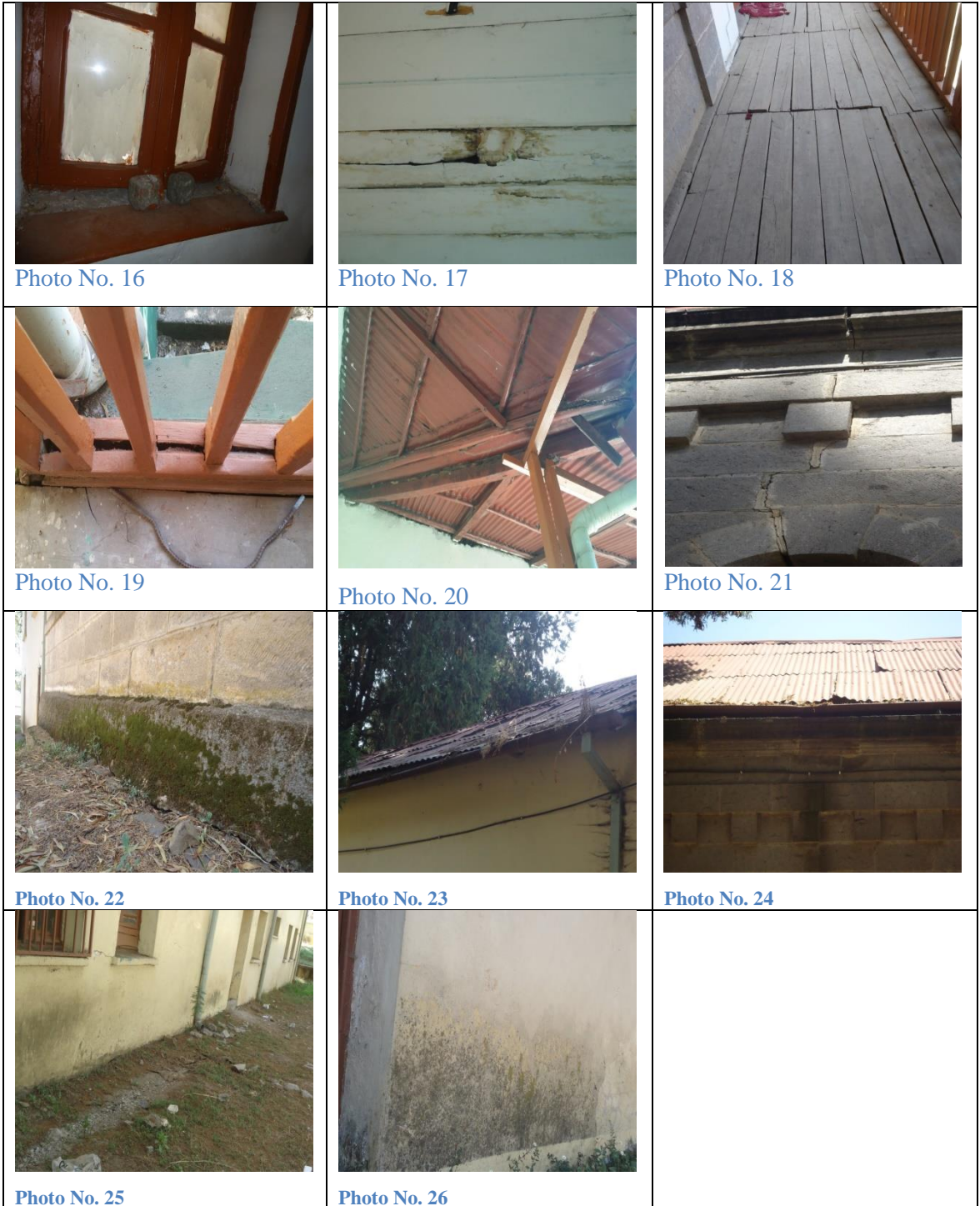
HISTORIC BUILDING NAME: <u>TAFARI MEKONNEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18,2016</u>						
CURRENT NAME: <u>ENTOTO POLY TECHNIQUE COLLEGE</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>GULELE SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Doors		1	Paint or protective coating damaged.	x		Pcs	8	2	3	7.5	11	
			2	Decaying exterior seal, or corrosion on steel/wood frames	x		Pcs	3	2	5	12.5	12	
			3	Loose or damaged seals	x		Pcs	6	3	4	17.14	13	
			4	Signs of decay on Door frames		x	Pcs			4			
			5	Sticking or jamming doors		x	Pcs			3			
		Windows		1	Paint or protective coating damaged, blistered.	x		Pcs	26	3	3	12.86	14
			2	Decaying exterior sill, or window frame		x	Pcs			4			
			3	Loose or damaged seals.\	x		Pcs	31	4	3	20	15	
			4	Signs of decay on Window Frames		x	Pcs			5			
			5	Sticking or jamming windows	x		Pcs	11	4	3	20	16	
		Roof		1	Severe wear, or rusting on roof		x	m ²			5		
			2	Corrosion on the underside of metal sheeted roofs		x	No			5			
			3	Joint problems leading to leakage on metal sheets	x		No	7	4	4	26.67	17	
			4	Evidence of decay in the rafter	x		No	17	3	4	17.14		
			5	Loose, missing or broken roofing materials		x	m ²			4			

HISTORIC BUILDING NAME: <u>TAFARI MEKONNEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18,2016</u>						
CURRENT NAME: <u>ENTOTO POLY TECHNIQUE COLLEGE</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>GULELE SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Balcony		1	Loose or deteriorated components		x	Ls	-		4			
			2	Cracked paint		x	m ²			2			
			3	Railings decayed or rusting and deteriorated	x		Ls	-		5		18	
			4	Plaster on walls loose or cracked		x	m ²			3			
			5	Dust and accumulation of Debris	x		m ²	26.8	2	3	7.5	19	
	Stair			1	Visible cracks on steps		x	Lm			4		
				2	Damage to staircase		x	m ²			5		
				3	Railings rotting or rusting leading to deterioration		x	Lm			4		
				4	Paint cracked		x	m ²			2		
				5	Plaster on walls loose or cracked		x	m ²			3		

HISTORIC BUILDING NAME: <u>TAFARI MEKONNEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18,2016</u>					
CURRENT NAME: <u>ENTOTO POLY TECHNIQUE COLLEGE</u>							WEATHER: <u>SUNNY</u>					
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>GULELE SUB-CITY</u>				INSPECTED BY (NAME & ADDRESS): _____					
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Structure	Roof structural Element		1	Deflections in the overall profile of the roof		x	Lm			4		
			2	Sagging ridge of the roof		x	Lm			4		
			3	Decaying on elements of truss system		x	m ²			5		
			4	Fascia boards and soffits loose, unsecured to structure		x	Lm			3		
			5	Sagging purlins		x	m ²			5		
	Structural Wall		1	Major cracks in stone masonry	x		Lm	0.04	3	5	21.43	21
			2	Stone masonry units missing, loose or deteriorating		x	m ²			4		
			3	Water stained walls, or mold grown on the wall surface	x		m ²	43.5	3	4	17.14	22
			4	Wood elements that are not firmly attached and painted		x	m ²			4		
			5	Signs of decay on structural wall		x	m ²			4		

HISTORIC BUILDING NAME: <u>TAFARI MEKONNEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18,2016</u>						
CURRENT NAME: <u>ENTOTO POLY TECHNIQUE COLLEGE</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>GULELE SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Services	Gutters and Down Pipes		1	Loose, or missing gutters or Down Pipes		x	No			5			
			2	Gutters and Down Pipes that are blocked with leaves and debris	x		No	5	2	4	10.00	23	
			3	Joints in Down Pipes not secured from leaks		x	Pcs	2	2	5	12.50		
			4	Sagging gutters or gutters sloping the wrong way	x		Lm	17	3	5	21.43	24	
			5	Outlets from Down Pipes have not extensions to ditch		x	Pcs	23	3	3	12.86		
	Drainage			1	Rainwater ponds around the base of the buildings	x		Ls			4		25
				2	Rainwater gullies not draining properly		x	Pcs			3		
				3	Rising dampness visible	x		m ²	26.5	2	3	7.50	26
				4	Manholes blocked with sedimentation and debris		x	Pcs			3		
				5	Wet stains, or efflorescence on exterior surfaces	x		m ²	33.2	2	3	7.50	22
Summation					27	38				380.83			





HISTORIC BUILDING NAME: <u>ETEGE HOTEL BUILDING</u>							DATE OF INSPECTION: <u>SEP 20, 2016</u>						
CURRENT NAME: <u>TAITU HOTEL BUILDING</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS):____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No			{a}	{b}	c=δ*a*b		
Building Interior	Internal Wall		1	Stains or damp spots on Walls		x	m ²			4			
			2	Paint Peeling or cracked	x		m ²		4	2	5.71	1	
			3	Plaster on walls cracked	x		m ²		4	3	9.23	2	
			4	Signs of structural movement such as cracking		x	Lm			5			
			5	Signs of fungal or insect attack in timber walls		x	m ²			4			
	Floor			1	Rise and Fall on timber floors	x		m ²		4	4	13.33	3
				2	Wear and tear on floor finishes	x		m ²		4	3	9.23	4
				3	Unclean floors	x		m ²		4	2	5.17	5
				4	Defect on joints	x		Lm		3	3	6.43	6
				5	Damage to floor surfaces		x	m ²			1		
	Ceiling			1	Sagging in ceilings		x	m ²			3		
				2	Cracked plaster on ceiling		x	m ²			3		
				3	Paint Peeling	x		m ²		4	2	5.71	7
				4	Signs of water leakage on Ceilings	x		m ²		3	5	12.5	8
				5	Hairline cracks in ceilings	x		m ²		3	1	1.88	9

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE HOTEL BUILDING</u>							DATE OF INSPECTION: <u>SEP 20, 2016</u>						
CURRENT NAME: <u>TAITU HOTEL BUILDING</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY (NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	External Wall		1	Evidence of mortar pointing deterioration in masonry walls		x	Lm			4			
			2	Cracks in walls		x	Lm			5			
			3	Signs of decay or deterioration in stone walls		x	m ²			4			
			4	Unclean walls	x		m ²		4	3	9.23	10	
			5	Cracked paint and loose plaster with hairline cracks	x		m ²		4	2	5.71	11	
	Doors			1	Paint or protective coating damaged.	x		Pcs		4	3	9.23	12
				2	Decaying exterior seal, or corrosion on steel/wood frames	x		Pcs		4	5	18.18	13
				3	Loose or damaged seals		x	Pcs			4		
				4	Signs of decay on Door frames		x	Pcs			4		
				5	Sticking or jamming doors		x	Pcs			3		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE HOTEL BUILDING</u>							DATE OF INSPECTION: <u>SEP 20, 2016</u>						
CURRENT NAME: <u>TAITU HOTEL BUILDING</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Windows		1	Paint or protective coating damaged, blistered.		x	Pcs			3			
			2	Decaying exterior sill, or window frame	x		Pcs		3	4	9.23	14	
			3	Loose or damaged seals	x		Pcs		4	3	9.23	15	
			4	Signs of decay on Window Frames		x	Pcs			5			
			5	Sticking or jamming windows		x	Pcs			3			
	Roof			1	Severe wear, or rusting on roof		x	m ²			5		
				2	Corrosion on the underside of metal sheeted roofs		x	No			5		
				3	Joint problems leading to leakage on metal sheets		x	No			4		
				4	Evidence of decay in the rafter		x	No			4		
				5	Loose, missing or broken roofing materials		x	m ²			4		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE HOTEL BUILDING</u>							DATE OF INSPECTION: <u>SEP 20, 2016</u>						
CURRENT NAME: <u>TAITU HOTEL BUILDING</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>ARADA SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS):_____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Balcony		1	Loose or deteriorated components	x		Ls		5	4	18.18		
			2	Cracked paint	x		m ²		4	2	5.71		
			3	Railings decayed or rusting and deteriorated	x		Ls		4	5	18.18		
			4	Plaster on walls loose or cracked		x	m ²			3			
			5	Dust and accumulation of Debris		x	m ²			3			
	External Stair			1	Visible cracks on steps		x	Lm			4		
				2	Damage to staircase		x	m ²			5		
				3	Railings rotting or rusting leading to deterioration		x	Lm			4		
				4	Paint cracked		x	m ²			2		
				5	Plaster on walls loose or cracked		x	m ²			3		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE HOTEL BUILDING</u>							DATE OF INSPECTION: <u>SEP 20, 2016</u>						
CURRENT NAME: <u>TAITU HOTEL BUILDING</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Structure	Roof structural Element		1	Deflections in the overall profile of the roof		x	Lm			4			
			2	Sagging ridge of the roof		x	Lm			4			
			3	Decaying on elements of truss system	x		m ²		4	5	18.18		
			4	Fascia boards and soffits loose, unsecured to structure	x		Lm		4	3	9.23		
			5	Sagging purlins		x	m ²			5			
	Structural Wall			1	Major cracks in stone masonry		x	Lm			5		
				2	Stone masonry units missing, loose or deteriorating		x	m ²			4		
				3	Water stained walls, or mold grown on the wall surface	x		m ²		4	4	13.33	
				4	Wood elements that are not firmly attached and painted	x		m ²		3	4	9.23	
				5	Signs of decay on structural wall		x	m ²			4		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE HOTEL BUILDING</u>							DATE OF INSPECTION: <u>SEP 20, 2016</u>						
CURRENT NAME: <u>TAITU HOTEL BUILDING</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY (NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Services	Gutters and Down Pipes		1	Loose, or missing gutters or Down Pipes		x	Lm			5			
			2	Gutters and Down Pipes that are blocked with leaves and debris	x		Lm		3	4	9.23		
			3	Joints in Down Pipes not secured from leaks	x		Pcs		4	5	18.18		
			4	Sagging gutters or gutters sloping the wrong way	x		Lm		3	5	12.5		
			5	Outlets from Down Pipes have not extensions to ditch	x		Pcs		4	3	9.23		
	Drainage			1	Rainwater ponds around the base of the buildings		x	Ls			4		
				2	Rainwater gullies not draining properly		x	Pcs			3		
				3	Rising dampness visible		x	m ²		3	3	6.43	
				4	Manholes blocked with sedimentation and debris		x	Pcs			3		
				5	Wet stains, or efflorescence on exterior surfaces		x	m ²		4	3	9.23	
Summation					18		47			237			



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HISTORIC BUILDING NAME: <u>ETEGE MENEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>OCT 10, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 PREPARATORY SCHOOL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>GULELE SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Interior	Internal Wall		1	Stains or damp spots on Walls	x		m ²	16.2	4	4	13.33	1	
			2	Paint Peeling or cracked	x		m ²	35.4	2	2	2.5	2	
			3	Plaster on walls cracked		x	m ²			3			
			4	Signs of structural movement such as cracking		x	Lm			5			
			5	Signs of fungal or insect attack in timber walls		x	m ²			4			
	Floor			1	Rise and Fall on timber floors		x	m ²			4		
				2	Wear and tear on Floors and floor finishes	x		m ²	281.75	3	3	6.43	3
				3	Unclean floors	x		m ²	46.5	2	2	2.5	4
				4	Defect on joints	x		Lm	68.4	1	3	1.87	5
				5	Damage to floor surfaces		x	m ²			1		
	Ceiling			1	Sagging in ceilings		x	m ²			3		
				2	Cracked plaster on ceiling		x	m ²			3		
				3	Paint Peeling		x	m ²			2		
				4	Signs of water leakage on Ceilings	x		m ²	13.5	5	5	25	6
				5	Hairline cracks in ceilings		x	m ²			1		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE MENEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>OCT 10, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 PREPARATORY SCHOOL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>GULELE SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	External Wall		1	Evidence of mortar pointing deterioration in masonry walls	x		Lm	23.6	3	4	9.23	7	
			2	Cracks in walls		x	Lm			5			
			3	Signs of decay or deterioration in stone walls	x		m ²	41.2	2	4	5.71	8	
			4	Unclean walls	x		m ²	121.3	3	3	6.43	9	
			5	Cracked paint and loose plaster with hairline cracks	x		m ²	473	3	2	4	10	
	Doors			1	Paint or protective coating damaged.	x		Pcs	18	3	3	6.43	11
				2	Decaying exterior seal, or corrosion on steel/wood frames	x		Pcs	9	4	5	18.18	12
				3	Loose or damaged seals		x	Pcs			4		
				4	Signs of decay on Door frames		x	Pcs			4		
				5	Sticking or jamming doors		x	Pcs			3		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE MENEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>OCT 10, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 PREPARATORY SCHOOL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>GULELE SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS):_____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Windows		1	Paint or protective coating damaged, blistered.	x		Pcs	47	3	3	6.43	13	
			2	Decaying exterior sill, or window frame	x		Pcs	36	4	4	13.33	14	
			3	Loose or damaged seals		x	Pcs			3			
			4	Signs of decay on Window Frames	x		Pcs	55	4	5	18.18	15	
			5	Sticking or jamming windows		x	Pcs			3			
	Roof			1	Severe wear, or rusting on roof		x	m ²			5		
				2	Corrosion on the underside of metal sheeted roofs		x	No			5		
				3	Joint problems leading to leakage on metal sheets	x		No	8	5	4	18.18	16
				4	Evidence of decay in the rafter		x	No			4		
				5	Loose, missing or broken roofing materials		x	m ²			4		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

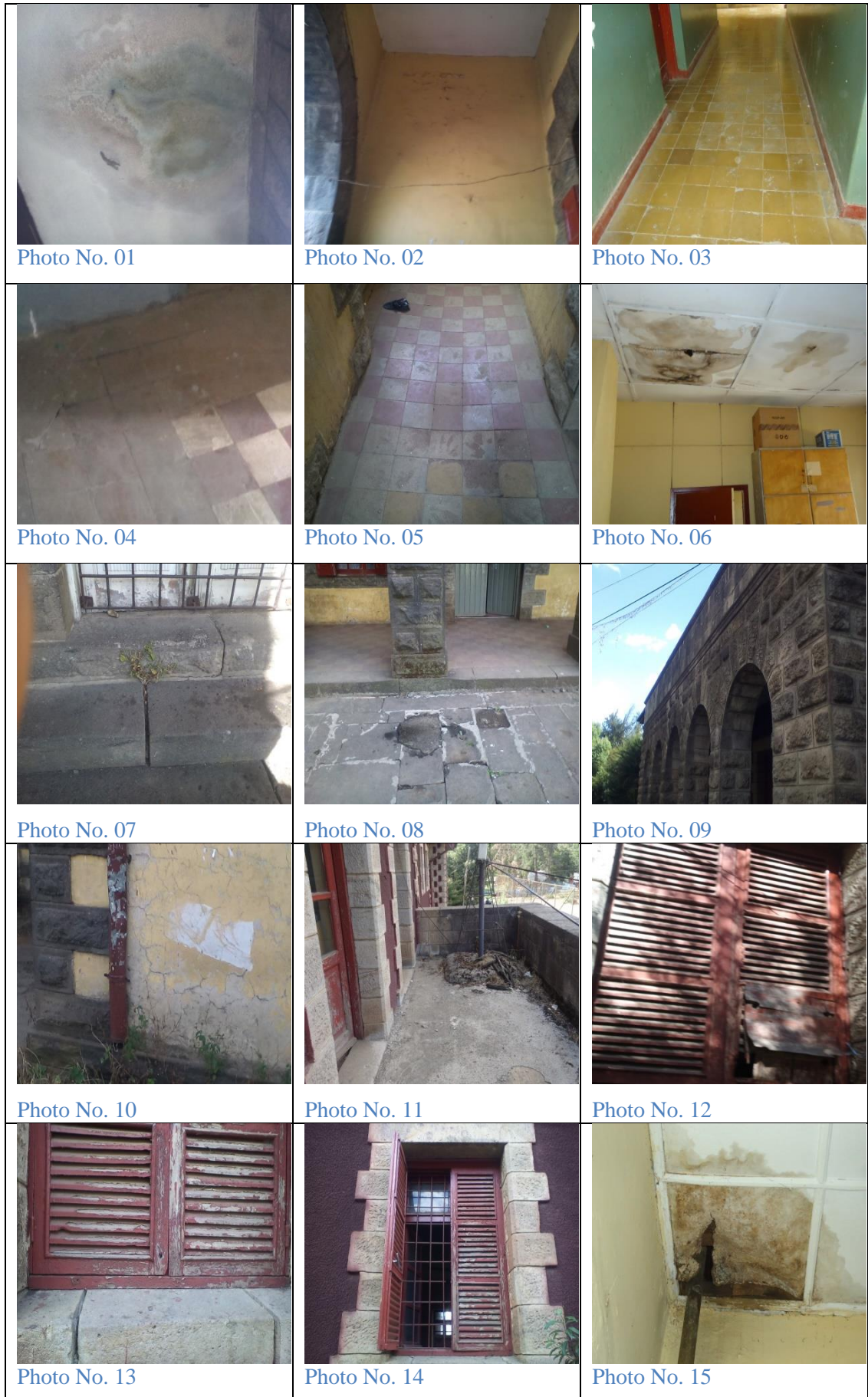
HISTORIC BUILDING NAME: <u>ETEGE MENEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>OCT 10, 2016</u>							
CURRENT NAME: <u>YEKATIT 12 PREPARATORY SCHOOL</u>							WEATHER: <u>SUNNY</u>							
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>GULELE SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS): _____							
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.		
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=$\delta$*a*b
Building Exterior	Balcony		1	Loose or deteriorated components	x		Ls	-	5	4		17		
			2	Cracked paint		x	m ²			2				
			3	Railings decayed or rusting and deteriorated		x	Ls				5			
			4	Plaster on walls loose or cracked	x		m ²	63.4	4	3	9.23	18		
			5	Dust and accumulation of Debris		x	m ²				3			
	External Stair			1	Visible cracks on steps		x	Lm			4			
				2	Damage to staircase		x	m ²			5			
				3	Railings rotting or rusting leading to deterioration		x	Lm				4		
				4	Paint cracked		x	m ²				2		
				5	Plaster on walls loose or cracked		x	m ²				3		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE MENEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>OCT 10, 2016</u>							
CURRENT NAME: <u>YEKATIT 12 PREPARATORY SCHOOL</u>							WEATHER: <u>SUNNY</u>							
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>GULELE SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS):_____							
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.		
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Structure	Roof structural Element		1	Deflections in the overall profile of the roof	x		Lm		3	4	9.23			
			2	Sagging ridge of the roof		x	Lm			4				
			3	Decaying on elements of truss system	x		m ²		3	5	12.5			
			4	Fascia boards and soffits loose, unsecured to structure		x	Lm			3				
			5	Sagging purlins		x	m ²			5				
	Structural Wall			1	Major cracks in stone masonry		x	Lm			5			
				2	Stone masonry units missing, loose or deteriorating	x		m ²		2	4	5.71		
				3	Water stained walls, or mold grown on the wall surface	x		m ²		3	4	9.23		
				4	Wood elements that are not firmly attached and painted		x	m ²			4			
				5	Signs of decay on structural wall	x		m ²		2	4	5.71		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>ETEGE MENEN SCHOOL BUILDING</u>							DATE OF INSPECTION: <u>OCT 10, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 PREPARATORY SCHOOL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>GULELE SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Services	Gutters and Down Pipes		1	Loose, or missing gutters or Down Pipes	x		No	9	4	5	18.18	19	
			2	Gutters and Down Pipes that are blocked with leaves and debris			No		5	4			
			3	Joints in Down Pipes not secured from leaks	x		Pcs	8	4	5	18.18	20	
			4	Sagging gutters or gutters sloping the wrong way		x	Lm			5			
			5	Outlets from Down Pipes have not extensions to ditch	x		Pcs	38	5	3	12.5	21	
	Drainage			1	Rainwater ponds around the base of the buildings	x		Ls	-	4	4		22
				2	Rainwater gullies not draining properly		x	Pcs			3		
				3	Rising dampness visible	x		m ²	45.9	4	3	9.23	23
				4	Manholes blocked with sedimentation and debris		x	Pcs			3		
				5	Wet stains, or efflorescence on exterior surfaces	x		m ²	21.6	3	3	6.43	24
Summation					26	39					273.89		





HISTORIC BUILDING NAME: <u>MERHA TIBEB PRINTING PRESS BUILDING</u>							DATE OF INSPECTION: <u>MARCH 14, 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Interior	Internal Wall		1	Stains or damp spots on Walls	x		m ²	25	4	4	13.33	1	
			2	Paint Peeling or cracked	x		m ²	72	5	2	7.69	2	
			3	Plaster on walls cracked	x		m ²	20.4	4	3	9.23	3	
			4	Signs of structural movement such as cracking		x	Lm			5			
			5	Signs of fungal or insect attack in timber walls		x	m ²			4			
	Floor			1	Rise and Fall on timber floors	x		m ²	73	4	4	13.33	4
				2	Wear and tear on Floors and floor finishes	x		m ²	608	5	3	12.5	5
				3	Unclean floors		x	m ²			2		
				4	Defect on joints		x	Lm			3		
				5	Damage to floor surfaces	x		m ²	40.2	4	1	2.67	6
	Ceiling			1	Sagging in ceilings		x	m ²			3		
				2	Cracked plaster on ceiling		x	m ²			3		
				3	Paint Peeling	x		m ²	120.4	4	2	5.71	7
				4	Signs of water leakage on Ceilings	x		m ²	24.48	5	5	25	8
				5	Hairline cracks in ceilings		x	m ²			1		

HISTORIC BUILDING NAME: <u>MERHA TIBEB PRINTING PRESS BUILDING</u>							DATE OF INSPECTION: <u>MARCH 14, 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY (NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	External Wall		1	Evidence of mortar pointing deterioration in masonry walls	x		Lm	18.8	4	4	13.33	9	
			2	Cracks in walls		x	Lm			5		10	
			3	Signs of decay or deterioration in stone walls		x	m ²			4			
			4	Unclean walls	x		m ²	13.5	4	3	9.23	11	
			5	Cracked paint and loose plaster with hairline cracks	x		m ²	44.2	3	2	4	12	
	Doors			1	Paint or protective coating damaged.	x		Pcs	8	4	3	9.23	13
				2	Decaying exterior seal, or corrosion on steel/wood frames	x		Pcs	10	3	5	12.5	14
				3	Loose or damaged seals		x	Pcs			4		
				4	Signs of decay on Door frames	x		Pcs	11	4	4	13.33	15
				5	Sticking or jamming doors		x	Pcs			3		

HISTORIC BUILDING NAME: <u>MERHA TIBEB PRINTING PRESS BUILDING</u>							DATE OF INSPECTION: <u>MARCH 14, 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S /n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Windows		1	Paint or protective coating damaged, blistered.	x		Pcs	32	5	3	12.5	16	
			2	Decaying exterior sill, or window frame	x		Pcs	26	5	4	18.18	17	
			3	Loose or damaged seals		x	Pcs			3			
			4	Signs of decay on Window Frames	x		Pcs	32	5	5	25	18	
			5	Sticking or jamming windows		x	Pcs			3			
	Roof			1	Severe wear, or rusting on roof		x	m ²			5		
				2	Corrosion on the underside of metal sheeted roofs	x		No	1	3	5	12.5	19
				3	Joint problems leading to leakage on metal sheets	x		No	4	3	4	9.23	20
				4	Evidence of decay in the rafter		x	No			4		
				5	Loose, missing or broken roofing materials		x	m ²			4		

HISTORIC BUILDING NAME: <u>MERHA TIBEB PRINTING PRESS BUILDING</u>							DATE OF INSPECTION: <u>MARCH 14, 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>ARADA SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Balcony		1	Loose or deteriorated components		x	Ls			4			
			2	Cracked paint		x	m ²			2			
			3	Railings decayed or rusting and deteriorated		x	Ls			5			
			4	Plaster on walls loose or cracked		x	m ²			3			
			5	Dust and accumulation of Debris		x	m ²			3			
	External Stair			1	Visible cracks on steps	x		Lm	14.8	5	4	18.18	21
				2	Damage to staircase	x		Ls	-	3	5	12.5	22
				3	Railings rotting or rusting leading to deterioration		x	Lm			4		
				4	Paint cracked	x		m ²	17.2	4	2	5.71	23
				5	Plaster on walls loose or cracked		x	m ²			3		

HISTORIC BUILDING NAME: <u>MERHA TIBEB PRINTING PRESS BUILDING</u>							DATE OF INSPECTION: <u>MARCH 14, 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>ARADA SUB-CITY</u>				INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Structure	Roof structural Element		1	Deflections in the overall profile of the roof		x	Lm			4			
			2	Sagging ridge of the roof		x	Lm			4			
			3	Decaying on elements of truss system		x	m ²			5			
			4	Fascia boards and soffits loose, unsecured to structure		x	Lm			3			
			5	sagging purlins		x	m ²			5			
	Structural Wall			1	Major cracks in stone masonry	x		Lm	0.012	4	5	18.18	24
				2	Stone masonry units missing, loose or deteriorating		x	m ²			4		
				3	Water stained walls, or mold grown on the wall surface	x		m ²	20.8	4	4	13.33	25
				4	Wood elements that are not firmly attached and painted		x	m ²			4		
				5	Signs of decay on structural wall		x	m ²			4		

Historic Building Name: <u>MERHA TIBEB PRINTING PRESS BUILDING</u>							Date of Inspection: <u>MARCH 14, 2017</u>						
Current Name: _____							Weather: <u>SUNNY</u>						
Owner Name: <u>GOVERNMENT</u>			Address: <u>ARADA SUB-CITY</u>				Inspected by (Name & Address): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Services	Gutters and Down Pipes		1	Loose, or missing gutters or Down Pipes	x		No	16	4	5	18.18	26	
			2	Gutters and Down Pipes that are blocked with leaves and debris	x		Lm	11	4	4	13.33	27	
			3	Joints in Down Pipes not secured from leaks	x		Pcs	3	4	5	18.81	28	
			4	Sagging gutters or gutters sloping the wrong way	x		Lm	5	5	5	25	29	
			5	Outlets from Down Pipes have not extensions to ditch		x	Pcs			3			
	Drainage			1	Rainwater ponds around the base of the buildings	x		Ls	-	4	4	13.33	30
				2	Rainwater gullies not draining properly		x	Pcs			3		
				3	Rising dampness visible	x		m ²	16.4	4	3	9.23	31
				4	Manholes blocked with sedimentation and debris		x	Pcs			3		
				5	Wet stains, or efflorescence on exterior surfaces		X	m ²			3		
Summation					29	36					400.3		





HISTORIC BUILDING NAME: <u>BETE SAIDA HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 HOSPITAL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Interior	Internal Wall		1	Stains or damp spots on Walls	x		m ²	56	2	4	5.71	1	
			2	Paint Peeling or cracked		x	m ²			2			
			3	Plaster on walls cracked		x	m ²				3		
			4	Signs of structural movement such as cracking		x	Lm					5	
			5	Signs of fungal or insect attack in timber walls		x	m ²					4	
	Floor			1	Rise and Fall on timber floors	x		m ²	17.5	2	4	5.71	2
				2	Wear and tear on Floors and floor finishes	x		m ²	63.2	3	3	6.43	3
				3	Unclean floors		x	m ²				2	
				4	Defect on joints	x		Lm	21	2	3	4	4
				5	Damage to floor surfaces		x	m ²				1	
	Ceiling			1	Sagging in ceilings		x	m ²			3		
				2	Cracked plaster on ceiling		x	m ²			3		
				3	Paint Peeling	x		m ²	75	2	2	2.5	5
				4	Signs of water leakage on Ceilings	x		m ²	8.8	1	5	3.57	6
				5	Hairline cracks in ceilings		x	m ²				1	

HISTORIC BUILDING NAME: <u>BETE SAIDA HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 HOSPITAL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No			{a}	{b}	c=a*b		
Building Exterior	External Walls		1	Evidence of mortar pointing deterioration in masonry walls	x		Lm	7.2	3	4	9.23	7	
			2	Cracks in walls		x	Lm			5			
			3	Signs of decay or deterioration in stone walls		x	m ²			4		8	
			4	Unclean walls	x		m ²	12	2	3	4	9	
			5	Cracked paint and loose plaster with hairline cracks		x	m ²			2			
	Doors			1	Paint or protective coating damaged.	x		Pcs	6	3	3	6.43	10
				2	Decaying exterior seal, or corrosion on steel/wood frames		x	Pcs			5		
				3	Loose or damaged seals		x	Pcs			4		
				4	Signs of decay on Door frames		x	Pcs			4		
				5	Sticking or jamming doors		x	Pcs			3		

HISTORIC BUILDING NAME: <u>BETE SAIDA HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 HOSPITAL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Windows		1	Paint or protective coating damaged, blistered.		x	Pcs			3			
			2	Decaying exterior sill, or window frame		x	Pcs			4			
			3	Loose or damaged seals		x	Pcs			3			
			4	Signs of decay on Window Frames		x	Pcs			5			
			5	Sticking or jamming windows		x	Pcs			3			
	Roof			1	Severe wear, or rusting on roof		x	m ²			5		
				2	Corrosion on the underside of metal sheeted roofs		x	No			5		
				3	Joint problems leading to leakage on metal sheets	x		No	4	3	4	9.23	11
				4	Evidence of decay in the rafter		x	No			4		
				5	Loose, missing or broken roofing materials		x	m ²			4		

HISTORIC BUILDING NAME: <u>BETE SAIDA HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 HOSPITAL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Balcony		1	Loose or deteriorated components	x		Ls	-	3	4	12	12	
			2	Cracked paint		x	m ²			2			
			3	Railings decayed or rusting and deteriorated	x		Ls	-	3	5		13	
			4	Plaster on walls loose or cracked		x	m ²			3			
			5	Dust and accumulation of Debris		x	m ²			3			
	External Stair			1	Visible cracks on steps	x		Lm	24	3	4	9.23	14
				2	Damage to staircase		x	m ²			5		
				3	Railings rotting or rusting leading to deterioration	x		Lm	14.8	3	4	9.23	15
				4	Paint cracked		x	m ²			2		
				5	Plaster on walls loose or cracked		x	m ²			3		

HISTORIC BUILDING NAME: <u>BETE SAIDA HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 HOSPITAL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY (NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Structure	Roof structural Element		1	Deflections in the overall profile of the roof		x	Lm			4			
			2	Sagging ridge of the roof		x	Lm			4			
			3	Decaying on elements of truss system		x	m ²			5			
			4	Fascia boards and soffits loose, unsecured to structure		x	Lm			3			
			5	sagging purlins		x	m ²			5			
	Structural Wall			1	Major cracks in stone masonry	x		Lm	0.003	3	5	12.5	16
				2	Stone masonry units missing, loose or deteriorating		x	m ²			4		17
				3	Water stained walls, or mold grown on the wall surface	x		m ²	11.4	3	4	9.23	18
				4	Wood elements that are not firmly attached and painted		x	m ²			4		19
				5	Signs of decay on structural wall		x	m ²			4		20

HISTORIC BUILDING NAME: <u>BETE SAIDA HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>NOV 18, 2016</u>						
CURRENT NAME: <u>YEKATIT 12 HOSPITAL</u>							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>ARADA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No		{a}	{b}	c=δ*a*b			
Building Services	Gutters and Down Pipes		1	Loose, or missing gutters or Down Pipes		x	Lm			5			
			2	Gutters and Down Pipes that are blocked with leaves and debris	x		No	15	2	4	5.71	22	
			3	Joints in Down Pipes not secured from leaks	x		Pcs	4	3	5	12.5	23	
			4	Sagging gutters or gutters sloping the wrong way		x	Lm			5			
			5	Outlets from Down Pipes have not extensions to ditch	x		Pcs	24	2	3	4	24	
	Drainage			1	Rainwater ponds around the base of the buildings	x		Ls	-	4	4		25
				2	Rainwater gullies not draining properly	x		Pcs	4	5	4	18.18	26
				3	Rising dampness visible		x	m ²			3		
				4	Manholes blocked with sedimentation and debris	x		Pcs	1	5	3	12.5	27
				5	Wet stains, or efflorescence on exterior surfaces		x	m ²			3		
Summation					21	44				155.45			

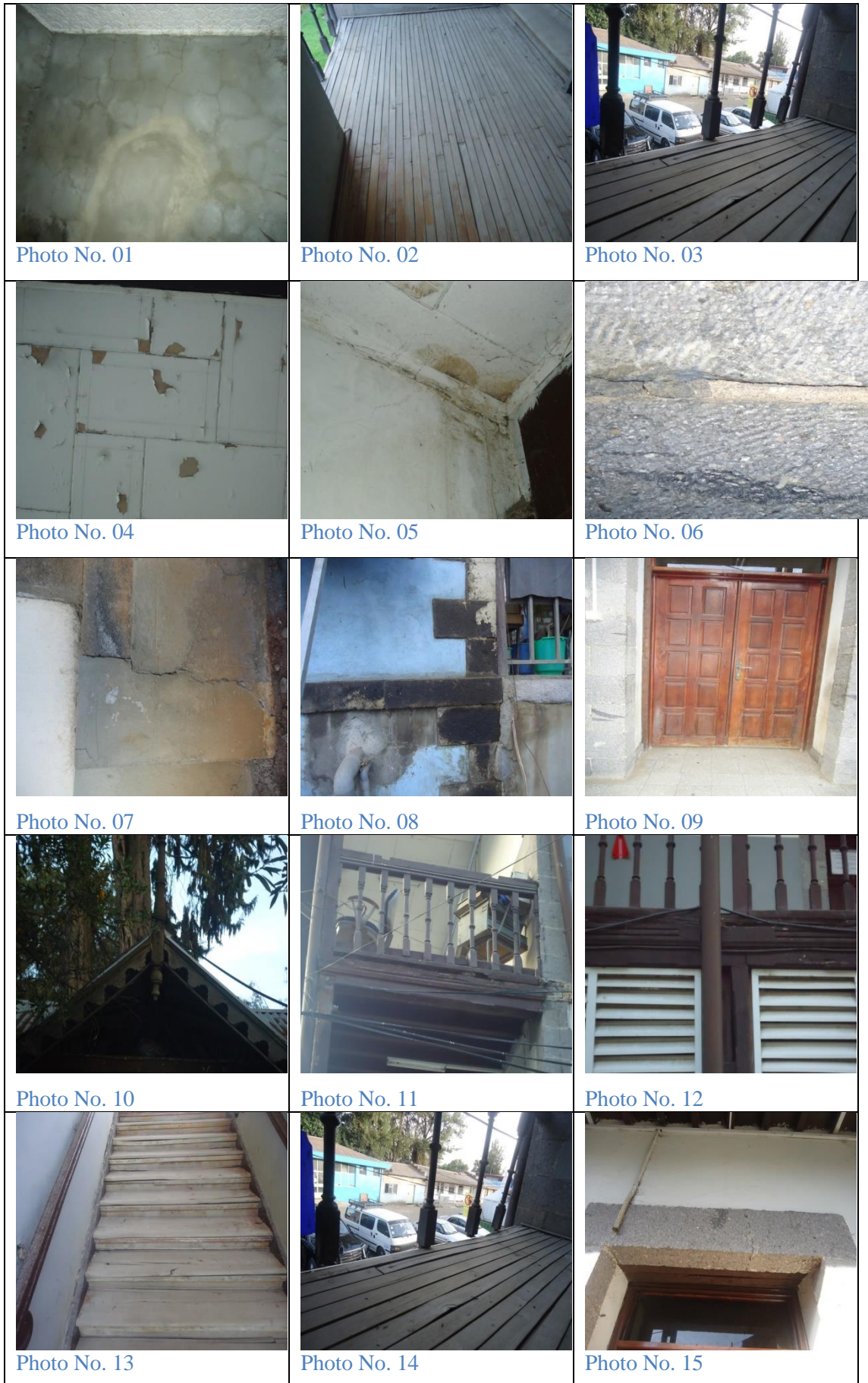




Photo No. 16



Photo No. 17



Photo No. 18



Photo No. 19

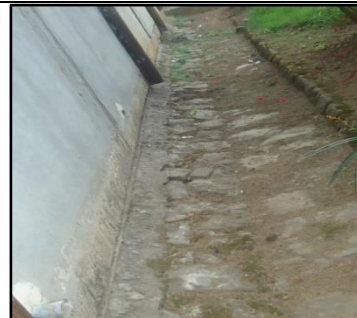


Photo No. 20

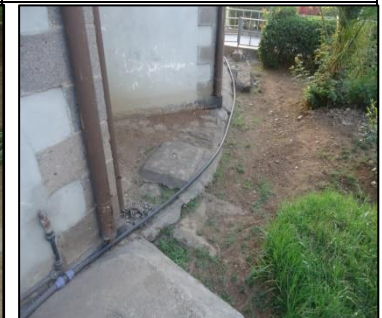


Photo No. 21



Photo No. 22

HISTORIC BUILDING NAME: <u>MENELIK II HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>FEB 20 , 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>YEKA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S / n	Description	Yes	No			{a}	{b}	c=δ*a*b		
Building Interior	Internal Wall		1	Stains or damp spots on Walls		x	m ²			4			
			2	Paint Peeling or cracked	x		m ²	63.4	4	2	5.71	1	
			3	Plaster on walls cracked		x	m ²			3			
			4	Signs of structural movement such as cracking		x	Lm			5			
			5	Signs of fungal or insect attack in timber walls		x	m ²			4			
	Floor			1	Rise and Fall on timber floors		x	m ²			4		
				2	Wear and tear on Floors and floor finishes	x		m ²	59.6	5	3	12.5	2
				3	Unclean floors		x	m ²			2		
				4	Defect on joints		x	Lm			3		
				5	Damage to floor surfaces		x	m ²			1		
	Ceiling			1	Sagging in ceilings		x	m ²			3		
				2	Cracked plaster on ceiling		x	m ²			3		
				3	Paint Peeling	x		m ²	28.6	5	2	7.69	3
				4	Signs of water leakage on Ceilings	x		m ²	9.5	5	5	25	4
				5	Hairline cracks in ceilings		x	m ²			1		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

Historic Building Name: <u>MENELIK II HOSPITAL BUILDING</u>							Date of Inspection: <u>FEB 20 , 2017</u>						
Current Name: _____							Weather: <u>SUNNY</u>						
Owner Name: <u>GOVERNMENT</u>				Address: <u>YEKA SUB-CITY</u>			Inspected by (Name & Address): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	External Walls		1	Evidence of mortar pointing deterioration in masonry walls		x	Lm			4			
			2	Cracks in walls	x		Lm	0.015	4	5	18.18	5	
			3	Signs of decay or deterioration in stone walls	x		m ²	39	5	4	18.18	6	
			4	Unclean walls	x		m ²	51.4	4	3	9.23	7	
			5	Cracked paint and loose plaster with hairline cracks	x		m ²	256	2	2	2.5	8	
	Doors			1	Paint or protective coating damaged.	x		Pcs	44	5	3	12.5	9
				2	Decaying exterior seal, or corrosion on steel/wood frames		x	Pcs			5		
				3	Loose or damaged seals		x	Pcs			4		
				4	Signs of decay on Door frames	x		Pcs	38	5	4	18.18	10
				5	Sticking or jamming doors	x		Pcs	4	5	3	12.5	11

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>MENELIK II HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>FEB 20 , 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>YEKA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S / n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Windows		1	Paint or protective coating damaged, blistered.	x		Pcs	76	5	3	12.5	12	
			2	Decaying exterior sill, or window frame	x		Pcs	65	5	4	18.18	13	
			3	Loose or damaged seals		x	Pcs			3			
			4	Signs of decay on Window Frames	x		Pcs	51	5	5	25	14	
			5	Sticking or jamming windows		x	Pcs			3			
	Roof			1	Severe wear, or rusting on roof	x		m ²	52.3	3	5	12.5	15
				2	Corrosion on the underside of metal sheeted roofs		x	No			5		
				3	Joint problems leading to leakage on metal sheets	x		No	7	4	4	13.33	16
				4	Evidence of decay in the rafter	x		No	3	2	4	5.71	17
				5	Loose, missing or broken roofing materials		x	m ²			4		

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

Building Component							Checklist Description					Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No
Component	Sub-component	Material type	S/n	Description	Yes	No	{a}	{b}	c=δ*a*b								
HISTORIC BUILDING NAME: <u>MENELIK II HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>FEB 20 , 2017</u>										
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>										
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>YEKA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS):_____										
Building Exterior	Balcony		1	Loose or deteriorated components		x	Ls	-		4							
			2	Cracked paint		x	m ²			2							
			3	Railings decayed or rusting and deteriorated		x	Ls	-		5							
			4	Plaster on walls loose or cracked		x	m ²			3							
			5	Dust and accumulation of Debris		x	m ²			3							
	External Stair			1	Visible cracks on steps	x		Lm	31.5	2	4	5.71	18				
				2	Damage to staircase	x		m ²	39	3	5	12.5	19				
				3	Railings rotting or rusting leading to deterioration		x	Lm			4						
				4	Paint cracked		x	m ²			2						
				5	Plaster on walls loose or cracked		x	m ²			3						

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>MENELIK II HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>FEB 20 , 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>YEKA SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	$c=\delta*a*b$
Building Structure	Roof structural Element		1	Deflections in the overall profile of the roof	x		Lm	18	4	4	13.33	20	
			2	Sagging ridge of the roof		x	Lm			4			
			3	Decaying on elements of truss system		x	m ²			5			
			4	Fascia boards and soffits loose, unsecured to structure	x		Lm		3	3	6.43	21	
			5	sagging purlins		x	m ²			5			
		Foundation and Structural Wall		1	Major cracks in stone masonry	x		Lm	0.018	4	5	18.18	22
			2	Stone masonry units missing, loose or deteriorating		x	m ²			4			
			3	Water stained walls, or mold grown on the wall surface	x		m ²	21	4	4	13.33	23	
			4	Wood elements that are not firmly attached and painted		x	m ²			4			
			5	Signs of decay on structural wall	x		m ²	26.9	3	4	9.23	24	

Maintenance Prioritization Guideline for Historical Buildings of Public Institutions in Addis Ababa

HISTORIC BUILDING NAME: <u>MENELIK II HOSPITAL BUILDING</u>							DATE OF INSPECTION: <u>FEB 20 , 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>			ADDRESS: <u>YEKA SUB-CITY</u>				INSPECTED BY (NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Services	Gutters and Down Pipes		1	Loose, or missing gutters or Down Pipes		x	Lm			5			
			2	Gutters and Down Pipes that are blocked with leaves and debris	x		Lm	43	5	4	18.18	25	
			3	Joints in Down Pipes not secured from leaks	x		Pcs	5	5	5	25	26	
			4	Sagging gutters or gutters sloping the wrong way	x		Lm	18	4	5	18.18	27	
			5	Outlets from Down Pipes have not extensions to ditch	x		Pcs	15	5	3	12.5	28	
	Drainage			1	Rainwater ponds around the base of the buildings		x	Ls	-		4		
				2	Rainwater gullies not draining properly		x	Pcs			3		
				3	Rising dampness visible	x		m ²	45.6	4	3	9.23	29
				4	Manholes blocked with sedimentation and debris		x	Pcs			3		
				5	Wet stains, or efflorescence on exterior surfaces		x	m ²			3		
Summation					29	36				391.23			





HISTORIC BUILDING NAME: <u>LA GARE BUILDING</u>							DATE OF INSPECTION: <u>MAR 30 , 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>KIRKOS SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S / n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Interior	Internal Wall		1	Stains or damp spots on Walls		x	m ²			4			
			2	Paint Peeling or cracked	x		m ²	21.2	3	2	4	1	
			3	Plaster on walls cracked		x	m ²			3			
			4	Signs of structural movement such as cracking		x	Lm			5			
			5	Signs of fungal or insect attack in timber walls		x	m ²			4			
	Floor			1	Rise and Fall on timber floors		x	m ²			4		
				2	Wear and tear on Floors and floor finishes	x		m ²	13.02	3	3	6.43	2
				3	Unclean floors	x		m ²	31.6	2	2	2.5	3
				4	Defect on joints		x	Lm			3		
				5	Damage to floor surfaces		x	m ²			1		
	Ceiling			1	Sagging in ceilings		x	m ²			3		
				2	Cracked plaster on ceiling		x	m ²			3		
				3	Paint Peeling		x	m ²			2		
				4	Signs of water leakage on Ceilings		x	m ²			5		
				5	Hairline cracks in ceilings		x	m ²			1		

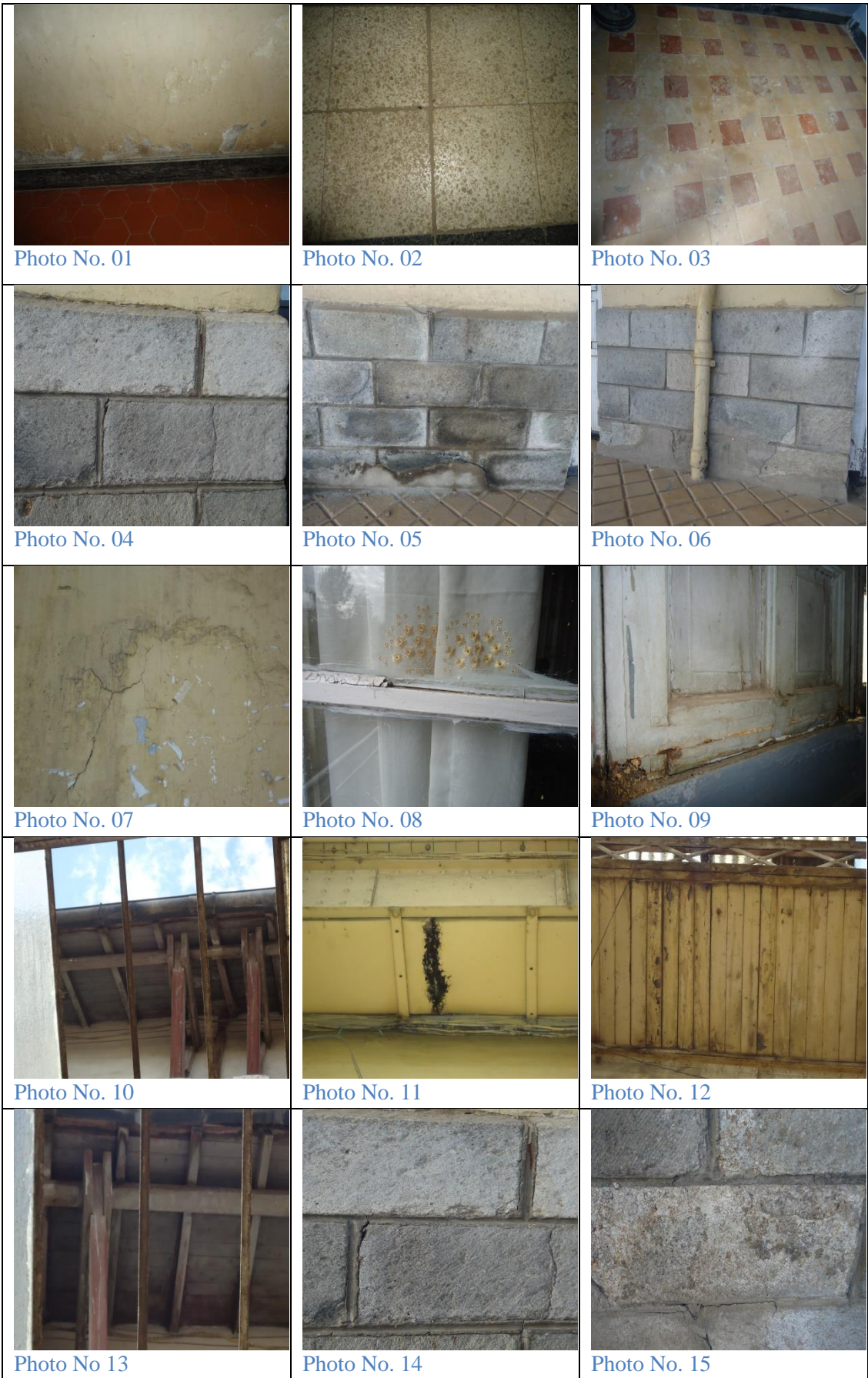
Historic Building Name: <u>LA GARE BUILDING</u>							Date of Inspection: <u>MAR 30 , 2017</u>						
Current Name: _____							Weather: <u>SUNNY</u>						
Owner Name: <u>GOVERNMENT</u>			Address: <u>KIRKOS SUB-CITY</u>				Inspected by (Name & Address): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No			{a}	{b}	$c=\delta*a*b$		
Building Exterior	External Walls		1	Evidence of mortar pointing deterioration in masonry walls		x	Lm			4			
			2	Cracks in walls	x		Lm	0.015	2	5	7.69	4	
			3	Signs of decay or deterioration in stone walls	x		m ²	39	2	4	5.71	5	
			4	Unclean walls	x		m ²	51.4	1	3	1.87	6	
			5	Cracked paint and loose plaster with hairline cracks	x		m ²	7.2	3	2	4	7	
		Doors		1	Paint or protective coating damaged.		x	Pcs			3		
			2	Decaying exterior seal, or corrosion on steel/wood frames		x	Pcs			5			
			3	Loose or damaged seals.		x	Pcs			4			
			4	Signs of decay on Door frames		x	Pcs			4			
			5	Sticking or jamming doors		x	Pcs			3			

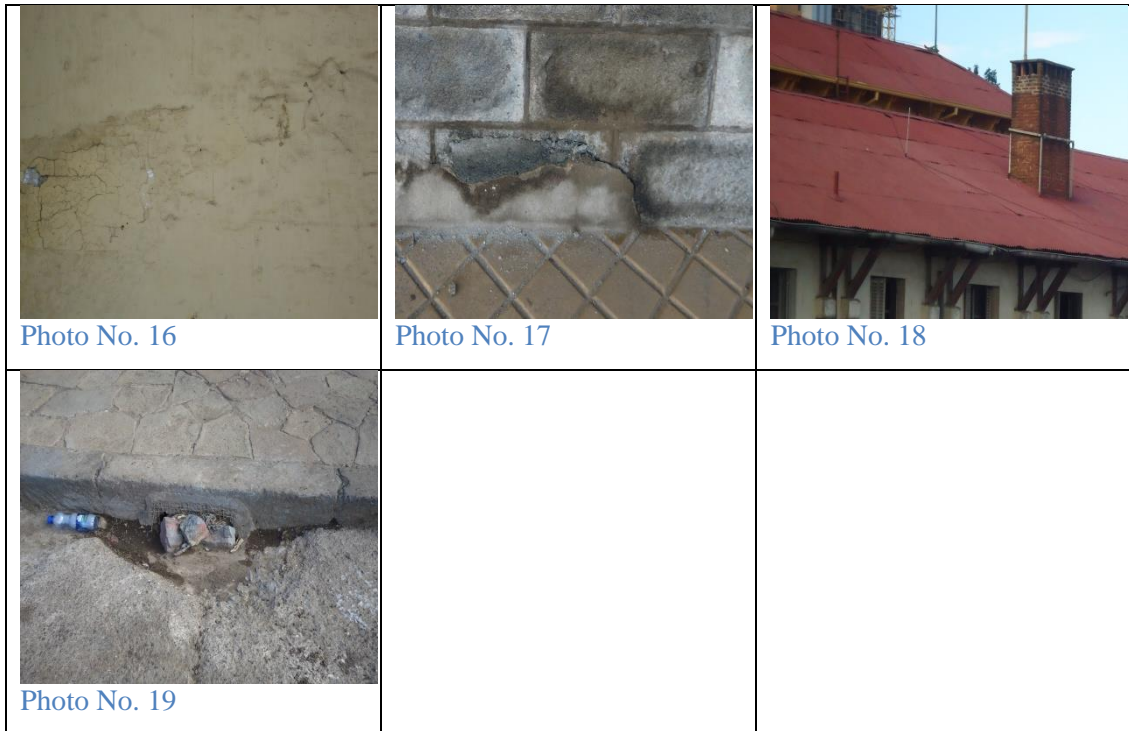
Historic Building Name: <u>LA GARE BUILDING</u>							Date of Inspection: <u>MAR 30, 2017</u>						
Current Name: _____							Weather: <u>SUNNY</u>						
Owner Name: <u>GOVERNMENT</u>				Address: <u>KIRKOS SUB-CITY</u>			Inspected by (Name & Address): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No.	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=a*b
Building Exterior	Windows		1	Paint or protective coating damaged, blistered.		x	Pcs			3			
			2	Decaying exterior sill, or window frame		x	Pcs			4			
			3	Loose or damaged seals	x		Pcs	42	3	3	4	8	
			4	Signs of decay on Window Frames	x		Pcs	51	4	5	18.18	9	
			5	Sticking or jamming windows		x	Pcs			3			
		Roof		1	Severe wear, or rusting on roof		x	m ²			5		
			2	Corrosion on the underside of metal sheeted roofs		x	No			5			
			3	Joint problems leading to leakage on metal sheets		x	No			4			
			4	Evidence of decay in the rafter	x		No	2	4	4	5.71	10	
			5	Loose, missing or broken roofing materials		x	m ²			4			

Historic Building Name: <u>LA GARE BUILDING</u>							Date of Inspection: <u>MAR 30 , 2017</u>						
Current Name: _____							Weather: <u>SUNNY</u>						
Owner Name: <u>GOVERNMENT</u>				Address: <u>KIRKOS SUB-CITY</u>			Inspected by (Name & Address): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Exterior	Balcony		1	Loose or deteriorated components	x		Ls	-	2	4	5.71	11	
			2	Cracked paint	x		m ²	126	3	2	4	12	
			3	Railings decayed or rusting and deteriorated		x	Ls	-		5			
			4	Plaster on walls loose or cracked		x	m ²			3			
			5	Dust and accumulation of Debris		x	m ²			3			
	External Stair			1	Visible cracks on steps		x	Lm			4		
				2	Damage to staircase		x	m ²			5		
				3	Railings rotting or rusting leading to deterioration		x	Lm			4		
				4	Paint cracked		x	m ²			2		
				5	Plaster on walls loose or cracked		x	m ²			3		

Historic Building Name: <u>LA GARE BUILDING</u>							Date of Inspection: <u>MAR 30, 2017</u>						
Current Name: _____							Weather: <u>SUNNY</u>						
Owner Name: <u>GOVERNMENT</u>			Address: <u>KIRKOS SUB-CITY</u>				Inspected by (Name & Address): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Structure	Roof structural Element		1	Deflections in the overall profile of the roof		x	Lm			4			
			2	Sagging ridge of the roof		x	Lm			4			
			3	Decaying on elements of truss system	x			m ²	58.06	3	5	12.5	13
			4	Fascia boards and soffits loose, unsecured to structure			x	Lm			3		
			5	sagging purlins			x	m ²			5		
		Foundation and Structural Wall		1	Major cracks in stone masonry	x		Lm	0.017	2	5	7.69	14
			2	Stone masonry units missing, loose or deteriorating	x			m ²	6.81	2	4	5.71	15
			3	Water stained walls, or mold grown on the wall surface	x			m ²	21	2	4	5.71	16
			4	Wood elements that are not firmly attached and painted			x	m ²			4		
			5	Signs of decay on structural wall	x			m ²	4.6	2	4	5.71	17

HISTORIC BUILDING NAME: <u>LA GARE BUILDING</u>							DATE OF INSPECTION: <u>MAR 30, 2017</u>						
CURRENT NAME: _____							WEATHER: <u>SUNNY</u>						
OWNER NAME: <u>GOVERNMENT</u>				ADDRESS: <u>KIRKOS SUB-CITY</u>			INSPECTED BY(NAME & ADDRESS): _____						
Building Component			Checklist Description				Unit	Defected Quantity	Condition Category	Priority Category	Condition Matrix	Photo No	
Component	Sub-component	Material type	S/n	Description	Yes	No							{a}	{b}	c=δ*a*b
Building Services	Gutters and Down Pipes		1	Loose, or missing gutters or Down Pipes		x	Lm			5			
			2	Gutters and Down Pipes that are blocked with leaves and debris		x	No			4			
			3	Joints in Down Pipes not secured from leaks		x	Pcs			5			
			4	Sagging gutters or gutters sloping the wrong way	x		Lm	18	4	5	18.18	18	
			5	Outlets from Down Pipes have not extensions to ditch		x	Pcs			3			
	Drainage			1	Rainwater ponds around the base of the buildings		x	Ls	-	3	4		
				2	Rainwater gullies not draining properly	x		Pcs	2	4	3	9.23	19
				3	Rising dampness visible		x	m ²			3		
				4	Manholes blocked with sedimentation and debris		x	Pcs			3		
				5	Wet stains, or efflorescence on exterior surfaces		x	m ²			3		
				Summation	19	46				142.94			





2) Appendix B

In appendix B, procedures used to estimate the cost of items prescribed under the formulated three alternative maintenance decisions, namely, preventive maintenance, repairing defects, replacing failed components are attached.

2.1. Appendix-B 1 describes detailed cost considerations under preventive maintenance

2.2. Appendix-B 2 presents cost breakdown details for items specified to repair defects of Menelik II school

2.3. Appendix-B 3 presents detailed cost breakdown for prescribed items for Menelik II School under Replacing Failed components

Appendix B-1: Cost break down for Preventive Maintenance

Item of work: Preventive maintenance

Cleaning Labor crew (1:01)					Painter crew Labor (1:02)				Equipment/tools/material's Cost (1:03)					
Labor by Grade	Number	UF	Daily Rate	Cost per Unit	Labor by Grade	Number	UF	Daily Cost	Hourly Cost	Type of Equipment	No./Unit	Daily Cost	Daily Cost	
Foreman	1	0.5	192.3077	96.1538	Foreman	1	0.5	192.31	96.15	Wheel cart	2	92.31	184.6	
Janitor	3	1	76.92308	230.769	carpenter	1	1	138.46	138.46	ladder	2	138.5	276.9	
Carpenter	2	1	138.4615	276.923	painter	2	1	92.31	184.62	Shovels	4	1.73	6.92	
Daily laborer	4	1	69.23077	276.923	laborer	3	1	69.23	207.69	Brush	4	0.96	3.85	
										Glove	12	1.92	23.08	
										Nonabrasive brush	4	2.31	9.23	
										Long cleaning broom	4	5.77	23.08	
Total (1:-01)				880.769	Total (1:02)				626.92	Total (1:03)				527.69
				A					B					C

Direct Cost of work item = A+B+C

=

2035.38 Birr/m²

Overhead Cost : 5% 101.77 "

Profit Cost: 10% 203.54 "

Total Unit Cost : **2340.69** Birr/day

Appendix B-2: Cost break down for repairing defected components

Item of Work: 40 cm diameter concrete half pipe

Labor Hourly Output: 3.13 Lm/hr.

Total Quantity of Work Item: 1 Lm

RESULT: 148.25 Birr/Lm

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
40 cm. Cement concrete half pipe	ml	1.05	70	73.50	Foreman	1	0.5	28.846154	14.42				
Cement	qt.	0.044	270	11.88	Mason II	2	1	20	40.00				
Sand	m ³	0.0056	545	3.05	Helper	4	1	10	40.00				
Total (1:-01)				88.43	Total (1:02)				94.42	Total (1:03)			
				A					B	C			

Direct Cost of Work Item

= A+B=

118.60 Birr/ml.

Overhead cost :

10%

11.86 "

Profit Cost:

15%

17.79 "

Total Unit Cost

148.25 Birr/ml.

Item of work: trench excavation not exceeding 150 cm. in loose and dry soil

Labor hourly output: 0.3 m³/hr.

Total quantity of work item: 1 m³

Result: 237.5 birr/ m³

Material Cost (1:01)					Labor Cost (1:02)					Equipment/Tool Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
					D/L	4	1	10	40	Tools	1	5	5
					Gang Chief	1	1	12	12				0
Total (1:-01)				0	Total (1:02)				52	Total (1:03)			5
				A	B					C			

Direct Cost of Work Item = A+B+C =		190.00 Birr/m ³
Overhead cost :	10%	19.00 "
Profit Cost:	15%	28.50 "
Total Unit Cost :		237.50 Birr/m ³

Item of Work: Gutter with 60 cm development length

Labor hourly output: 2.6 Lm/hr

TOTAL QUANTITY OF WORK ITEM: 1 Lm

Result: 329.53 Birr/ hr

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
G28 Sheet Metal Gutter Dev. Size 60 cm.	m	1.05	200	210.00	Foreman	1	0.5	28.84	14.42				
					Carpenter	1	1	22	22.00				
Staffa For Gutter	pcs	2	15	30.00	Helper	1	1	15	15.00				
					D/L	1	1	10	10.00				
Total (1:-01)				240.00	Total (1:02)				61.42	Total (1:03)			0.00
				A					B				C

Direct Cost of Work Item = A+B+C =	263.62 Birr/Lm.
Overhead cost : Overhead cost :	10% 26.36 Birr/Lm.
Profit cost : Profit Cost:	15% 39.54 Birr/Lm.
Total unit cost : Total Unit Cost :	329.53 Birr/Lm.

Item of work: Down Pipe with development size 60 cm

Labor hourly output: 3.4 Lm/hr

Total quantity of work item: 1 Lm

Result: 304.45 Birr/Lm

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
G28 Sheet Metal Down Pipe Dev. Size 60 cm	Lm	1.05	180	189.00	Foreman	1	0.5	25	12.50				
					Carpenter	1	1	22	22.00				
Staffa For Down Pipe	pcs	2	20	40.00	Helper	1	1	15	15.00				
Total (1:-01)				229.00	Total (1:02)				49.50	Total (1:03)			0.00
				A					B				C

Direct Cost of Work Item = A+B+C = 243.56 Birr/m.

Overhead cost : 10% 24.36 Birr/m.

Profit cost 15% 36.53 Birr/m.

Total unit cost : 304.45 Birr/m.

Item of work: 2 coats of cement plastering

Labor hourly output: 0.75 m²/hr

Total quantity of work item: 1 m²

Result: 198.41 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Cement	qt.	0.233	270	62.91	Foreman	1	0.25	33.3	8.33				
Sand	m ³	0.034	545	18.53	Plasterer	1	1	25	25				
Water	lit	10	0.01	0.100	Chiseler	1	0.10	7.5	0.75				
					Daily Laborer	2	1	7.5	15				
Total (1:01)				81.54	Total (1:02)				49.08	Total (1:03)			0
				A					B				C

Direct Cost of Work Item = A+B+C = 146.97 Birr/m²

Overhead cost : 15% 22.05 "

Profit Cost: 20% 29.39 "

Total Unit Cost : 198.41 Birr/m²

Item of work: 2 coats of plastic Paint

Labor hourly output: 3.76 m²/hr

Total quantity of work item: 1 m²

Result: 61.62 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	
Plastic paint	lit	0.28	90	25.2	foreman	1	0.2	33.3	6.66	tools	1	2.5	2.5	
Stucco	kg	0.08	20	1.6	painter	1	1	15	15.00					
Animal glue	kg	0.023	23	0.529	DL	1	1	7.5	7.5					
Brush	pcs	0.3	40	12										
Sand paper	pcs	0.4	10	4										
Gypsum	kg	0.07	5.6	0.392										
Total (1:-01)				43.721	Total (1:02)				29.16	Total (1:03)				2.5
				A					B					C

Direct Cost of Work Item = A+B+C =		45.65 Birr/m ²
Overhead cost :	15%	6.85 "
Profit Cost:	20%	9.13 "
Total Unit Cost :		61.62 Birr/m ²

Item of work: 2 coats of plastic Paint

Labor hourly output: 1.25 m²/hr

Total quantity of work item: 1 m²

Result: 46.80 Birr/m²

Material Cost (1:01)					Labor (1:02)				Equipment Cost (1:03)					
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	
					Foreman	1	0.1	33.3	3.33					
					Carpenter I	1	1	25	25					
					Helper	2	1	7.5	15					
Total (1:-01)				0	Total (1:02)				43.33	Total (1:03)				0
				A					B					C

Direct Cost of work item = A+B+C = **34.66 Birr/m²**

Overhead Cost : 15% 5.20 "

Profit Cost: 20% 6.93 "

Total Unit Cost : **46.80 Birr/m²**

Item of work: 30 x 30 cm. terrazzo tile flooring

Labor hourly output: 1 m²/hr

Total quantity of work item: 1 m²

Result: 212.23 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Cement	qt.	0.268	270	72.36	Foreman	1	0.25	33.3	8.33				
Sand	m ³	0.032	545	17.44	Mason II	1	1	25	25				
Water	lit	30	0.01	0.300	D/L	1	1	7.5	7.5				
Cement grout	qt.	0.014	270	3.78	Helper	1	1	7.5	7.5				
Polish	lit	0.1	150	15.00									
Total (1:01)				108.88	Total (1:02)				48.33	Total (1:03)			0
				A					B				C

Direct Cost of Work Item = A+B+C = 157.21 Birr/m²

Overhead cost 15% 23.58 "

Profit Cost: 20% 31.44 "

Total Unit Cost : 212.23 Birr/m²

Item of work: Relaying timber flooring

Labor hourly output: 1.25 m²/hr

Total quantity of work item: 1 m²

Result: 95.27 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Nail-8mm	kg	0.061	545	33.245	Foreman	1	0.2	33.3	6.66				
					Carpenter	1	1	25	25				
					D/L	1	1	7.5	7.5				
					Helper	1	1	7.5	7.5				
Total (1:01)				33.25	Total (1:02)				46.66	Total (1:03)			0
				A					B				C

Direct Cost of Work Item = A+B+C = 70.57 Birr/m²

Overhead cost : 15% 10.59 "

Profit Cost: 20% 14.11 "

Total Unit Cost 95.27 Birr/m²

Item of work: Replacing 8 mm thick chip wood Ceiling

Labor hourly output: 5 m²/hr

Total quantity of work item: 1 m²

Result: 210.46 Birr/m²

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	
Chip wood	m ²	1.05	90.00	94.5	Foreman	0.25	1	33.3	8.33					
Nail - 8 mm	kg	0.23	24	5.52	Carpenter I	1	1	25	25					
- 6 mm	kg	0.06	24	1.44	Helper	1	1	7.5	7.5					
Total (1:-01)				101.46	Total (1:02)				40.83	Total (1:03)				0
				A					B					C

Direct Cost of work item = A+B+C = 155.89 Birr/m²
 Overhead Cost : 15% 23.38 "
 Profit Cost: 20% 31.18 "
 Total Unit Cost : 210.46 Birr/m²

Item of work: Cement mortar pointing to stone wall
 Total quantity of work item: 1 m²

Labor hourly output: 4 m²/hr
 Result: 197.45 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	
Cement	qt.	0.23	180	41.4	Foreman	1	0.2	33.3	6.66					
Sand	m ³	0.08	545	43.6	Plasterer	1	1	25	25					
Water	lit	10	0.01	0.100	Chiseler	1	1	22	22					
					D/L	1	1	7.5	7.5					
Total (1:01)				85.10	Total (1:02)					61.16	Total (1:03)			0

Direct Cost of Work Item = A+B+C =		146.26	Birr/m ²
Overhead cost :	15%	21.94	"
Profit Cost:	20%	29.25	"
Total Unit Cost :		197.45	Birr/m ²

Item of work: Cement mortar Grouting

Total quantity of work item: 1 m²

Result: 476.19 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Sand	m ³	0.07	545	38.15	Foreman	1	0.2	33.3	6.66	Air Compressor	1	375	375
Cement (PPC)	qt.	0.44	180	79.2	Skilled person	2	1	22.5	45.00	Grouting Machine	1	450	450
Water	Lit	22	0.01	0.22	Helper	4	1	7.5	30.00				
					Machine Operator	1	1	34	34.00				
Total (1:01)				117.57	Total (1:02)				115.66	Total (1:03)			825
				A					B				C

Direct Cost of Work Item = A+B+C

=

352.74 Birr/m²

Overhead cost : 15% 52.91 "

Profit Cost: 20% 70.55 "

Total Unit Cost : 476.19 Birr/m²

Item of work: Scarifying decayed wood frames

Labor hourly output: 1 m²/hr

Total quantity of work item: 1 m²

Result: 152.22 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Sand paper	pcs	0.1	8	0.8	Foreman	1	0.1	33.3	3.33				
Brush	pcs	0.02	100	2	Carpenter I	1	1	25	25				
Water	Lit	5	0.01	0.05	Helper	1	1	7.5	7.5				
		Total (1:01)		2.85	Total (1:02)				35.83	Total (1:03)			0
				A					B				C

Direct Cost of Work Item = A+B+C =	38.68 Birr/m ²
Overhead cost :	15% 5.80 "
Profit Cost:	20% 7.74 "
Total Unit Cost :	52.22 Birr/m ²
plus Cost of making window/door element (ref. replace sheet)	100.00 Birr/m ²
Total cost of demolishing plus making	<u>152.22 Birr/m²</u>

WORK ITEM: G 32 CIS Roofing (Including Truss & Purlins)

Total Quantity Of Work Item: 108 m² = 9 Trusses =127 ml. Purlin

Material Cost (1:01)					Labor (1:02)				
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost
Roofing Nails	kg.	15	170	2550	Carpenter I	1	1	25	25.00
Plastic Washer	pkt.	5	10	50	Helper	1	1	7.5	7.50
Ridge Cover	m.	13	70	910	D/L	1	1	7.5	7.50
				3510					40.00
Upper Chord	ml.	83	10	830	Fore Man	1	0.25	33.3	8.33
Lower chord	ml.	78	10	780	Carpenter II	1	1	27	27.00
Vertical & Diagonal Members	ml.	79	6	474	Carpenter I	1	1	25	25.00
6 & 8 mm. Nails	kg.	15	30	450	Helper	2	1	7.5	15.00
Fixing Bands	kg.	16	20	320					75.33
				2854	Fore Man	1	0.25	33.3	8.33
5 X 7 cm. Zigba Purlin	ml.	140	180	25200	Carpenter I	1	1	25	25.00
8 mm. Nails	kg.	5	30	150	Helper	1	1	7.5	7.50
				25350	D/L	3	1	7.5	22.50
									63.33
Total (1:-01)				31714	Total (1:02)				

Overhead cost : 15% 49.31 Birr/m²

Profit Cost: 20% 65.75 Birr/m²

Total Unit Cost : 443.80 Birr/m²

Appendix B-3: Cost break down for replacing failed components

Item of work: 50 cm thick elevation wall (Two sides dressed)

Labor hourly output: 0.375 m³/hr

Total quantity of work item: 1 m³

Result: 2503.70 Birr/m³

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Stone material	m ³	1.5	625	937.5	Foreman	1	0.2	33.3	6.67				
Cement	qt.	0.8	270	216	Mason	2	1	25	50				
Sand	m ³	0.25	545	136.25	D/L	4	1	7.5	30				
Water	lit	40	0.01	0.40									
Total (1:-01)				1290.15	Total (1:02)				86.67	Total (1:03)			0.00

Direct Cost of Work Item = A+B+C =	1521.26 Birr/m ³
Overhead cost :	15% 228.19 "
Profit Cost:	20% 304.25 "
Total Unit Cost :	2053.70 Birr/m ³

Labor hourly output: 0.125 pcs/hr

Item of work: Framed & Paneled solid Doors & Windows

Equipment output: 0.50 pcs/hr

Total quantity of work item: 1 pcs 1.89 m²

Result: 2863.82 Birr/m²

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Unit Cost	Labor by Grade	No .	UF	Hourly Cost	Hourly Cost	Type of Equipment	No .	Hourly Rental	Hourly Cost	
					Making					Compinanto	2	100.00	200.00	
Tid wood frame (external)	m ³	0.08 1	8400.0 0	680.40	Carpenter II	1	1	25	25.00	Vice	1	60.00	60.00	
Tid wood frame (internal)	m ³	0.04 5	8400.0 0	378.00	Helper	1	1	7.5	7.50					
Tidwood panel	m ²	1.46	200.00	292	Foreman	1	0.2	33.3	6.66					
Door list	ml.	7.1	100.00	710	Carpenter I	1	1	18.75	18.75					
Cylindrical Lock	Pcs.	1	550.00	550					57.91					
Hinges	"	3	24.00	72	Fixing									
Screw	"	10	0.30	3	Carp. foreman	1	0.25	33.3	8.33					
Colla	lit.	0.4	70.00	28	Carpenter II	1	1	25	25.00					
Nails of diff Sizes	kg	0.2	30.00	6	helper	1	1	7.5	7.50					
				0					40.83					
Total (1:-01)				2719.4	Total (1:02)						Total (1:03)			260.00

Overhead Cost : 15% 601.40 "

Profit Cost 20% 801.87 "

Total Unit Cost 5412.62 Birr/pcs.

Item of work: G 32 CIS Roofing (Including Truss & Purlins)
 Total quantity of work item: 108 m² = 9 trusses = 127 Lm Purlin

Labor hourly output: 0.48 m²/hr
 Result: 706.46 Birr/m²

Material Cost (1:01)					Labor (1:02)				
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost
G32 Corugated iron sheet	m ²	108	230	24840	Fore Man	1	0.25	33.3	8.33
Roofing Nails	kg.	12	50	600	Carpenter I	1	1	25	25.00
Plastic Washer	pkt.	5	10	50	Helper	1	1	7.5	7.50
Ridge Cover	m.	13	70	910	D/L	1	1	7.5	7.50
				26400					48.33
Upper Chord	ml.	83	10	830	Fore Man	1	0.25	33.3	8.33
Lower chord	ml.	78	10	780	Carpenter II	1	1	27	27.00
Vertical & Diagonal Members	ml.	79	8	632	Carpenter I	1	1	25	25.00
6 & 8 mm. Nails	kg.	15	30	450	Helper	2	1	7.5	15.00
Fixing Bands	kg.	16	23	368					75.33
				3060	Fore Man	1	0.25	33.3	8.33
5 X 7 cm. Zigba Purlin	ml.	127	180	22860	Carpenter I	1	1	25	25.00
8 mm. Nails	kg.	5	30	150	Helper	1	1	7.5	7.50
				23010	D/L	3	1	7.5	22.50
Total (1:-01)				52470	Man power cost = 37.47				

Direct Cost of Work Item = 523.30 Birr/m²

Overhead cost : 15% 78.50 Birr/m²

Profit Cost: 20% 104.66 Birr/m²

Total Unit Cost : 706.46 Birr/m²

Item of work: G 32 CIS Roofing

Labor hourly output: 3.5 m²/hr

Total quantity of work item: 108 m²

Result: 266.57 Birr/m²

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
G32 CIS	m ²	108.00	170	18360.00	Foreman	1	0.167	33.3	5.5611				
Roofing nails.	kg	12	50	600.00	Carpenter I	1	1	25	25				
Plastic Washer	pkt.	5	10	50.00	Helper	1	1	7.5	7.5				
Ridge cover	ml.	13	70	910.00	D/L	1	1	7.5	7.5				
Total (1:-01)				19920.00	Total (1: 02)				45.56	Total (1:03)			0.00
				A					B				C

Direct Cost of Work Item = A+B+C = 197.46 Birr/m²
 : Overhead cost : 15% 29.62 "
 Profit Cost: 20% 39.49 "
 Total Unit Cost : 266.57 Birr/m²

Item of work: 10-cm. dia. Upper & Lower Chords Eucalyptus Wood

Labor hourly output: 8.59 Lm/hr

Total quantity of work item: 108 m² 17.89 Lm = 1 Truss

Result: 33.45 Birr/Lm

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Dia. 10 cm. Upper Chord	ml	9.22	15	138.30	Foreman	1	0.25	33.3	8.325				
Dia. 10 cm. Lower Chord	"	8.67	15	130.05	Carpenter I	1	1	25	25				
10 - 12 mm. Nails	kg	1.11	30	33.30	Helper	2	1	7.5	15				
Fixing Bands	"	1.78	23	40.94									
Total (1:-01)				342.59	Total (1: 02)				48.33	Total (1:03)			0.00
				A					B				C

Direct Cost of Work Item =

A+B+C =

24.78 Birr/ml.

Overhead cost :

15%

3.72 "

Profit Cost:

20%

4.96 "

Total Unit Cost :

33.45 Birr/ml.

Item of work: 6 cm. dia. Vertical & Diagonal Members of a Truss

Labor hourly output: 8.59 Lm/hr

Total quantity of work item: 8.78 Lm = 1 truss

Result: 29.25 Birr/Lm

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Dia. 6 cm. Eucalyptus Wood	ml.	8.78	15	131.70	Foreman	1	0.25	33.3	8.33				
6 - 8 mm. Nails	kg.	0.56	30	16.80	Carpenter 1	1	1	25	25				
					Helper	1	1	7.5	7.5				
Total (1:-01)				148.50	Total (1: 02)				40.83	Total (1:03)			0.00
				A					B				C

Direct Cost of Work Item = A+B+C =		21.67 Birr/ml.
Overhead cost :	15%	3.25 "
Profit Cost	20%	4.33 "
Total Unit Cost		29.25 Birr/Lm

Item of work: 6 cm. dia. Vertical & Diagonal Members of a Truss

Labor hourly output: 7 Lm/hr

Total quantity of work item: 14.11 Lm = 1 truss

Result: 256.67 Birr/Lm

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No .	UF	Hourly Cost	Hourly Cost	Type of Equipment	No .	Hourly Rental	Hourly Cost
5 X 7 cm. Tid Purlin	ml.	14.11	180	2539.80	Foreman	1	0.17	33.3	5.56				
6 - 8 mm. Nails	kg.	0.56	30	16.80	Carpenter II	1	1	27	27				
					Helper	1	1	7.5	7.5				
					D/L	3	1	7.5	22.5				
Total (1:-01)				2556.60	Total (1: 02)				62.56	Total (1:03)			0.00
				A					B				C

Direct Cost of Work Item = A+B+C =		190.13	Birr/ml
Overhead cost	15%	28.52	"
Profit			
Cost:	20%	38.03	"
Total			
Unit Cost		256.67	Birr/ml.

Item of work: wood railing for verandah/porch

Labor hourly output: 0.4 Lm/hr

Total quantity of work item: 1 Lm

Result: 520.28 Birr/Lm

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Trade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
MAKING													
10X 4cm. Tid wood frame	ml.	1.05	56.3	59.1 15	carpenter	2	1	25	50				
5 X 7 cm. wood Tid frame	ml.	1.05	42.5	44.6	Helper	2	1	7.5	15				
Nail-8mm	kg	3	30	90.0	Forman	1	0.1 25	33.3	4.16				
					D/L	1	1	7.5	7.5				
Total (1:-01)				193. 74	Total (1:02)				76.662 5	Total (1:03)			0

Direct Cost of work item =

A+B+C =

385. Br./M²

Overhead Cost:

15% 57.8 "

Profit Cost:

20% 77.1 "

Total Unit Cost

520 " Br./Lm

Item of work: Two coats of plastic paint to wall components

Labor hourly output: 3.76 m²/hr

Total quantity of work item: 1 m²

Result: 68.22 Birr/m²

Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Plastic paint	lit	0.18	90	16.2	foreman	1	0.2	33.3	6.66	tools	1	2.5	2.5
Stucco	kg	0.05	20	1	painter	1	1	15	15.00				
Animal glue	kg	0.013	35	0.455	DL	1	1	7.5	7.5				
Brush 4x14	pcs	0.01	100	1									
Sand paper	pcs	0.01	10	0.1									
Gypsum	kg	0.03	5.6	0.168									
Total (1:-01)				18.923	Total (1:02)				29.16	Total (1:03)			2.5
				A					B				C

Direct Cost of Work Item = A+B+C = 20.85 Birr/m²
 Overhead cost : 15% 7.58 "
 Profit Cost: 20% 10.11 "
 Total Unit Cost 68.2 Birr/m²

Item of work: 50 cm. thick masonry foundation

Labor hourly output: 0.375 m³/hr

Total quantity of work item: 1 m³

Result: 1779.97 Birr/m³

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Cement	Qt.	0.8	270.00	216	Foreman	1	0.2	33.3	6.66				
Sand	m ³	1.3	545.00	708.5	Mason II	2	1	25	50.00				
Stone	m ³	0.25	650.00	162.5	D/L	4	1	7.5	30.00				
Water	Lit	40	0.01	0.4									
Total (1:-01)				1087.4	Total (1:02)				86.66	Total (1:03)			0

Direct Cost of work item = A + B + C =	1318.49	Birr/m ³
Overhead Cost :	15%	197.77 "
Profit Cost:	20%	263.70 "
Total Unit Cost :	1779.97	Birr/m ³

Item of work: 8 mm thick chip wood Ceiling

Labor hourly output: 0.75 m²/hr

Total quantity of work item: 1 m²

Result: 401.81 Birr/m²

Material Cost (1:01)					Labor (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost per Unit	Labor by Grade	No.	UF	Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	
Chip wood	m ²	1.05	90.00	94.5	Foreman	0.25	1	33.3	8.33					
Batten (4 X 5 cm)	lm	4	24.25	97	Carpenter II	1	1	27	27					
Corner list	lm	1.25	8.00	10	Carpenter I	1	1	25	25					
Nail - 8mm	kg	0.13	30	3.9	Helper	1	1	7.5	7.5					
- 6mm	kg	0.06	30	1.8										
Total (1:01)				207.2	Total (1:02)				67.83	Total (1:03)				0

Direct Cost of work item =

A+B+C = 297.6 Birr/m²

Overhead Cost : 15% 44.65 "

Profit Cost: 20% 59.53 "

Total Unit Cost : 401.8 Birr/m²