Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering

Highway Engineering Stream

The Application of Expert Choice Approach Based On Analytical Hierarchy Process in Priority Rating Of Pavement Maintenance: A Case Study in Addis Ababa

A Thesis Submitted to The School of Graduate Studies of Jimma University in Partial Fulfillment of The Requirements for The Degree of Masters of Science in Civil Engineering (Highway Engineering)

By

Hanna Mengistu

March, 2018

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Main Advisor: Prof. Emer T. Quezon

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March, 2018

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DECLARATION

I, the undersigned, declare that this thesis entitled "The Application of expert choice approach based on analytic hierarchy process in priority rating of pavement maintenance: Case Study in Addis Ababa City." is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for theses have been dually acknowledged.

Candidate:

Ms. Hanna Mengistu

Signature_______________________

As Master Research Advisors, we hereby certify that we have read and evaluate this MSc research prepared under our guidance, by Ms. Hanna Mengistu entitled: "The Application of expert choice approach based on analytic hierarchy process in priority rating of pavement maintenance: Case Study in Addis Ababa City."

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Prof. Emer T. Quezon	___________________	15/02/2018 G.C
Main Advisor	Signature	Date
Engr. Markos Tsegaye (MSc)	__________________	____________________
Co-Advisor	Signature	Date

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ABSTRACT

Maintenance of the road transport network of a country is very crucial to the overall infrastructural development especially for developing countries like Ethiopia. Deferred maintenance activities resulting from budget fluctuations can lead to deteriorated pavement conditions and expose road users to a higher level of risk. As a result, there is a need for methods that can help to select the most cost-effective maintenance projects to control and minimize the risk for road users under budget constraints. This research tries to fill a gap that decision makers in maintenance prioritization. These kinds of arbitrary decisions do not usually guarantee the effectiveness of budget allocation. To overcome these difficulties an objective based AHP method is proposed in this study. The main objective was to use the expert choice approach based on Analytical Hierarchy Process for priority rating of pavement maintenance in AACRA.

In this study, ten sample roads were selected form roads that are planned for maintenance in the AACRA by using a purposive sampling method. The distress data for the selected road were collected using visual condition assessment survey and the ranking of most dominant distress were done in Decision Analysis Module for Excel. The percentage damage of identified dominant distress occurred at the selected roads was determined. By taking the ranked distress in Decision Analysis Module for Excel and the road class the weights for each criteria and sub criteria were derived using AHP approach in Supper Decision Software. A questionnaire has been prepared for pair wise comparison of criteria and sub criteria and has been distributed among pavement experts and the results have been calculated in super decision software. Finally priory weights and ranking for the sample roads were obtained.

As a conclusion the rating of selected sample roads for maintenance were obtained. The percentage damage of distress for the selected road were also obtained from visual condition assessment survey and the ranking were obtained for the most dominant distress that affect a maintenance prioritization. The weightage influence for the criteria and sub criteria using AHP concept were the other result.on the criteria comparision the principal arterial street has 46% influence and sub arterial street, local and collector road has got 32.4%,14.86% and 6.65% influence respectively. Also the sub criteria raveling, rutting, shoving, crocodile crack and pothole has got 49%, 26.68%, 14.53%, 5.99% and 3.69% respectively.

Finally in this research it was observed that the developed analytic hierarchy process model works sufficiently and yields adequate results as well as providing accurate decisions. Considering the multi criteria's to prioritize the pavement sections for maintenance can have great benefit for the decision maker. AHP method is simple and can be easily understood. For the AACRA it is better to apply a systematic way of prioritization which helps to utilize the maintenance budget properly and fairly.

Key words: AHP, DAME, Pavement maintenance, maintenance prioritization

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ACRONYMS

AACRA	Addis Ababa City Road Authority
AHP	Analytical Hierarchy Process

ANP	Analytical Network Process
BOCR	Benefit–Opportunity–Cost–Risk
EAC	East African Community
DA	Damage Area
DAME	Decision Analysis Module for Excel
GDP	Gross Domestic Product
HDM-4	Highway Development and Management
IRI	International Index
MCDM	Multi Criteria Decision Making
PDA	Percentage Damage Area
PMS	Pavement Management System
SCRIM	Sideways for the coefficient Routine Investigation Machine
SDF	Sideways of force coefficient
SWOT	strength, weakness opportunity treats
TDA	Total Damage Area
VOC	Vehicle Operating Costs
UK	United Kingdom
UN	United Nations
USA	United States of America

CHAPTER ONE

INTRODUCTION

1.1.Background

Maintenance of the road transport network of a country is crucial to the overall infrastructural development. Most development projects depend on good road transport network infrastructure for delivery of goods and services [1]. For sustainable development of a country, a well maintained road transport network infrastructure is fundamental in the promotion of socio-economic and industrial developments. Economically, road transport infrastructure has been found not only to boost the livelihood of cities, which are the major sources of national economic activities and growth [2] but also the agricultural sector in the country side.

The road transport sector in Africa also contributes significantly to the economic growth and poverty eradication in the continent through various ways, especially, through trade and tourism. Pavements are the important component of the inland transport system it is very important to maintain the existing pavement network in its serviceable condition within the available resources. Excessive road deterioration, due in part to improper and irregular maintenance, results in increased Vehicle Operating Costs (VOC), increased number of accidents and in general reduced reliability of transport services [3]. Sustainable funding for road maintenance has however proven to be particularly difficult for many developing countries. Many developing countries manage a road system which is larger than they can afford. Therefore there is need to maximize the returns on the limited funds available [4].

The function of pavement maintenance is to diminish pavement deterioration and extend the life of a pavement. Based on their relative perceived urgency of need for repair, engineers and managers are able to prioritize and schedule the maintenance of pavement sections. To prioritize pavement maintenance activities, a number of decision making methods have been introduced and implemented under Pavement Management System (PMS) study. These methods vary from simple ranking to complex optimization [5]. A widely adopted practice is to express maintenance priority in the form of a priority index, computed by means of an empirical mathematical expression. Though convenient to use, empirical mathematical indices often do not have a clear physical meaning and cannot accurately and effectively convey the priority assessment or intention of highway agencies and engineers. In an attempt to overcome this limitation, this study explores the use of an analytic hierarchy process (AHP) for the prioritization of pavement maintenance activities. The main aim is to identify an approach that can reflect the engineering judgment of highway agencies and engineers more closely. According to [6] AHP method solve the complex decision making with pairwise comparison form a multilevel hierarchical structure through a set of pairwise comparisons to solve complex problems. Score weights were derived to meet the goal and sorted in ranking order [7].

Deferred maintenance activities resulting from budget fluctuations can lead to deteriorated pavement conditions and expose road users to a higher level of risk. As a result, there is a need for methods that can help select the most cost-effective maintenance projects to control and minimize the risk for road users under current budget constraints. By doing so, the agency can select and implement the most cost-effective projects within the budget constraints and revise their maintenance plans to accommodate budget fluctuations.

Nowadays, rating approach in Analytical Hierarchy Process (AHP) is one of the most effective techniques in decision making process which was used to facilitate the prioritization of alternatives on the basis of important parameters like pavement condition index, traffic volume and road type [7]. In this study, relative weights of criteria, sub-criteria and inconsistency rate in each pairwise comparison matrix were calculated with the help of Super Decision software.

1.2. Statement of the Problem

Road authorities around the world thus emphasizes more on better efficiency and lower expenses due to limited funds. Since maintenance expenditures normally comprise half the annual road infrastructure funds, it is very important to prioritize efficiency in road maintenance [8]. The inadequate road infrastructure is also increasingly limiting farmers in applying pesticides and fertilizers and transporting their produce on harvest. In an effort to facilitate import and export activities, the East African Community (EAC) identified five major transport corridors in the East African region [9]. It was since 1942 that road maintenance and rehabilitation duty within Addis Ababa was made to be the responsibility of the Roads and Building Department of the Addis Ababa city. However, the city was unable to cope up with its maintenance duties due to lack of resource particularly experienced personnel in the field of road construction [10].

In Addis Ababa city, the road work funding is allocated by government. However, recent situation shows that the allocated funds always do not meet with the financing needs. In other words, there is a lack of funding for effective road management. Decision makers often perform pavement repairs without considering the maintenance priority and without utilizing a systematic procedure. These kinds of arbitrary decisions do not usually guarantee the effectiveness of budget allocation.

In this study prioritization of road sections for maintenance was done using the approach of Analytical Hierarchy Process, because AHP is one of the most effective techniques in decision making process which is used to facilitate the prioritization of road maintenance and dealing with different kinds of decision problems. AHP is flexible, straightforward and provides a rational and consistent way for decision making thus complex decision-making problem is simplified to many small comparison tasks.

1.3. Research Questions

1. What is the percentage damage of distress for the selected road samples?
2. How the most dominant types of distresses that govern the pavement maintenance work prioritization are selected?
3. How can the sample roads were ranked in super decision software?
4. What is the recommended approach for priority ranking of maintenance works comparing with the current prioritization used in the AACRA?

1.4. Objectives

1.4.1. General objective

The general objective of this study is, to apply the expert choice approach based on Analytical Hierarchy Process for priority rating of pavement maintenance in Addis Ababa city.

1.4.2 Specific objective

1. To determine the percentage damage of distresses for the sample roads using visual condition assessment survey.
2. To rank the most dominant distresses that governs the selection of maintenance priority for the selected roads using decision analysis module for excel.
3. To determine the rank of sample roads for maintenance based on the weights of each criterion's and sub criterion's using AHP approach in supper decision software.
4. To compare the current prioritization technique of AACRA with the study result and recommend the appropriate and systematic prioritization approach based on the study result.

1.5. Scope of the study

Road maintenance encompasses a wide range of activities, among those activities the road section prioritization is the most crucial step to save the scarce budget which is allocated for road maintenance. The point of intervention on a road to perform maintenance works is quite important and determines the type of maintenance activity to be undertaken [11]. Maintenance in general is the combination of all the technical and associated administrative actions intended to retain an item, or restore it to, a city in which it can perform its required function. Road maintenance therefore embodies both the technical and administrative actions by the responsible persons to retain or restore the road in the city in which it can perform its function [12].

Addis Ababa city road authority maintenance plan is to ensure that the roads constructed, improved or maintained, is in its serviceable condition for a designed period of life as much as possible. In order to achieve this objective, the authority was commencing different maintenance plans based on annual maintenance need. As it is known circumstance that the road networks in Addis Ababa City which needs to be maintained each year was very immense, the systematic way of road prioritization for maintenance is very crucial to maintain as many roads as possible in each year. Now a day the roads authority needs effective prioritization technique to address each year maintenance requirement. This study is conducted to fill this gap which is identified during the interview with the engineers. Since it is not possible to include all the road sections in the city, purposive sampling technique was used and the scope was limited to ten sample roads which are taken from the roads that are planned for maintenance in the year 2010 E.C of Addis Ababa city.

The priority rating process of the pavement maintenance work is done using the AHP approach by identifying the distress types which are the most dominant in the ten sample roads of Addis Ababa city road network and by determining the percent damage of those distresses on the selected road samples is conducted in the study. After determining the types of distresses and percentage damage the study applies the AHP approach to derive the weights for the selected criteria's. Finally the road sections will be prioritized based on the criteria's by AHP in the supper decision software.

1.6. Limitation of the Study

To address these research objectives, different tasks were accomplished starting from identifying the gap by interviewing the engineers and field road condition survey. During the study period, there were some minor challenges. Among those challenges faced, the limitation of research's previously conducted at this area and the missing of general road information and distress data records. Another limitations faced during the study were in gaining quick response for the questionnaire and also some unwillingness to be interviewed.

1.7. Significance of the study

Addis Ababa City Roads Authority is among one of the governmental organization who has a responsibility to construct, maintain and manage the roads in the city. In order to release his duty and to give better service for the city residents and the road users, the city roads authority was conducting different short and long term activities. Among the activities, maintaining those significant numbers of older and deteriorated roads that have not been properly maintained for years is a major works which was given the most attention now a day. To maintain the roads, the effective and systematic way of road section prioritization is very important and fundamental to include many roads as much as possible in the network at the same time to properly distribute the scarce budget allocated.

In this study the AHP technique based on multi criteria which can incorporate the qualitative data and the verbal judgment of the engineers in the prioritization process of the pavement sections for maintenance activities was applied to come up with optimum solution. This study also has a significant importance to know the application of supper decision software based on AHP technique in pavement section prioritization for maintenance. In addition to this the study shows how to analyze the current pavement condition data in decision analysis module for Excel (DAME) software.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Road transport is an essential factor in the economic growth of developing countries. It provides for 85% or more of total Inland and/or border crossing traffic. The effect of lack of maintenance on road users is also significant, with vehicle operating costs increasing by similar or greater amounts [6]. Cost-effective road infrastructures and their systematic maintenance are therefore vital [13]. Road maintenance as defined in the UN Road Maintenance Hand book consists of routine and periodic activities to pavements, shoulders, slope drainage and all other structures and property within the right of way to keep them as nearly as possible in their as constructed or renewed condition [14].

Analytical Hierarchy Process is one of the simplest and most useful processes in this field which is appropriate for decision making. The AHP method of decision making was introduced by Thomas L. Saaty [15]. Moazami et al. demonstrated an AHP methodology for evaluation and prioritization of road corridors based on pavement condition, where each road is considered as single entity. Thus more weightage is given to overall development of the Road Network than the rehabilitation of individual roads [16].

2.2. Flexible Pavements

Generally, pavements are divided mainly into flexible and rigid classes. Flexible pavements contribute most percent of Addis Ababa paved roads. Therefore, focus will be concentrated on flexible pavements analysis. Figure 1 shows a typical flexible pavement structure. It is comprised of several layers of carefully selected materials designed to gradually distribute loads from the pavement surface to the layers underneath [17].

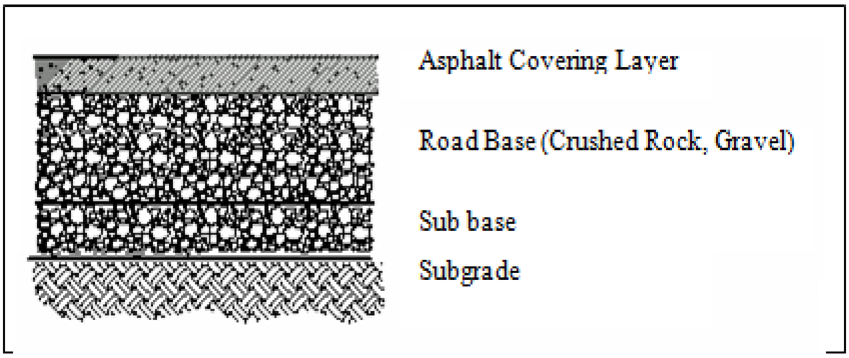


Figure 1: Typical Flexible Pavement Structure.

They also support loads through bearing rather than flexural action as in rigid pavements. Figure 2 illustrates the distribution of load stresses in flexible pavement. The design is such that the load transmitted to each successive layer does not exceed the layers load-bearing capacity.

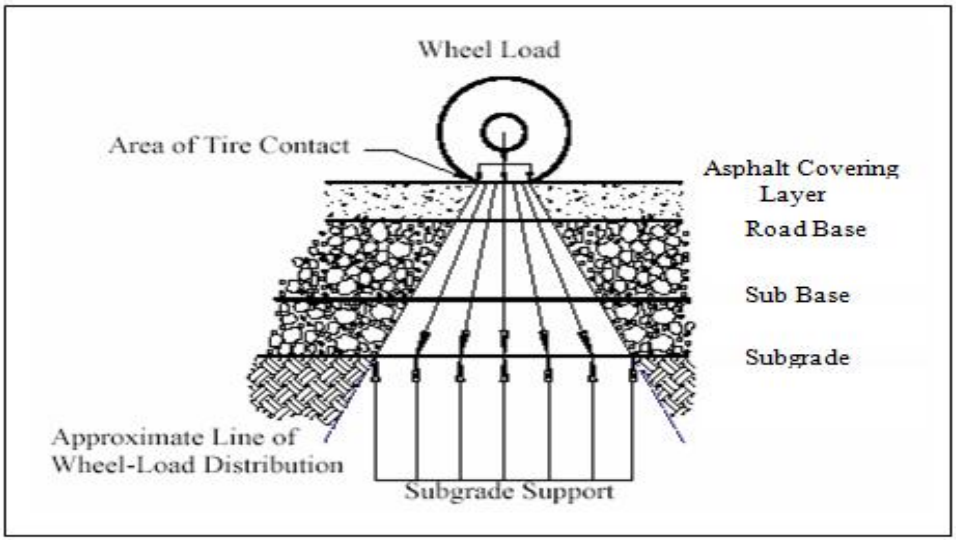


Figure 2: Distribution of Load Stresses in Flexible Pavements.

The various layers comprising a flexible pavement are described below [17].

Asphalt Covering Layer: It is generally comprised of a wearing and a binder course layers. They include a mixture of various selected aggregates bounds together with asphalt cement or other bituminous binders. Its function is to prevent the penetration of surfaces water to the road base, provide smooth, well bond surface, resist the stresses and furnish a skid resistant surface.

Road Base: It is the principal structure component. It may include either crushed rock or gravel road bases. Its function is to distribute imposed wheel load to the pavement foundation: the sub base and/or subgrade. The materials comprising the base course are selected hard and durable aggregates, which are stabilized and granular.

Sub Base: This layer is used in areas where frost action is severe or in locations where the subgrade soil is extremely weak. The materials requirements are not strict as those for the road base since the sub base is subjected to lower load stresses.

Subgrade: The subgrade is the compacted soil layer that forms the foundation of the pavement system. Subgrade soils are subjected to lower stresses. The combined thickness of sub base, base and surface must be great enough to reduce the stresses occurring in the subgrade to values, which will not cause excessive distortion or displacement of the subgrade soil layer.

2.3 Pavement Deterioration

Damage and deterioration of pavements are made apparent as a result of traffic, pavement and climatic or environmental factors. These factors cause surface fatigue, consolidation, or shear, developing in the subgrade, sub base, or surface [18].

Traffic factors include heavy axle-load repetitions, accelerating and decelerating traffic while pavement factors may include excess asphalt, poorly graded, inadequate particle interlock and poor subgrade drainage. Temperature variations and rainfall are examples of climatic factors that may cause damage to pavements. The deterioration of a pavement is also apparent by various external signs and indicators called distresses [17].

2.3.1 Causes of Pavement Deterioration

Road deterioration is caused by the effects of the physical environment, traffic, material properties, and quality of road construction, design standards and the age of the pavement. The details are discussed in the following paragraphs.

2.3.1.1 Environmental Factors

Climatic factors such as rain water, solar radiation, temperature, soil type and terrain may cause roads to deteriorate. Rain water can alter the moisture balance in the sub grade of a road with clayey and silt soils. This may cause swelling and shrinkage resulting in reflective cracking and heaving in the road surface. Sunlight may cause a continuous, slow hardening action on bituminous surfaces. This can increase the cracking process of the surface chip seal. Seasonal changes in temperature or night and day temperatures may cause expansion and contraction of the carriageway. This may progressively cause fatigue, failures and reflective cracks in the road surface [19]. The major climatic effects of road deterioration include hot equatorial temperatures which cause the rapid formation of corrugations. Torrential rainfall also reduces the load bearing capacity of roads if not well drained on the road side, surface or beneath due to the high clayey content of the soil type [20].

2.3.1.2 Traffic Volume and Loading

Roads are structures basically built to carry and sustain vehicular loads. Therefore traffic is an important factor that influences pavement performance. Every vehicle, which passes over a road, causes a momentary but significant deformation in the road structure. This is determined by the magnitude of each of its axle loads, the spacing between the axles, the number of wheels, the contact pressures of the tire and the travelling speed. The passage of many vehicles has cumulative effect which causes repeated flexing of the pavement leading to fatigue, crazing and structural failure [11].

2.3.1.3 Material Properties and Composition

The choice of materials used for the construction of pavement layers may also cause road deterioration. This is due to inherent variability in the materials used for road construction in terms of soil properties such as strength or load bearing capacity, gradation mix properties of elastic and resilience modulus. Poor choice of materials used for pavement layers can have a drastic effect on the strength of the layers and their subsequent performance [21].

2.3.1.4 Construction Quality

The quality of road construction if not built to the desired specifications can also facilitate road deterioration. For example, failure to obtain proper compaction, improper moisture conditions during construction, poor quality of materials and inaccurate layer thickness (after compaction) all directly affect the performance of a pavement [21].

2.3.2 Types of Pavement Defects

Pavement deterioration manifests itself in various kinds of distresses. Pavement distress is defined as any indication of poor or unfavorable pavement performance; or signs of impending failure or any unsatisfactory performance of a pavement short of failure [22]. There are different classifications of pavement distresses with different manifestations but a more comprehensive classification is defined in Table 1 [22].

Table 1: Classification of Pavement Distress

Mode	Manifestation	Mechanism
Fracture	Cracking	Excessive loading, repeated loading, thermal changes, moisture changes, slippage
Disintegration	Stripping, Raveling, edge break, potholes	Adhesion loss, chemical reactivity, abrasion by traffic, degradation of aggregate, failure of binder, environment.
Distortion	Permanent Deformation(Rutting)	Excessive loading, repeated loading, consolidation
Profile	Roughness	Structural deformation surface distresses, age, Environment.
Friction	Texture depth skid-resistance	Abrasion by traffic, aggregates embedded

Source: Highways Agency, 1997 [22].

Table 2: Types of Pavement Defects.

Pavement Deficiency	**Description**
Surface Distress	
Cracking	These are caused by fatigue failure due to repeated loads, or shrinkage of the asphalt and daily temperature cycling. They may be single or multiple with varying degrees of severity. They are expressed as a percentage of carriageways.
Ravelling,	Raveling is the wearing away of the pavement surface caused by the dislodging (raveling) of aggregate particles and loss of asphalt binder. This generally indicates that the asphalt binder has hardened significantly. They are also expressed as a percentage of carriageways.

Potholing	Potholes are small usually less than one meter in diameter bowl-shaped depressions on the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free water collecting inside the hole. They a produced when traffic abrades small pieces of the pavement surface. The pavement then continues to disintegrate because of poor surface quality, weak spots in the base or subgrade. The number of potholes per km expressed in terms of the number of standard sized potholes of area 0.1m$^{2.}$
Shoulder Distress	Shoulder elevated over road surface, or excessive gravel wind-rows along roadway edge. Possible causes are loose gravel on road surface combined with traffic action, poor construction and improper maintenance. They are expressed in meters per km.
Deformations Distress	
Rutting	Rutting is characterized by longitudinal depressions in the pavement surface that occur in the wheel paths of a roadway. Poor mix stability, excessive bitumen in the mix and repetitive loading on poorly compacted mix are several causes of rutting. They are as expressed as the maximum depth under 2meter straightedge transversely across a wheel path.
Depressions and Sags,	Depressions are localized pavement surface areas with elevations higher than those of the surrounding pavement. They are also created by settlement of the foundation soil or are the result of improper compaction during construction.
Profile	
Roughness	Deviations of surface from true planer surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage expressed in International Index (IRI m/km).
Friction	
Skid Resistance	Resistance to skidding expressed by the sideways of force coefficient (SDF) at 50km/ph measured using sideways for the coefficient Routine Investigation Machine (SCRIM)
Texture Depth	Average Depth of the surface of a road expressed as the quotient of a given volume of standard material (sand) and the area of that material spread in a circular pattern on the surface being tested.
Drainage	Drainage condition defines the drainage factor as either good fair or poor.
Gravel Loss	Deterioration of unpaved roads is characterised primarily by material loss from the surface.

Source: Highway Development and Management [23].

2.4 Pavement Evaluation

A major objective of pavement evaluation system is to assist highway engineer in making timely cost effective decision making related to the maintenance rehabilitation of pavements [24]. It is necessary to know the condition of pavements from the standpoint setting up design criteria and for establishing maintenance and priority programs. Evaluation surveys give reasons why the pavement condition is as it is [18]. Depending on the failure type mentioned earlier, the pavement evaluation systems are basically categorized into two major types: Functional and Structural evaluation.

2.5. Pavement Maintenance

Pavement maintenance can be defined as the planned strategy of cost-effective treatments to an existing roadway pavement system that preserves the system, retards future deterioration and maintains or improves the functional conditions of the system without including the structural capacity (does not include reconstruction or other improvements). On the other hand, highway maintenance has more generality and is concerned with the task of preserving, repairing and restoring a system of roadways with its elements, to its designed or accepted configuration. System elements include carriageway surfaces, shoulders, roadsides, drainage facilities, bridges, tunnels, signs, markings and lighting fixtures [25].

Road pavements are built for an expected design life but deteriorate over time. This causes the road pavement to exhibit a number of fatigue symptoms. The deterioration process continues up to a point where maintenance intervention is applied to remove the defects. Then the cycle repeats itself until the road reaches the end of its service life known as terminal serviceability where it is reconstructed. Road maintenance intervention delays the rate of total failure until the pavement reaches the end of its design life. The process is referred to as the road deterioration cycle [11] and it is illustrated in Figure 3.

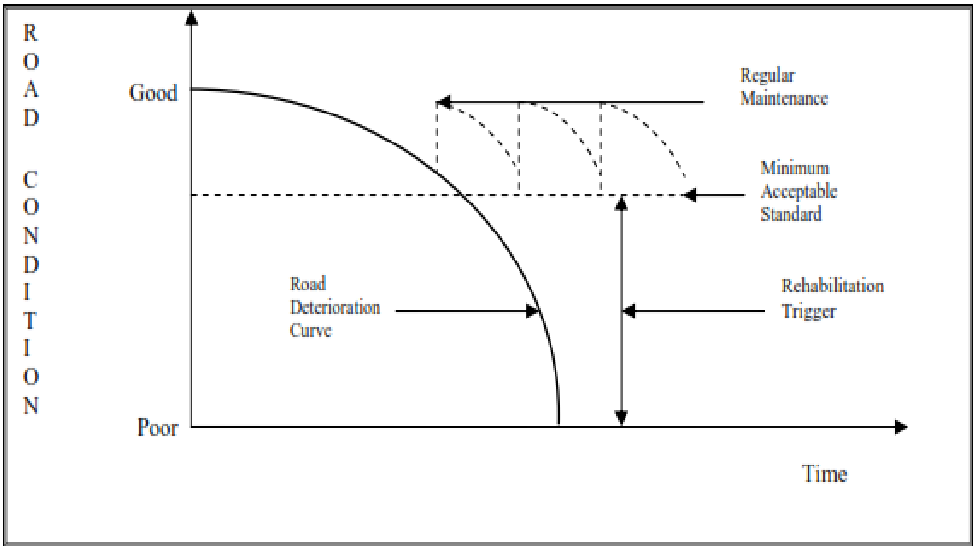


Figure 3: Pavement Deterioration Curve

Source: Adapted from Highway Engineering Economy [11].

Figure 3 above shows a generic deterioration curve and illustrates how the overall condition of the pavement changes as it ages. When first built, the pavement is hopefully in very good condition. Typically, the condition slowly decreases in the first years of service from very good to good condition. As the pavement approaches the end of its service life, the rate of deterioration accelerates.

Investment in the City's highways in recent years has focused on improving the strategic and distributor road network, vehicle and pedestrian safety features and improved lighting. However the consequences of significant under–investment over many previous years continue to challenge efforts to bring the network up to an acceptable standard in many areas of the City. Desirable levels of safety and serviceability have been difficult to maintain and perhaps more importantly the ability of the network to effectively fulfill its wider community function continues to give rise to concerns. As a consequence of this the trust of future year's investment must focus on the unclassified (neighborhood) roads, which form the majority of the network [26].

2.5.1 Pavement Maintenance Standards

The rate of pavement deterioration is directly affected by the maintenance standards applied to repair road defects. When a maintenance standard is defined it imposes a limit to the level of deterioration that a pavement is allowed to attain. Low maintenance standard therefore causes roads to deteriorate at a faster rate [21]. As pavements age and experience traffic repetitions, pavement distresses begin to accumulate. For example the hardening effect increases the stiffness of asphalt with age making the material more susceptible to thermal cracking [27]. Road maintenance may be described as an intervention that reduces the rate of pavement deterioration. The purpose of road maintenance is to enable the continued use of the pavement by traffic in an efficient and safe manner [28].

2.5.2. Road Maintenance Activities

Road maintenance activities are categorized according to the frequency of operation [28]. It involves minor activities undertaken on routine basis and major activities undertaken on periodic basis to eliminate pavement defects [11]. It could also be in response to an urgent situation. The road maintenance activities determine the threshold of funding needed for road maintenance. Each activity corresponds to a specific budget head and this determines the threshold of funding required for maintenance.

2.5.2.1 Routine Maintenance

It is a timely intervention to prevent minor faults from further deterioration which might require costly repair. The operations are carried out on a regular or cyclic basis. The frequency may vary in a particular year or season. They are small scale but widely dispersed and require skilled or unskilled manpower. Routine maintenance is funded under recurrent budget heads and its application is aimed at achieving savings in delivery costs. It is considered to be the most effective use of funds to assist the pavement to remain in sustainable condition for further time before periodic maintenance is applied [28]. A summary of the routine activities is presented in Table 3.

Table 3: Types of Routine Maintenance Activities

Type of Maintenance Activity	**Description**
Surface Maintenance	-Pothole Patching -Repair of depressions, Ruts, Shoving and Corrugations -Edge failure repairs, Crack Sealing, Break-up Spot and Grading of High Gravel Shoulder
Surface Maintenance on Gravel Roads	-Reshaping of Gravel Roads -Grading of Gravel Roads -Sectional Patching
Drainage Maintenance	-Ditch cleaning -Re-excavation of Drainage Ditches -Cleaning and Minor Repairs of Culverts -Crack repairing on drainage structures -Erosion and Scour Repairs
Road Side Maintenance	-Grass cutting
Road Side Furniture Maintenance	-Cleaning, repairing and replacement of traffic signs guide posts and guard rails, road line marking

Source: Maintenance Management for District Engineers [28]

2.5.2.2 Periodic Maintenance

These are operations that are occasionally required on a section of road after a number of years to protect the structural integrity. It includes development works to expand the capacity of the network, the provision of stronger pavement and the improvement of the geometric characteristics of the road [11]. The timely application of periodic maintenance delays ultimate full reconstruction at higher costs. Periodic maintenance activities are funded under capital budget heads. They include large scale pavement maintenance such as sealing of cracked surfaces, resurfacing, overlay, pavement reconstruction or strengthening, maintenance of drains and road shoulders [11]. Examples of periodic maintenance activities are summarized in Table 4.

Table 4: Types of Periodic Maintenance Activities.

Type of Periodic	Description
Re-gravelling	Placing of adequate sub-base gravel on an existing gravel road to strengthen the pavement. (This is usually performed at 3-5 years interval depending on the traffic and climatic condition.

Resealing	Placing of a fresh seal coat on an existing bituminous surfaced to seal cracks and improve resistance. (This is usually performed at 5-7 years interval depending on the traffic and climatic condition
Overlay	Placing of asphaltic concrete on an existing bituminous surfaced or asphaltic concrete road to strengthen the pavement. (This is usually performed at 10-12 years interval depending on the traffic and climatic condition.
Partial Reconstruction (Resurfacing)	Scarifying of existing bituminous surfaced road, strengthening the base year with addition of adequate thickness of base material and applying surface treatment.
Minor Rehabilitation	Improvement of an unpaved or paved road including widening, earthworks and construction of drainage structures.

Source: Adapted from Highway Engineering Economy [11].

2.5.2.3 Emergency Works

These include works of any nature which arises out of emergency and requires immediate attention. It normally has a lumped sum budget which may be drawn from a special account set for the purpose. It includes activities such as clearing debris and repairing washouts [11].

2.5.3 Road Maintenance Intervention Criteria

The selection of road maintenance interventions are based on two fundamental rules which determines the timing and limits on the works to be carried out. The rules ensure that a consistent approach is undertaken to planning and specifying works. It also ensures that funds are spent to the greatest effect [29].

The two rules are defined as either scheduled or responsive.

1. Works are fixed at intervals of time or points in time for maintenance and at a fixed time for improvement or construction works.
2. Responsive: Road works are triggered when road condition reaches a critical threshold known as ‘intervention level’. It is considered to be very useful for judicious disbursement of maintenance funds.

2.5.4 The Road Maintenance Process

The approach involves defining activities, planning, allocating resources, overseeing implementation, monitoring and evaluation of works [30]. It normally contains the following components:

1. **Inventory**: This is used as the basic reference for planning and carrying out maintenance and inspections. Inspection of road condition is the process of taking physical measurements of defects on the road network in the field.
2. **Maintenance needs**: These are determined by comparing the measurements of road condition with predetermined maintenance intervention levels that are based upon economic criteria.
3. **Costing**: Unit costs are applied to the identified maintenance tasks to determine the budget required.
4. **Priority setting**: If the budget is insufficient for all of the identified work to be carried out, it is then necessary to determine priorities to decide which work should be undertaken and which should be deferred.
5. **Execution of works**: The work identified is carried out through with the assistance of several systems of scheduling and cost-accounting.
6. **Monitoring**: Monitoring serves two purposes. That is it ensures that work identified has, in fact, been carried out and it also provides data to enable unit cost and intervention levels to be checked and adjusted if necessary.

2.5.5 Benefits of Road Maintenance

The benefits of road maintenance include the protection of initial capital investment in road construction, reduction in transport costs, traffic safety, environmental sustainability and the facilitation of social and economic development.

2.5.5.1 Protection of Investments

Road maintenance prevents the loss of investment made in an initial road construction. Routine and periodic maintenance cost for the entire life of a road is estimated to be between 2 and 3 percent of the initial capital investment [31] However, neglected maintenance could cause this amount to increase. According to Harral and Faiz [32] timely maintenance expenditures of US $12 billion in Africa would save road reconstruction costs of $ 45 billion over a decade. A [31] estimates the threshold of capital investment which is lost on annual basis from neglected maintenance to be about 1 to 3 percent of GDP of individual countries in Sub Saharan Africa. About 75 percent of this is in the form of scarce foreign exchange. In Latin America and the Caribbean equivalent figures were estimated at $1.7 billion per year in 1992, amounting to 1.4 percent of the individual country's GDP. A summary of the replacement costs of lost capital from neglected maintenance in some selected African countries is presented in Figure 4.

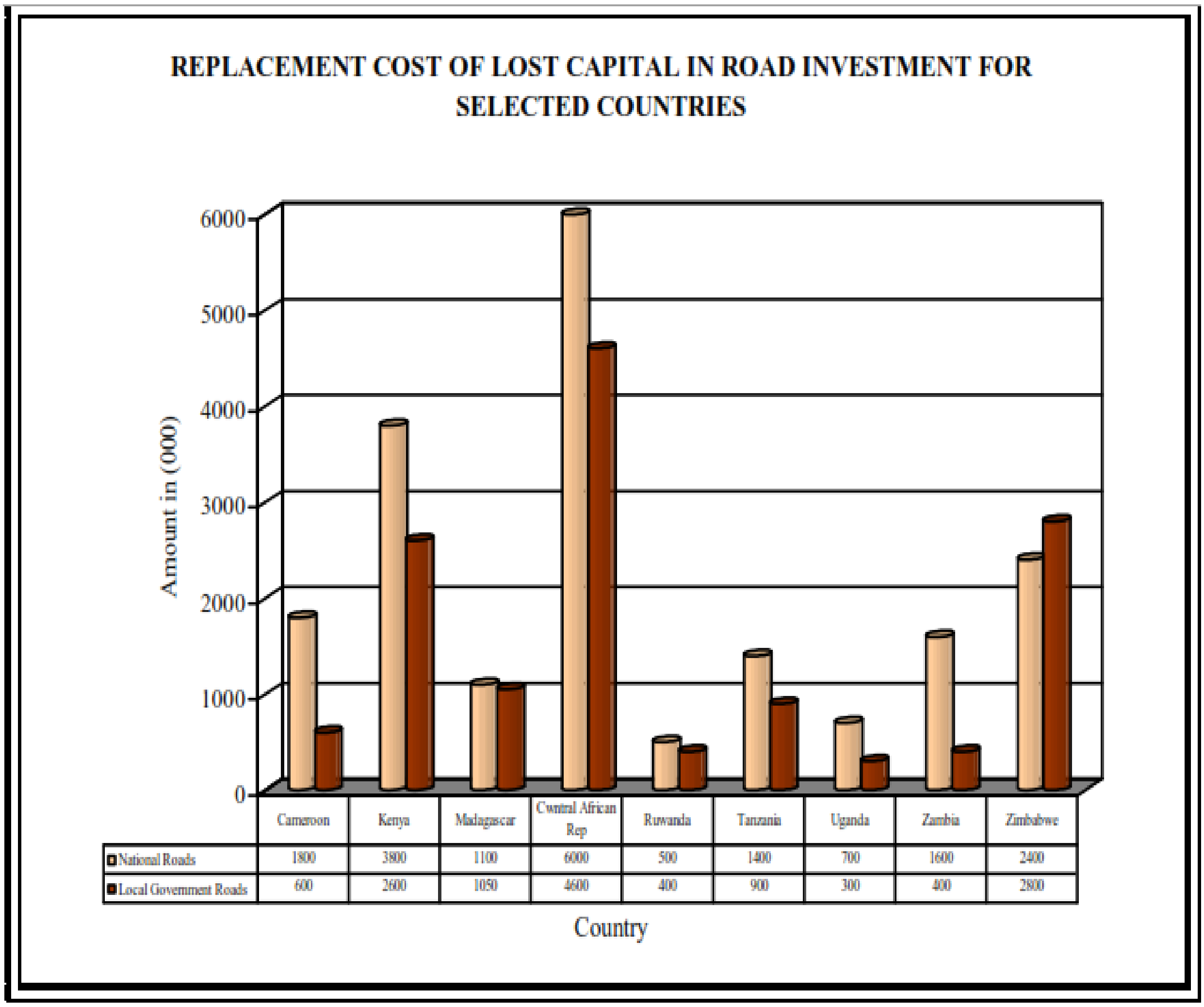


Figure 4: Replacement Costs of Invested Capital.

Source: Highway Development & Management [31].

2.5.5.2 Reduction in Transport Costs

Empirical evidence suggests that well maintained roads reflect in savings in vehicle operating cost (VOC). This is from reduced fuel and oil consumption, vehicle maintenance, tire wear and vehicle depreciation [33]. An illustration of the relative discounted life cycle costs of maintenance spending scenarios is provided in Figure 5. For, a traffic level of about 1000 vehicles/day a road in good condition will require 2 percent of discounted total costs to be spent on maintenance. However if maintenance funds are reduced, VOC's are likely to increase by about 15 percent. If there is complete neglect of maintenance, a paved road will eventually start to disintegrate and annual VOC will increase by 50 percent and if continued will result in the need for new road development [34]. Estimates that each dollar spent on patching on an annualized basis, saves at least US $3 [29] suggests a 10 fold or more returns on each dollar spent on patching.

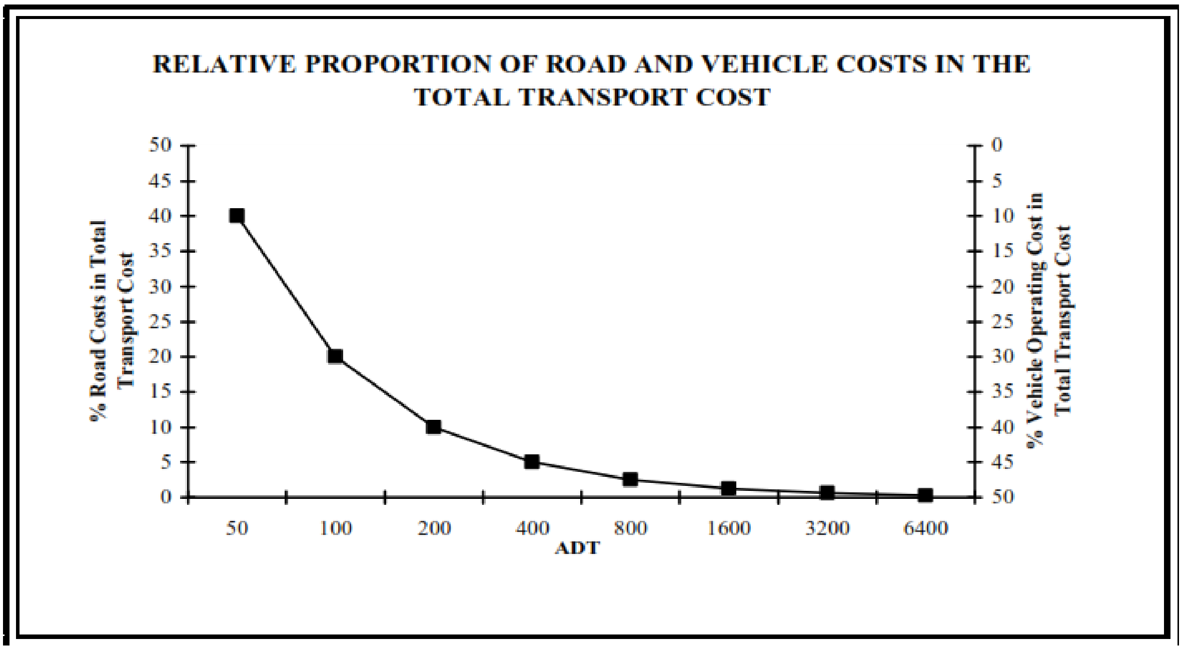


Figure 5: Relative Proportions of Road and Vehicle Costs in Total Transport Cost.

Source: Management and Financing of Roads [34].

2.5.5.3 Safety

A significant number of road accidents and fatalities can be directly attributed to the state of the road network. For example, inadequate skid resistance on neglected roads can contribute to traffic accidents [34]. Potholes pose a threat to all road users, particularly to cyclists and motorcyclists. The correction of such defects through road maintenance interventions can reduce the number of road accidents. However, improved riding quality from road maintenance interventions can also have negative impacts from increased speeds which can result in accident fatalities [34].

2.5.5.4 Environmental Sustainability

Road maintenance has a positive impact on the environment. For example, well planned maintenance schemes can have good environmental vehicle performance which can reduce vehicular pollution. However road maintenance can also cause negative impacts through environmental damage such as water contamination from oil spillage, poor air quality from dust pollution and noise and vibration during construction [29].

2.5.5.5 Facilitation of Social and Economic Development

The road network is the only transport infrastructure that reaches virtually any location. Logically a road is the main provider of individual and goods mobility. Improvement in the quality of road service therefore increase personal mobility and facilitate economic growth which contributes towards poverty reduction in developing countries [29].

2.5.6 Causes of Poor Road Maintenance

The road maintenance problem in developing countries can be attributed to the large size of the road network, the mode of road maintenance management and funding shortfalls [33]

2.5.6.1 Road Network Size

Roads built at the beginning of post-colonial period in most Sub Saharan-African countries have been increased due to increased growth. Also though roads are designed for a twenty (20) year life they tend to last for only ten (10) years. This is attributed to traffic growth and the problem of overloading which causes roads to deteriorate at a faster rate. This has resulted in many roads coming to the ends of their design life at the same time, increasing the need for reconstruction [21].

2.5.6.2 Road Maintenance Management

Road management is described as the combination of technical and administrative actions for retaining the road in the state that it can perform its required function [30]. The asset value of the road network in Sub-Sahara Africa is in the order of US $ 150 billion which is a huge asset by any standard. He indicates that, even though the asset value of roads is huge, they are not subjected to market discipline [34]. Most public road administrations responsible for keeping the road networks in good condition do not know the asset value of these roads or the economic consequence of poor maintenance. Roads are therefore administered like a small government department with internal planning, contracting, supervision and the actual execution of maintenance works. This creates operational and structural inefficiencies resulting from overstaffing, lack of discipline and control. Others are lack of accountability which is a disincentive for good performance [29].

Asset management is recommended for effective road maintenance management. It is based on enhancing the capital value of the asset. The approach combines management, financial, economic, engineering and other practices for effectiveness. It requires the use of a multi-disciplinary approach to management to develop and implement programs for asset creation, operation, maintenance, renewal and disposal, over the life cycle of the asset. Performance monitoring is also needed to ensure that the desired levels of service and other operational objectives are achieved at optimum cost [35].

The general direction of the approach includes the following.

A. Establishing a more autonomous road agency.
B. Identifying clear roles and responsibilities between the autonomous road agency and the parent ministry.

C. Streamlining the structure of the road agency and improving terms and conditions of employment for road agency staff.
D. Separating the planning and management of roads from implementation of road works and replacing force account with contracting of work to the private sector.

These actions regularly produce cost savings of 15 to 20 percent and exceptionally, may reduce cost by 30 percent or more. However there is no empirical evidence to support this assertion [36].

2.5.7 Road Maintenance Funding

Many countries in Africa and Asia have invested heavily in road construction over the last fifty (50) years with the help of international funding agencies and donors. Unfortunately, these countries did not succeed in allocating sufficient financial resources of their own to continue the investment in the maintenance of their networks [37].

2.5.7.1 Cost - Effective Maintenance Practices

Cost effective mechanisms are also introduced to cut down the cost of maintenance. The options for maintenance are varied according to the type of road and by the type of contracting and procurement systems chosen [37]. These include the following.

i. 'Term Maintenance': This involves outsourcing road maintenance activities to contractors on a long term basis. The contractor is paid for agreed work done over a specific term according to contracted unit rates. The advantages are that it ensures a more efficient use of available resources, greater flexibility with financing and allows for up front projects to proceed where they have been deferred or delayed under government budgeting. It also allows for greater control of cash flow and lower risk to the principal which generates savings which can be invested in other services. However, without the 'right' performance criteria being established this type of contract can fail because performance cannot be measured nor controlled [37].
ii. 'Performance Based' maintenance contracts: The contractor makes a bid based on his assessment of the work to be undertaken to keep the road in a specified condition. Provided the road is kept up to standard the contractor will be paid according to the bid irrespective of the work undertaken. Penalties are included if a specified standard is not achieved and special provisions are made for severe road damage due to unforeseen situations such as extreme weather [37].
iii. Labor Based Road Construction Methods: According to the comparative studies of employment-intensive and equipment-intensive projects have shown that labor based

methods of road construction are cheaper than equipment intensive methods. Whilst these methods may be cost-effective, they need careful planning, oversight and support from road management organizations for sustenance in the long-term [37].

2.5.7.2. The Road Fund Approach

This involves an off-budget road maintenance financing arrangement created as the main source of finance for road maintenance. It operates on a "user charge" system to generate revenues. It emerged in some developed countries as far back as the early nineties. For example the UK set up a Road Improvement Fund from 1910 to 1920; Japan established the Road Improvement Special Account in 1954; the United States of America (USA) established the Highway Trust Fund in 1956 and New Zealand established their Land Transport Fund in 1953. The advantage is that money can be accumulated and spent over several years on road maintenance without being constrained by the annual government budgeting cycle. However, most developing countries which applied the system could not provide the expected flow of funding for road maintenance for a number of reasons. This is because according to [34] the system was purely administrative with no legal backing nor financial rules and regulations [38] also indicated that there was a weak correlation between earmarking and the proportion of funds devoted to roads. He explained that there was no strict budget discipline and revenues were often not spent on roads but were diverted to other sectors.

There was no explicit connection between the rates of taxation and the levels of road maintenance provision and regular work schedules were distorted by the erratic flow of funds. Thus according to [34] it was impossible to sustain road maintenance programs by this approach.

2.6. Prioritization

A common feature is that any prioritization of maintenance projects is concerned only with the forthcoming financial year and is based upon budget allocation arising from the network view [39]. Depending on the funding levels, location, and specific conditions of a transportation agency, different methods ranging from a simple subjective ranking of projects based on judgment to comprehensive optimization by mathematical programming models, are being used for determining priorities [40].

2.6.1 The Analytic Hierarchy Process and Analytic Network Process

The foundation of the Analytic Hierarchy Process (AHP) is a set of axioms that carefully delimits the scope of the problem environment [41]. It is based on the well-defined mathematical structure of consistent matrices and their associated right eigenvector's ability to generate true or approximate weights [42] and [43]. The mathematics of the AHP and the calculation techniques are briefly explained by Coyle [44] and [45] but its essence is to construct a matrix expressing the relative values of a set of attributes.

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision making process [46], to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. Both qualitative and quantitative information can be compared using informed judgments to derive weights and priorities. AHP is a general problem-solving method that is useful in making complex decision (e.g. multi-criteria decisions) based on variables that do not have exact numerical consequences [47].

Designed to reflect the way people actually think, AHP is a mathematical method developed in the 1970"s by Dr. Thomas Saaty, while he was a professor at the Wharton School of Business, and continues to be the most highly regarded and widely used decision-making theory [48].

The Analytic Network Process (ANP) is the most comprehensive framework for the analysis of societal, governmental and corporate decisions that is available today to the decision-maker. It is a process that allows one to include all the factors and criteria, tangible and intangible that has bearing on making a best decision. The Analytic Network Process allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback best captures the complex effects of interplay in human society, especially when risk and uncertainty are involved [49].

One of the major advantages of the AHP is that the analysis does not always require statistically significant sample size. The simplicity of AHP approach is that, unlike other" conjoint" methods, the qualities (or levels) of different attributes are not directly compared. The AHP approach thus removes the need for complex survey designs and can even be applied (in an extreme case) with only a single respondent [50]. The Analytic Hierarchical Process (AHP) is one of the methodological approaches that may be applied to resolve highly complex decision making problems involving multiple scenarios, criteria and actors [46].

The techniques including AHP and Fuzzy AHP have been selected to obtain preference weights of land suitability criteria in a case study area located in south-east Queensland [51]. According to them, these techniques have proved useful to handle the problems which involve the design of alternatives which optimize the objectives. On the other hand it enables researchers to put more expert knowledge together to make more precise decision and moderate personal. Kurttila et al. [52], Stewart et al. [4], Usman and Murakami [53] and Osuna and Aranda [54] have pooled AHP with SWOT to provide a new hybrid method for improving the usability of SWOT analysis. However, instead of SWOT the AHP uses the ideas of Benefit–Opportunity–Cost–Risk (BOCR) from which SWOT was adopted. BOCR modeling using AHP/ANP receives large popularity in a decision making society in last few decades [55].

2.6.1.1. AHP Application

Analytical Hierarchy Process (AHP), has been extensively used in almost all the applications related to MCDM or MCDA are known acronyms for "multiple criteria decision making" and "multiple criteria decision analysis" in the last 20 years and used in scientific studies, adopted in many applications including resource allocation, business performance evaluation, project selection, auditing and additional application areas include problems in public policy, marketing, procurement, health care, corporate planning and transportation planning [56].

AHP and its broad application across a variety of natural resource and environmental problems have been mentioned by Schmoldt *et al* [57]. AHP application can be noticed in the studies related to coastal management and resources. Analytic Hierarchy Process can be useful as a decision-support method in project management in instances where a few options (be it requirements, risks or other "alternatives" need to be prioritized or selected [58].

AHP application can be seen in Abad [59] work as a part of environmental impact assessment and integrated coastal zone management studies. Ni *et al.* and Qin *et al.* [60] describe their use of AHP in determining the optimal length and location for a coastline reclamation project considering both developmental and environmental factors.

2.6.2. Super Decision Software for AHP and ANP

The Super Decisions software implements the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) for decision making with dependence and feedback, a mathematical theory for decision making developed by Thomas L. Saaty. The software for the decision making with dependence and feedback was developed by William Adams in 1999-2003. He and his team have developed software which can undergo AHP and ANP and is known as Super Decision from Creative Decisions Foundation, 4922 Ellsworth Avenue, Pittsburgh, PA 15213, USA [61]. Adams and Saaty mentions that ANP is an extension of his Analytic Hierarchy Process (AHP) for decision making which involves breaking down a problem into its decision elements, arranging them in a hierarchical structure, making judgments on the relative importance of pairs of elements and synthesizing the results [62].

With the AHP the process is top-down. With the ANP it is recognized that there is feedback between the elements in different levels of the hierarchy and also between elements in the same level, so the decision elements are organized into networks of clusters and nodes. The Super Decisions software is a simple easy-to-use package for constructing decision models with dependence and feedback and computing results using the super matrices of the Analytic hierarchy process and Analytic Network Process [63]. For making AHP and ANP calculations easier it was developed Super Decision Software by T. Saaty which implementing the AHP and ANP for decision making with dependence and feedback. The process of decision making using AHP methodology looks like the following: at the top it is created the main goal (Level 1); by doing pairwise comparison the criteria of importance getting their weights (Level 2); and finally at the bottom level there are situated the alternatives (Level 3), which are compared according to each criterion [64].

In AHP method, from the goal to the criteria and to the alternatives arranged in a hierarchic structure. This hierarchy structure is presented in figure 6. The hierarchy consists of 3 levels: main goal, criteria of importance and alternatives (choices). The main goal putted on the first the criteria in the second and the alternatives on putted on the bottom unlike to Analytic Network process in which all criteria have an equal importance with the main goal. In purpose to choose the best option it was made by prof. Saaty special scale from 1 to 9, using which all criteria of importance and alternatives are evaluated. The goal of practical part of this paper is to choose the best country to invest money [65].

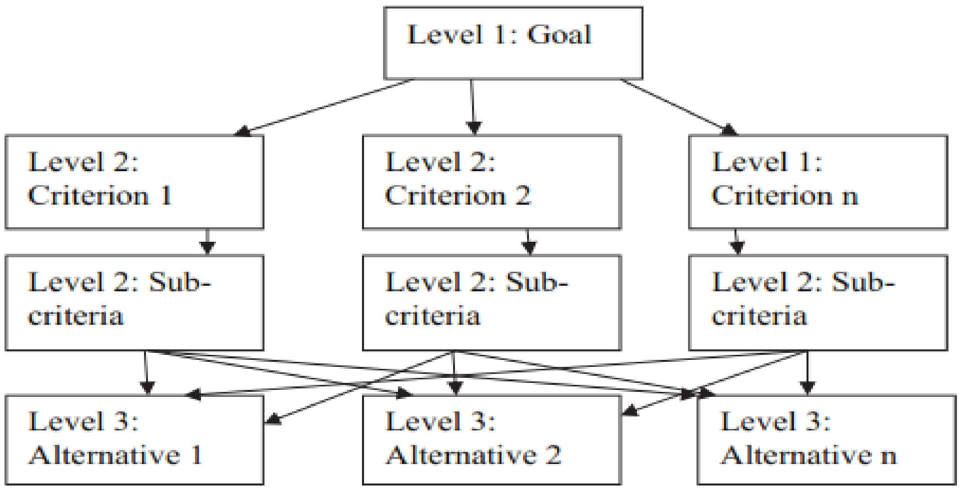


Figure 6: Levels of hierarchical structure of decision making process with use of AHP.

Source: International Journal of multi criteria decision based model for road network [66].

2.7 Decision Analysis Module for Excel (DAME)

There are many Group evaluation techniques used for decision making and group decision making is always challenging. Today there are a whole software packages specializing only in decision analysis just like Expert Choice, for example. But what if you don't want to shell out thousands of dollars and achieve a comparable result? There is a way and it is rather simple and virtually free. DAME stands for Decision Analysis Module for Excel and it is quite a useful solution. Decision making in situations with multiple variants, multiple criteria and multiple decision makers is an important area of research in decision theory and has been widely studied [67]. When compared to other software products for solving multi criteria decision problems, DAME is free, able to work with scenarios or multiple decision makers, allows for easy manipulation with data and utilizes capabilities of widespread spreadsheet Microsoft Excel [68]. On the contrary to similar packages it is very important that DAME add-in is not just a black box but it displays all intermediate calculations. Important feature is also using Geometric Mean Method which is very fast comparing to Saaty’s Method and therefore all calculations are instant. In DAME users can structure their decision models into three levels – scenarios/users, criteria and variants [69]. Standard pair-wise comparisons are used for evaluating both criteria and variants. For each pair-wise comparison matrix there is calculated an inconsistency index to indicate consistency of their pair-wise comparisons [70]. There are provided three different methods for the evaluation of the weights of criteria, variants as well as the scenarios/users Saaty's Method, geometric mean and fuller triangle [71].

CHAPTER THREE

MATERIALS AND RESEARCH METHOD

3.1 Study Area

The study area selected for this research is Addis Ababa city which is the capital city of Ethiopia. Addis Ababa is not only the capital city of Ethiopia but it is also the seat of African Union head quarter and more than 100 embassies. Due to the fact that Addis Ababa is the political and economic center of the nation, it is the highly populated city in the country. Addis Ababa is one of the metropolitans in Africa which is found at the horn of the continent with geographical coordinates $9^{o}1'48''$ North and $38^{o}44'24''$ East and an average elevation of 2355 above sea level. The city has a total area of about 530.14 Km^2 and a population of 2,738, 248 according to 2007 censes. The city is divided in to 10 administrative sub-cities and 99 kebeles. From the 10 sub cities the roads that are planned for maintenance during the study periods only ten road sample sections were selected by purposive sampling method.

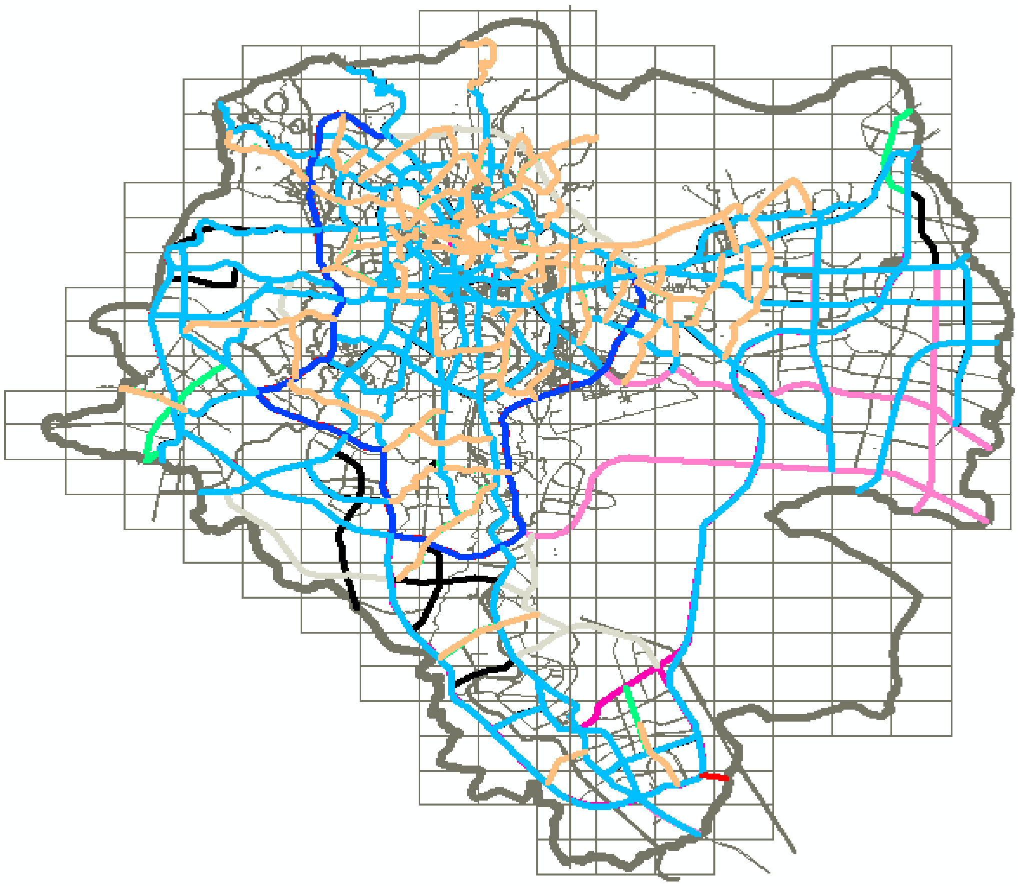


Figure 7: Map of the study area (source: AACRA road master plan road network updated March-2012.dwg base map).

3.2 Study Design

Explanatory, descriptive and comparative studies are used. The occurrence of certain distress on the selected sample roads were briefly explained by taking a pictorial account of the phenomena after that the result were compared with the previous studies and related literatures.

3.3 Study Populations

The research includes 10 road sections selected from the following road hierarchies of AACRA. Table 5 below shows the road hierarchy classification of Addis Ababa city 10 administrative sub-cities.

Table 5 Addis -Ababa Road Network classification

Road Class	
PAS	Principal Arterial Streets
SAS	Sub Arterial Streets
C	Collector Streets
L	Local Streets

Source: Addis Ababa Road Authority (AACRA).

By taking in account of these road classifications, in this research the data's like Pavement Condition, Types of pavement distress, Extent/Severity of pavement distress and Width of road section is studied for the selected samples roads only.

3.4 Sample Size and Sampling Procedures

In this research it is not possible to include all the road section of Addis Ababa city that are planned for maintenance therefore only 10 representative road sections were selected using purposive sampling technique. The sampling technique considers

[1]. Fair representative road classes and

[2]. Road section that include various types of distresses. The road sections are selected from the planned road sections for maintenance by the AACRA in 2010 E.C the following table will show the selected road section data.

Table 6: study sample road sections.

Road Name Origin - Destination	Road Hierarchy	Total Area(m^2)
Sar Bet -Minaye Biulding	PAS	9884
Alemtsehay Bridge-Wolega Hotel	SAS	25900
Adissu Gebeya-Comercial Bank Powlos Branch	SAS	11942

Paster - Shewa Tsega (Mesalemiya)	Local	6874
Berbere Tera -Mola Maru (Kebele Meznagna)	Local	5719
Debrezeit Menged -Sene Zetegn-Behere Steige	Collector	7030
Leadership Institute Jan Meda	Local	5400
Alert Round About -Fm Radio Station	SAS	12250
Asfaw Tekle Hotel - Ehil Berenda	Collector	27000
Kolfe Coprative School - Filidoro School	PAS	42408

3.5 Study Variables

The dependent and independent variables that are used in this research were mentioned below.

3.5.1. Dependent variable:

Prioritization of road section for pavement maintenance.

3.5.2. Independent variables:

- ✓ Road condition data
    - Distress type
    - Severity of distress
    - Area of distress
- ✓ Ranking of dominant distress from Decision Analysis Module for Excel.
- ✓ Analytical Hierarchy process preference rating
- ✓ Ranking priority from super decision software.

3.6 Methods of Data Collection and Management

Data collection plays the major role in the output of the research. The wrong data may lead to a wrong decision which in turn leads to wastage of precious resources like money, time and labor resources. Data collection is a back bone for a research to make a convincing and acceptable prioritization decision. Therefore, attention should be given for the data collection method and the instruments used.

3.6.1 Data Collection Instrument

The instruments used to conduct a field condition assessment survey are: - Wheel odometer, scale and meter. To measure the distance from origin to destination of a selected road samples a wheel odometer were used. The scale was used for measuring the area of distresses and the meter for measuring the road width, damage length and damage width.

3.6.2 Data Collection Method

In order to achieve the specific objectives of these study different types of quantitative and qualitative data was used. All the data's are obtained from the primary and secondary sources. The primary data was collected using the following techniques:

- Interview: - The maintenance experts and officials in the AACRA were interviewed to get the information regarding the data collection and identification of distresses , how the maintenance prioritization were done in the authority, fund allocation and general information about the roads expected to be maintained in 2010 E.C.
- Field condition survey: - A field condition surveys were conducted to measure the length, width and the severity of distresses and to identify the types of distresses occurred on the selected sample roads, and also to get the information about the sample roads like length width and location.
- Questioner: - A questioners were distributed for maintenance engineers in order to incorporate the verbal judgments and preferences of maintenance experts in the prioritization of maintenance work.

The secondary data was collected from existing data sources. These data was mainly obtained from AACRA.

- Road classification: - The road classifications used in this study were adopted from AACRA classification system. The sample roads selected for this study includes Principal Arterial Street (PAS), Sub Arterial Street (SAS), Local and Collector type of roads.
- Maintenance data for planned to be maintained roads in 2010 E.C. The ranking given by the AACRA.

In general, the data acquiring was challenging as there was no trend in the authority for a permanent data acquisition and computerized system in any of the field operating system.

Figure 8: Distress data collection process photos.

Pavement condition data collected in this study includes different types of distresses. The selected sections were found to be prone to a number of distresses.

Table 7: AACRA Pavement and Inventory Condition Survey Format.

Road number	Road Name		Origin	Wereda
Block Number	Length	Start Chain age:	Start Description	Start Code
Measured Length		End Chain age:	End Description	End Code
Surface Type	Surface Width		Carriage way	Road Class
No Lane		No Ways	Survey Date	Rates

PAVEMENT

Chg	Pothole	Croc.Cr	Rutting	Subsid	Corru	Trns.Cr	Long. Cr	Bleed	Ravell	Shov	La Ed

The above able shows the data sheet format used by AACRA in order to record the detail information about a road section. The sheet has two parts the first part gives detail information about the road section and the second is about the length width and severity of distress occurred at specific section. The inspections was conducted by walking through the selected sample road sections and measuring the length from origin to destination using odometer and then record the occurred distresses using different measuring instruments and recording on the AACRA format shown on Table 7.

3.7 Data Processing and Analysis

The data obtained from primary and secondary data collection were analyzed using super decision software by applying Analytical Hierarchy process concept.

3.7.1 The Analysis of Identified Dominant Distresses

The dominant distresses were analyzed by using the field condition assessment survey data

Record the length, width and severity of each distresses occurred at the sample road sections using the measuring instruments.

The percentage damages of each distress were calculated for each selected road sections. The length and width dimensions of the selected road sections was obtained from the field survey then after the percentage damage for each selected road section was calculated. First the distress area (DA) of the road section was obtained by multiplying the Length and the Width of the total damage of the distress and the total damage area (TDA) obtained by summing up all the distress damage areas. Finally the percentage damage was calculated using a formula;

$$\% \text{ Distress} = DA/TDA * 100$$

Where; DA – Distress Area, TDA – Total Damage Area

- Analysis of distresses data using DAME (decision analysis module for Excel)
  - ✓ Scenarios by considering the maximum occurrence of distress occurred on the selected roads.
  - ✓ The Criteria's were framed by considering the Area and the Severity of each distresses, and
  - ✓ The Variants (distresses) were prepared by incorporating the visually observed distresses on the sample roads.
  - ✓ There are three different methods in DAME for the evaluation of weights of criteria, the variants as well as the scenarios/users – Saaty's Method, Geometric Mean Method and Fuller's Triangle Method. Among those three methods, the Geometric mean method was used in this study to rank the distresses.
  - ✓ By taking the top five ranked distresses from DAME the processing and analysis for the prioritization of roads for maintenance was done on the super decision software.

3.7.2 Prioritization of pavement sections for maintenance on Super Decision Soft Ware

In this study the prioritization ranking for the roads the processing and analysis of data's obtained from DAME and the road class were utilized. The data from DAME were used as sub criteria and road class data which is obtained from AACRA were used as criteria in the prioritization process. For each criteria and sub criteria pair wise comparison was done to get the percentage influence in the prioritization of roads. To determine the weights for the alternatives on the super decision software the first procedure is to build a hierarchy model.

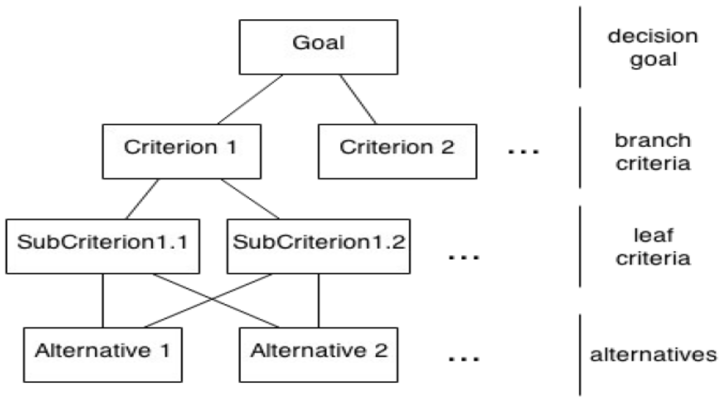


Figure 9: Hierarchies of goal, criteria, sub criteria and alternatives on super decision software

The lines connecting the goal to each criterion means that the criteria must be pairwise compared for their importance with respect to the goal. Similarly, the lines connecting each criterion to the sub criteria was pair wisely compared to the alternatives mean the alternatives are pairwise compared as to which is more preferred for that criterion and sub criterion. Thus in the hierarchy that is shown below which shows the connectivity of alternatives, sub criteria's and criteria's to the goal then the weightage factors for each were calculated using a pairwise comparison matrix. The matrix was filled using AHP concept in the AHP there are scale with values from 1 to 9 to rate the relative preferences for the items as shown in the table 8 below.

Table 8: Scale values with relative preferences.

Verbal Judgment of Preference	Numerical Rating
Extremely preferred	9
Very strongly to extremely	8
Very strongly preferred	7
Strongly to very strongly	6
Strongly preferred	5
Moderately to strongly	4
Moderately preferred	3
Equally to moderately	2
Equally preferred	1

Based on the judgmental preference, questioners were distributed for the maintenance experts in the AACRA for 15 engineers, 9 engineers were from AACRA and 6 engineers were the engineers from JiCA who works co jointly with the AACRA on maintenance department.

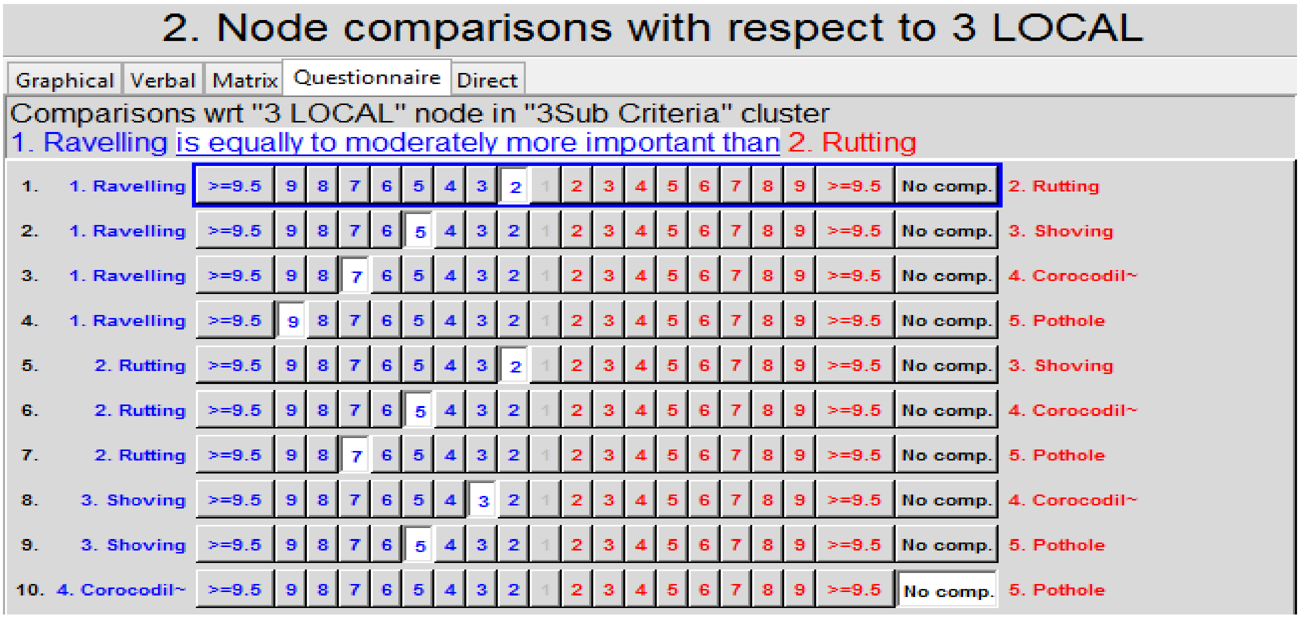


Figure 10: Sample format for matrix on super decision soft ware

Then in order to check the reliability of the obtained data the consistency and sensitivity analysis was done. The consistency shows whether the questioner data can be logically accepted or not using consistency ratio and it's accepted if it is less than 0.1 and also the sensitivity was done to analyze how the priorities of the alternatives change as we vary the priority of a criterion. A positive reciprocal matrix which consists of a different set of pairwise comparison is represented where i, j and n, n indicates the number of alternatives being compared within one set of pairwise comparisons, a_{ij} denotes the importance of alternative i over alternative j.

The judgmental values to each element in matrix A are assigned, and the priority vector w is determined. Saaty's Eigen vector method is often applied to derive the priorities of the alternatives and compute the value of w_0, the principal Eigen vector, the vector corresponding to the largest Eigen value, k_{max} of the matrix A.

The comparison among the AHP and the current approach used by the AACRA were compared in the fourth section of this study.

3.8 Ethical Considerations

The data was collected only after ethical permission or a Consent letter gained from AACRA and civil engineering department of Jimma University. In order to avoid confusion or misunderstanding the aim of the study was clearly described to the organization, individuals and to anyone who will have contribution for the study. Personal information's will be kept confidential.

3.9 Data quality assurance

Checking again for the completeness and internal consistency was performed. There were no any inconsistency exists in the correction, return or exclude measures were taken. All data's will be kept confidential and going to be used only for research purpose.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Condition Assessment Survey

A condition assessment survey was done for the selected 10 sample roads and the results were recorded using the condition assessment survey sheet of AACRA. The data sheet has two parts. The first part of the sheet about the general description of the road and the second part were about the distress recorded as severity/ width/ length format for each distress at each station. For example the distress data recorded as 2/4/5 means 2 indicates severity of the distress, 4 indicates the width of a particular distress type and 5 indicates the length of the specific distress occurred at that specific station. The following Table 9 shows the condition data for the road sample1.

Table 9: distress data for road sample one

Road number		Road Name	Origin	Wereda
188.1		Minaye Building	Sar bet	
Block Number	Length	Start Chain age:	Start Description	Start Code
000	1412m	0+000		
Measured Length	End Chain age:		End Description	End Code
1410m	1+400		-	-
Surface Type	Surface Width		Carriage way	Road Class
Paved	7		7	PAS
No Lane			Survey Date	Rates
2			14/02/10 E.C	

PAVEMENT				
Chainage	0+000 - 0+400	0+400 - 0+800	0+800 - 1+200	1+200 - 1+410
Pothole	2/4/5	2/3/4	2/6/7	2/5/8
		2/4/4		
Crocodile Crack	2/4/4	2/5/8	2/6/7	2/4/5
	2/3/4			
Rutting				
Subsidence	3/4/5	3/4/5	3/5/8	3/4/4
		3/6/7	3/3/4	
Corrugation				
Transverse .Cr.				
Longitudinal. Cr.	2/4/5			
Bleeding				
Raveling	2/5/5	2/7/8	2/7/7	2/8/10
			2/4/5	
Shoving				
Lacy Edge	3/4/5	3/10/12	3/11/15	3/6/8
		3/5/6	3/5/8	3/3/5
	3/9/11	3/6/7	3/8/8	3/1/7

In this study ten sample roads were selected to show the applicability of super decision software based on the Analytical Hierarchy Process technique depending on the expert's choice (preference). The road sample one represents the route that originates at around Sar bet and its destination is at Minaye Building. The route has a total length of 1410 (one thousand four hundred and ten) meters and 7 meters carriage way width. The length between the two successive stations was 400 meters except for the end station that was 212 meters. The road identification number that was designated by AACRA was 188. According to the AACRA road classification system this road was categorized under Principal Arterial Street (PAS). At this road section six types of distresses were observed and recorded during the field condition survey at each station. The major distress types occurred at this sample road includes; Pothole, Crocodile Cracking, Subsidence, Ravelling and Lacy Edge.

Table 10: Damage area and percentage damage calculation for road one.

Road from Sar Bet to Minaye Building	Distress Area L*W of distress (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	130	1310	9.92
crocodile Cracking	130	1310	9.923
Subsidence	150	1310	11.45
Longitudinal Cracking	20	1310	1.53
Raveling	230	1310	17.56
Lacy Edge	650	1310	49.62

To determine the percentage damage of the sample road the length and width data of the distresses were required. This data were obtained from the field measurement of each distress types with the appropriate distress measurement technique. The areas of each distress were calculated by multiplying the length and the width of each distress occurred on each sample road. As discussed above, at road sample one, six types of distresses were observed and recorded during the field condition assessment survey at each station.

The distresses observed includes pothole, crocodile Cracking, Subsidence, Longitudinal Cracking, Raveling and Lacy Edge. For those distresses the area was calculated by multiplying the length and width of the distress for each particular distress types as shown in the table 10. The Total Damage Area were obtained by summing the Distress Area values of each distress. The percentage damage of distresses was obtained by dividing Distress Area to Total Damage Area and multiplying by 100.

Table 11: Distress data for road sample two.

Road number	Road Name		Origin		Wereda
66	Wolega Hotel		Alemtsehay bridge		
Block Number	Length	Start Chain age:	Start Description		Start Code
000	1400m	0+000			
Measured Length	End Chain age:		End Description		End Code
1400m	1+400		-		-
Surface Type	Surface Width		Carriage way		Road Class
Paved	18.5		7		SAS
		Survey Date	15/02/10 E.C		Rates
PAVEMENT					

Chainage	0+000 - 0+400	0+400 - 0+800	0+800 - 1+200	1+200 - 1+400
Pothole	2/5/5	2/7/8	2/7/7	2/5/6
	2/4/5		2/7/10.	
Croc.Crack		2/1/4.	2/3/4	
Subsidence		2/2/5	2/2/7.	
Long. Cr	2/4/5			
Ravelling	2/6/9.	2/7/8	2/7/10	2/8/9.
		2/4/5		
Shoving	2/8/9.	2/9/9.	2/9/10	
	2/6/7.		2/8/11.	2/7/9.
Lacy Edge	3/4/5	3/4/5.5	3/6/7	3/8/8
	3/4/8	3/5/6.		

The road from Alemtsehay Bridge to Wolega Hotel was categorized under Sub Arterial Street (SAS) and as of AACRA the unique identification number for this road were 66. For this sample road, the lengths between the two successive stations were 400m except for the end station that was 200m. During the field condition survey, at this road section mainly seven types of distresses were observed. The major distress types occurred at this sample road includes Shoving, Ravelling, Pothole, Crocodile Crack, Subsidence, Longitudinal Crack and Lacy Edge. The data for each distress types were measured and recorded for each station as shown in table 11.

The recorded data for this sample road reveals that, the shoving distress were occurred two times at the station from 0+00 up to 0+400 with medium severity, one times at the station from 0+400 up to 0+800 observed as medium severity, two times at the station from 0+800 up to 1+200 with the severity of medium condition and one times at the station from 1+200 up to 1+400 with medium severity. The Ravelling distress were occurred one times at the station from 0+00 up to 0+400 with medium severity, two times at the station from 0+400 up to 0+800 observed as medium severity, one times at the station from 0+800 up to 1+200 with the severity of medium condition and one times at the station from 1+200 up to 1+400 with medium severity. The Pothole distress were occurred two times at the station from 0+00 up to 0+400 with medium severity, one times at the station from 0+400 up to 0+800 observed as medium severity, two times at the station from 0+800 up to 1+200 with the severity of medium condition and one times at the station from 1+200 up to 1+400 with medium severity. The Crocodile Crack distress were occurred one time at the station from 0+400 up to 0+800 and one time at the station from 0+800 up to 1+200 with the severity of medium condition and one times at the station from 1+200 up to 1+400 with medium severity. The Subsidence distress were occurred one time at the station from 0+400 up to 0+800 with medium severity and one time at the station from 0+800 up to 1+200 with the severity of medium condition and one times at the station from 1+200 up to 1+400 with medium severity. The Longitudinal Crack distress was occurred one time at the station from 0+000 up to 0+400 with the severity of medium condition. The Lacy Edge distress type were occurred two times at the station from 0+00 up to 0+400 with high severity, two times at the station from 0+400 up to 0+800 observed as high severity, one time at the station from 0+800 up to 1+200 with the severity of high condition and one times at the station from 1+200 up to 1+400 with high severity. The length and width for each respective distress were measured and the details were given in the table 11.

Table 12: Damage area and percentage damage calculation for road two.

Alemtsehay Bridge - Wolega Hotel	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	250	1208	20.7
crocodile Cracking	16	1208	1.32
Subsidence	24	1208	1.99
Raveling	272	1208	22.52
Shoving asphalt	436	1208	36.09
Lacy Edge	210	1208	17.38

As shown in table 12, the area of the distresses observed at sample road two were calculated using the length and width of each distress types. As discussed earlier,Potholes, crocodile, Cracking, Subsidence, Raveling, Shoving asphalt and Lacy Edge were the distresses occurred at sample road two. The percentage damage of each those distresses were calculated by dividing the Distress Area to Total Damage Area and multiplying by 100.

Table 13: Distress data for route three.

Road number	Road Name		Origin	Wereda	
63	CBE Powlos Branch		Adissu Gebeya		
Block Number	Length	Start Chain age:	Start Description	Start Code	
000	1706m	0+000			
Measured Length	End Chain age:		End Description	End Code	
1706m	1+700		-	-	
Surface Type	Surface Width		Carriage way	Road Class	
Paved	7		7		SAS
	Survey Date		16/02/10 E.C	Rates	
PAVEMENT					
Ch.g	0+000-0+400	0+400-0+800	0+800-1+200	1+200-1+600	1+600- 1+706
Pothole	2/4/5.0	2/3/4	2/6/7	2/5/8	2/4/4
	2/2/13.				
Croc.Cr		2/1/3.5		2/4/6.	2/4/5.
Subsidenc		2/2/5	2/2/7.		
Ravell	1/6/9.	1/7/8	1/7/10	1/4/5	1/8/9
	1/4/3.25				
La Ed	2/4/5	2/3/5	2/6/7	2/4/8	2/5/6
	2/1/7	2/6/9.	2/4/11.	2/4/5.	

The road named CBE Pawlos branch starts from its origin Adissu Gebeya and ends at destination of Commercial Bank of Ethiopia Powlos Branch. This route has a total length of 1706 (one thousand seven hundred six) meters with a carriage way width of seven meters. This road sample has a length of 400 (four hundred) meters between the two successive stations except at the end station that was 106 (one hundred six) meters length. The specified road number designated by AACRA to represent this road was 63. According to the AACRA road classification system the road was categorized under Sub Arterial Street (SAS). At this road section mainly five types of distresses were observed and recorded during the field condition survey for each station. The major distress types occurred at this sample road includes; Pothole, Crocodile Cracking, Subsidence, Ravelling and Lacy Edge.

Table 14: Damage area and percentage damage calculation for road three.

Road from Adissu Gebeya to Comercial Bank Powlos Branch	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	156	752.5	20.73
crocodile Cracking	47.5	752.5	6.312
Raveling	285	752.5	37.87
Lacy Edge	264	752.5	35.08

Among the distress types which can affect the pavement; Pothole, crocodile Cracking, Raveling and Lacy Edge were the defect types which occurred on the road sample three. For those distresses the distress area, total damage area and the percentage damage of distresses were calculated as detailed in table 14. The Percentage damage area of these distresses depicts that this road section is highly affected by the raveling distress and lacy edge distress types.

Table 15: Distress data for route four.

Road number	Road Name		Origin	Wereda
AD 99	Shewa Tsega (Mesalemiya)		Paster	
Block Number	Length	Start Chain age:	Start Description	Start Code
000	982m	0+000		
Measured Length	End Chain age:		End Description	End Code
982m	0+982		-	-
Surface Type	Surface Width		Carriage way	Road Class
Paved	7		7	Local
No Lane: 2	Survey Date: 18/02/10 E.C		Rates	

PAVEMENT			
Ch.g	0+000 - 0+400	0+400 - 0+800	0+800 - 0+982
Pothole	3/5/7	3/6/8	3/7/9
	3/5/8.6	3/4/5	3/8/9.
	3/4/5		3/12/14.
	3/5/6.	3/6/8.	3/2/7.
Croc.Cr	2/4/4.	2/3/2004	2/4/5
		2/8/9.	2/6/10.
	2/6/10.	2/5/8.	2/5/7.
Ravell	2/7.75/8.	2/7/8	2/7/10
	2/8/12		2/8/8.5
	2/15/17.	2/11/11.	2/8/20.
	2/2/5.5	2/3/5	2/6/7
	2/4/8		

The road number 99 represents the road which originates at Paster and its destination at Shewa Tsega (Mesalemiya). This road is known by its name Shewa Tsega (Mesalemiya) road which is designated by AACRA and it was categorized under Local Street. The Pothole, Crocodile Cracking, Ravelling and Lacy Edge were among the distress types observed at this sample road. The information for all of these distresses was recorded during the field condition assessment survey and all of the information was detailed at the table 15.

The data obtained from the field condition assessment survey for this sample road shows that, the pothole distress were occurred four times at the station from 0+000 up to 0+400 with a high severity, three times at the station from 0+400 up to 0+800 observed as a high severity and four times at the station from 1+200 up to 1+400 with a high level severity. The Crocodile Cracking distress were occurred two times at the station from 0+400 up to 0+800 and three times at the station from 0+800 up to 1+200 and three times at the station from 1+200 up to 1+400 with the severity of medium condition.

The Raveling distress were occurred three times at the station from 0+00 up to 0+400, two times at the station from 0+400 up to 0+800 and three times at the station from 0+800 up to 1+200 with the severity of medium condition. The Lacy Edge distress type were occurred two times at the station from 0+00 up to 0+400 and one time at the station from 0+400 up to 0+800 and at the station from 0+800 up to 1+200 respectively with the severity level of high condition. The observed real condition of this sample road depicts that this pavement surface is highly affected by pothole distress among the other distress types.

Table 16: Damage area and percentage damage calculation for route four.

Road from Paster to Shewa Tsega (Mesalemiya)	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	561	1864	30.1
crocodile Cracking	315	1864	16.9
Raveling	888	1864	47.64
Lacy Edge	100	1864	5.36

The Potholes, crocodile Cracking, Raveling and Lacy Edge are the four distresses observed on route section four. As the calculated result shows the five hundred sixty one square meter area was affected by the pothole distress type, 315 square meter area was affected by crocodile Cracking distress type, 888 square meter area was affected by Raveling distress type and 100 square meter area was affected by Lacy Edge distress types. The Percentage damage area of these distresses set forth that this road section is highly affected by the raveling distress and Pothole distress types. As shown in table 16 raveling covers 47.64 percent of damage area among the total and the pothole covers 30.1 percent of distress among total 100 percent damage it implies that this distresses are dominant at this route section.

Table 17: Distress data for route five.

Road number	Road Name		Origin	Wereda
	Mola Maru (Kebele Meznagna)		Berbere Tera	
Block Number	Length	Start Chainage:	Start Description	Start Code
000	817m	0+000		
Measured Length	End Chain age:		End Description	End Code
810m	0+817		-	-
Surface Type	Surface Width		Carriage way	Road Class
Paved	7		7	Local
	Survey Date	17/02/10 E.C	Rates	
PAVEMENT				
Chainage	0+000 - 0+400	0+400- 0+800	0+800 - 0+817	
Pothole	3/3.5/11	3/5/8	3/7/7	
	3/8/10	3/1/3.	3/4/5	
Croc.Crack		3/1/3.5		
Ravelling	2/9.5/12	2/7/8	2/7/10	
	2/10/12.	2/6/9.	2/8/9.	
	2/4/5	2/5/10.	2/10/13.	
Shoving	2/6/8.	2/8/9.	2/5/7.	
	2/3/5.	2/4/4.5	2/2/7.	
Lacy Edge	3/3/3.5	3/1/1.5		

The road named Molla Maru (Kebele Meznagna) was originates at Berbere Tera and its destination is at Mola Maru (Kebele Meznagna). This sample road is categorized under Local Street as per the AACRA road classification system and it has a total length of 817 (eight hundred seventeen) meters with a carriage way width of seven meters. The length between the two successive stations was 400 meters except for the end station that was 17 meters. At this sample road section five types of distresses were observed and recorded at each station. The frequency of occurrence for each distress at each station also varies like the other sample roads. The pothole distress type occurs two times at the first two stations with a high severity and two times at the last station with a medium level of severity. The crocodile cracking occurs only one time at the station from 0+400 up to 0+800 with a high severity level. The raveling distress type occurs three times at the three stations with a medium level of severity. The shoving distress type occurs two times at each station intervals with a medium severity condition and the lacy edge distress types occur two times at the first two stations with a high severity condition.

Table 18: Damage area and percentage damage calculation for route five.

Berbere Tera -Mola Maru (Kebele Meznagna)	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	230.5	1133	20.34
crocodile Cracking	3	1133	0.26
Raveling	686	1133	60.55
Shoving asphalt	202	1133	17.83
Lacy Edge	11.5	1133	1.02

On route section five the percentage damage of the sample road were obtained from the length and width data of the distresses. This data were obtained from the field measurement of each distress types and the areas of each distress were calculated by multiplying the length and the width of each distress occurred on each sample road. On route section five mainly five types of distresses were obtained. The distresses observed includes pothole, crocodile Cracking, Raveling, Shoving asphalt and Lacy Edge. For those distresses the area was calculated by multiplying the length and width of the distress for each particular distress types as shown in the table 18. The Total Damage Area were obtained by summing the Distress Area values of each distress. The percentage damage of distresses was obtained by dividing Distress Area to Total Damage Area and multiplying by 100.

Table 19: Distress data for route six.

Road number	Road Name		Origin	Wereda
18C	Sene Zetegn-Bhere Steige		Debrezeit Menged	
Block Number	Length	Start Chainage:	Start Description	Start Code
000	1406m	0+000		
Measured Length: 1406m	End Chain age: 1+400		End Description	End Code
Surface Type: Paved	Surface Width: 7		Carriage way:7	Road Class: Collector
No Lane: 2	Survey Date	20/01/10 E.C	Rates	

PAVEMENT				
Chainage	0+000 - 0+400	0+400 - 0+800	0+800 - 1+200	1+200 - 1+406
Pothole	3/5/6.	3/7/8	3/7/7	3/4/5
		3/8/10		
	3/8/9.	3/4/5	3/3/9.	3/4/7.
Croc.Cr	2/5/7.	2/1/4.	2/3/4	2/5/9.
Rutting		1/3/4.		
Subsidence	1/1.5/2			
Ravelling	1/6/9.	1/7/8	1/7/10	1/4/5
	1/8/9	1/5/11.6		
	1/4/11.	1/8/9.	1/5/6.	1/3.5/13
Lacy Edge			3/6/7	

Road sample 6 was from Debrezeit Menged to Sene Zetegn-Bhere Steige. This sample road is categorized under Local Street as per the AACRA road classification system and it has a total length of 1406 (one thousand four hundred six) meters with a carriage way width of seven meters.The length between the two successive stations was 400m except for the end station that was 206m. According to the AACRA road classification system the road was categorized under Collector Street. At this road section mainly six types of distresses were observed and recorded for each station as shown above.

Rutting, subsidence, raveling, lacy edge, pothole and crocodile cracking were the six distress types that were observed and recorded at this sample road section. From those distress types, the pothole distress occurs two times at the first third and the last stations with a high severity and three times at the second station with a high level of severity. The crocodile cracking occurs one time at each station with a medium severity level. The rutting distress type occurs only one time at the second station with a low level of severity. The subsidence distress type occurs only one time at the first station with a low severity. The lacy edge distress type occur one time at the third station with a high severity condition and raveling distress type occurs three times at the first and second stations with a low level of severity and two times at the third and fourth stations with a low severity condition.

Table 20: Damage area and percentage damage calculation for route six.

Road from Debrezeit Menged through Sene Zetegn to Bhere Steigie	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	382	1056.5	36.16
crocodile Cracking	96	1056.5	9.09
Rutting	12	1056.5	1.14
Subsidence	3	1056.5	0.28
Raveling	521.5	1056.5	49.36
Lacy Edge	42	1056.5	3.98

The areas were calculated by multiplying the length and width of each distress. Among the distress types which can affect the pavement; Pothole, crocodile Cracking, Rutting, Subsidence, Raveling and Lacy Edge were the defect types which occurred on the road sample six. For those distresses the distress area, total damage area and the percentage damage of distresses were calculated as detailed in table 20. The Percentage damage area of these distress depicts that this road section is highly affected by the raveling distress and lacy edge distress types. Total damage area were obtained by summing the distress area values for each distresses. The percentage damage of distresses was obtained by dividing distress area by total damage area then multiplying by 100.

Table 21: Distress data for route seven.

Road number	Road Name		Origin Wereda	
GU 133	Jan Meda		Leadership institute	
Block Number	Length	Start Chainage:	Start Description	Start Code
000	900m	0+000		
Measured Length	End Chain age:		End Description	End Code
900m	0+900		-	-
Surface Type	Surface Width		Carriage way	Road Class
Paved	6		6	Local
No Lane: 2			Survey Date: 25/01/10 E.C	Rates
PAVEMENT				
Ch.g	0+000 - 0+400		0+400 - 0+800	0+800 - 0+900
Pothole	3/3.5/8.		3/5/7.02	3/4/7
Croc.Cr	3/5/5		3/3/3.	
Rutting	3/8/9.			
	3/3/5.		3/3/4.	3/6/7.
Corru	3/3/7.			
La Ed	3/3/3.5		3/1/1.5	3/4/8.
	3/9/11.			3/4/5.
	3/5/7.		3/4/9.	3/6/6.

The road identified with a designation of GU133 which is named as Jan Meda represents the road that starts around Leadership institute and its destination is at Jan Meda. This road was categorized under Local Street. The Pothole, Crocodile Cracking, Rutting, Corrugation and Lacy edge were among the distress types observed at this sample road. The information for all of these distresses was recorded during the field condition assessment survey and all of the information was detailed at the table 21.

Table 22: Damage area and percentage damage calculation for route seven.

Leadership institute Jan Meda	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	1161	1602	72.47
crocodile Cracking	9	1602	0.56
Rutting	141	1602	8.80
Corrugation	21	1602	1.31
Lacy Edge	270	1602	16.85

As shown in table 22, the area of the distresses observed at sample road seven were calculated using the length and width of each distress types. As discussed earlier, Potholes, crocodile, Cracking, Subsidence, Rutting, Corrugation and Lacy Edge were the distresses occurred. The percentage damage of each those distresses were calculated by dividing the Distress Area to Total Damage Area and multiplying by 100. At this road section pothole covered large percent of damage among the other distresses it was 72.47.

Table 23: Distress data for route eight.

Road number	Road Name			Origin	Wereda
145	FM radio station			Alert Round about	
Block Number	Length	Start Chain age:		Start Description	Start Code
000	1750 m	0+000			
Measured Length	End Chain age:			End Description	End Code
1750m	1+750			-	-
Surface Type	Surface Width			Carriage way	Road Class
Paved	7			7	SAS
				Survey Date	Rates
				26/01/10 E.C	

PAVEMENT					
Chainage	0+000 - 0+400	0+400 - 0+800	0+800 - 1+200	1+200 - 1+600	1+600 - 1+750
Rutting	3/4/5.	3/3/4	3/6/7	3/5/8	3/4/4
		3/7/9.	3/3/5.	3/4/8.	
Long. Crack	3/3/5.	3/2.8/4.	3/2.6/3		
Ravelling		3/4.25/8			
Lacy Edge		2/3/3.5			

The road named FM Radio station starts from its origin Alert Roundabout and ends at destination of FM radio station. The route has a total length of 1750 (one thousand seven hundred fifty) meters with a carriage way width of seven meters. This road sample has a length of 400 (four hundred) meters between the two successive stations except at the end station that was 150 (one hundred fifty) meters length. The specified road number designated by AACRA to represent this road was 145. According to the AACRA road classification system the road was categorized under Sub Arterial Street (SAS). At this road section four types of distresses were observed and recorded during the field condition survey. The distress types occurred at this sample road includes; Rutting, Longitudinal Cracking, Raveling and Lacy Edge. All the distress and other data s which is related to this route were observed during the field condition assessment survey and detailed in table 23.

Table 24: Damage area and percentage damage calculation for route eight.

Alert Roundabout -FM radio station	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Rutting	240	318.5	75.35
Longitudinal Cracking	34	318.5	10.68
Raveling	34	318.5	10.68
Lacy Edge	10.5	318.5	3.3

The Rutting, Longitudinal Cracking, Raveling and Lacy Edge are the four distresses observed on route section eight. As the calculated result shows the two hundred forty square meter area was affected by the rutting distress type which is 75.35 percent of the total percentage damage. The Percentage damage area of these distresses set forth that this road section is highly affected by the rutting distress. The areas were obtained by multiplying the length and width of each distress occurred on route section eight and total damage area were obtained by summing the distress area values.

Table 25: Distress data for route nine.

Road number		Road Name	Origin		Wereda
88C		Ehil Berenda	Asfaw Tekle Hotel		
Block Number	Length	Start Chain age:	Start Description	Start Code	
000	1350m	0+000			
Measured Length	End Chain age:		End Description	End Code	
1350m	1+350		-	-	
Surface Type	Surface Width		Survey Date	Road Class	
Paved	20		14/02/10 E.C	Collector	

PAVEMENT				
Chainage	0+000 - 0+400	0+400 - 0+800	0+800 - 1+200	1+200 - 1+350
Pothole	2/5/6.	2/7/8	2/7/7	2/5/8.
	2/8/10	2/9/9.	2/3.85/5	
	2/8/9.	2/4/5	2/6/9.	2/6/7.
	2/6.25/7	2/3/8.	2/8/8.	2/4/5.
Crocodile Craking	3/7/9.15	3/7/12.	3/8/10	3/5/9.
	3/10/13.	3/9/15.	3/9/18.	
	3/8/11.	3/6/7.5	3/7/8.	3/9/11.
	3/8/12.	3/9/10.	3/8/8.	3/7/9.
Delimination	3/5/5	3/7/8	3/7/7	3/4/5
	3/8/10	3/4/5		
Ravelling	2/7/17.	2/7/12.	2/8/10	2/6/17.
	2/10/13.	2/9/15.	2/12/18.	2/14/16.
	2/6/19.	2/14/19.	2/7/14.	2/9/15.
	2/8/12.	2/12/14.	2/8/18.	2/7/9.
	2/9/11.	2/9/14.	2/10/13.	2/9/15.

Road from Asfaw Tekle Hotel to Ehil Berenda was the ninth sample road which were selected for this study. The road was categorized under Collector Street and as of AACRA the unique identification number for this road were 88C. For this sample road, the lengths between the two successive stations were 400m except for the end station that was 150 meter.the total length of route sample seven were 1.35km. In this route section there are a high coverage of distresses on each section. The data obtained from the field condition assessment survey for this sample road shows that, the pothole distress were occurred four times at the station from 0+000 up to 0+400 with a medium severity, four times at the station from 0+400 up to 0+800 observed as a medium severity and three times at the station from 0+800 – 1+350 with a medium level of severity. All the data's for the remaining distress were recorded on table25.

During the field condition survey, five types of distresses were observed. The distress types recorded at this sample road includes Ravelling, Bleeding, Pothole, Crocodile Cracking and Delimination. The data for each distress types were measured and recorded at each station as shown in table 25. The recorded data for this sample road shows that, the crocodile cracking, pothole and the raveling distresses were the main distresses that damages the pavement surface.

Table 26: Damage area and percentage damage calculation for route nine.

Asfaw Tekle Hotel to Ehil Berenda	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Potholes	695	4910	14.15
crocodile Cracking	1301	4910	26.5
Delimination	250	4910	5.09
Raveling	2664	4910	54.26

To determine the percentage damage of the sample road the length and width data of the distresses were required. This data were obtained from the field measurement of each distress types with the appropriate distress measurement technique. The areas of each distress were calculated by multiplying the length and the width of each distress occurred on each sample road. As discussed above, at road sample nine, four types of distresses were observed and recorded during the field condition assessment survey at each station.

The distresses observed includes pothole, crocodile Cracking, Delimination, and Raveling. For those distresses the area was calculated by multiplying the length and width of the distress for each particular distress types as shown in the table 26. The Total Damage Area were obtained by summing the Distress Area values of each distress. The percentage damage of distresses was obtained by dividing Distress Area to Total Damage Area and multiplying by 100.

Table 27: Distress data for route ten.

<table>
<tr><td>Road number</td><td colspan="2">Road Name</td><td colspan="2">Origin</td><td colspan="2">Wereda</td></tr>
<tr><td>55</td><td colspan="2">Kolfe Cooperative School</td><td colspan="2">Filidoro Schoo</td><td colspan="2"></td></tr>
<tr><td>Block Number</td><td>Length</td><td>Start Chainage:</td><td colspan="2">Start Description</td><td colspan="2">Start Code</td></tr>
<tr><td>000</td><td>4712m</td><td>0+000</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Measured Length</td><td colspan="2">End Chain age:</td><td colspan="2">End Description</td><td colspan="2">End Code</td></tr>
<tr><td>4712m</td><td colspan="2">4+4700</td><td colspan="2">-</td><td colspan="2">-</td></tr>
<tr><td>Surface Type</td><td>Surface Width</td><td></td><td colspan="2">Survey Date</td><td colspan="2">Road Class</td></tr>
<tr><td>Paved</td><td>9</td><td></td><td colspan="2">14/02/10 E.C</td><td colspan="2">PAS</td></tr>
<tr><td colspan="7">Pavement</td></tr>
<tr><td>Chainage</td><td>0+000 - 0+800</td><td>0+800 - 1+600</td><td>1+600 - 2+400</td><td>2+400 - 3+200</td><td>3+200 - 4+000</td><td>4+000 - 4+700</td></tr>
<tr><td rowspan="3">Rutting</td><td>2/9.5/11</td><td>2/7/8</td><td>2/7/10</td><td>2/4/5</td><td>2/5/10.</td><td>2/10/13.</td></tr>
<tr><td></td><td></td><td></td><td>2/8/9.</td><td></td><td></td></tr>
<tr><td>2/4/5.</td><td>2/6/9.</td><td>2/6/8.</td><td>2/2/6.</td><td>2/2.75/4</td><td>2/7/9.</td></tr>
<tr><td rowspan="2">Low shoulder Gravel</td><td>2/5/5</td><td>2/7/8</td><td>2/2/7</td><td>2/4/5</td><td>2/2/5.</td><td>2/4/5</td></tr>
<tr><td>2/4/8.</td><td>2/2/2.</td><td>2/5/7.</td><td>2/3/6.</td><td>2/2/5.</td><td>2/3/4.</td></tr>
<tr><td rowspan="2">Raveling</td><td>2/4/5</td><td>2/5/5</td><td>2/5/8</td><td>2/4/4</td><td>2/3/4</td><td>2/6/7</td></tr>
<tr><td></td><td></td><td>2/3/5.</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Shoving</td><td>2/5/6.</td><td>2/7/8</td><td>2/7/7</td><td>2/4/5</td><td>2/8/10</td><td>2/4/7.</td></tr>
<tr><td>2/8/9.</td><td>2/4/5</td><td>2/3/5.</td><td>2/3/9.</td><td></td><td></td></tr>
</table>

Road sample 10 was from Filidoro School to Kolfe Cooperative School. It has a total length of 4712 (four thousand seven hundred twelve) meter and seven meter carriage way width. The length between the two successive stations was 800 meter except for the end station that was 700 meter. The road number was given by AACRA as 55. The road was categorized under Principal Arterial Street (PAS) as of AACRA. Rutting, Raveling, Shoving and Low shoulder gravel were the four distress types that were observed and recorded at this sample road section. From those distress types, the rutting distress occurs two times at the first, second, third, fourth and fifth stations with a medium severity and three times at the third station with a medium level of severity. The Low shoulder gravel occurs two times at each station with a medium severity level. The Raveling distress type occurs one time at stations except the third station with the occurrence of two times. The Shoving distress type occurs two times with a medium severity level except at station fifth and sixth. Additional to the severity, the length and width data of each distress for the respective sample roads were measured and recorded using the AACRA condition assessment survey sheet during the survey. The details of the information were provided at each table which incorporates the distress data with the general information of the route.

Table 28: Damage area and percentage damage calculation for route ten.

Kolfe Coprative School To Filidoro School	Distress Area (m^2)	Total Damage Area (m^2)	Percentage damage of distress
Rutting	710.5	1533.5	46.33
Raveling	170	1533.5	11.09
Shoving asphalt	397	1533.5	25.89
Low Shoulder gravel	256	1533.5	16.69

On route section ten the percentage damage of the sample road were obtained from the length and width data of the distresses. This data were obtained from the field measurement of each distress types and the areas of each distress were calculated by multiplying the length and the width of each distress occurred on each sample road. On route section ten four types of distresses were obtained. The distresses observed includes Rutting, Shoving asphalt and Low shoulder gravel. For those distresses the area was calculated by multiplying the length and width of the distress for each particular distress types as shown in the table 28. The Total Damage Area were obtained by summing the Distress Area values of each distress. The percentage damage of distresses was obtained by dividing Distress Area to Total Damage area.

After calculating all the above the second step was analyzing those distresses data on Decision analysis module for excel (DAME).

4.2. Identification of the most dominant distress types

In this study a Microsoft Excel add-in called DAME (Decision Analysis Module for Excel) were used. Comparing to other computer programs DAME is free, can work with scenarios or multiple decision makers, allows for easy manipulation with data, utilizes capabilities of Microsoft Excel and displays all intermediate calculations. To apply the DAME analysis in this study, the decision models were structured into three levels:

- ✓ Scenarios
- ✓ Criteria (at this circumstances the Area and the Severity of each distresses), and
- ✓ Variants (At this scenario the visually identified distress types *i.e.* pothole, crocodile, rutting, raveling, subsidence, shoving, Lacy edge low shoulder gravel, Delimination, corrugation and longitudinal crack).

Elements on all three levels can be evaluated by direct values which are obtained from the field condition survey for each distress types. There are three different methods for the evaluation of the weights of criteria, the variants as well as the scenarios/users – these are Saaty's Method, Geometric Mean Method and Fuller's Triangle Method.

The main goal of this research is to make a good decision among the alternatives based on the set of criteria's and sub criteria's. This contribution introduces a Microsoft Excel add-in called DAME – Decision Analysis Module for Excel. Multiplicative and additive syntheses are supported. All calculations are instant so users can easily see what happen if anything is modified. Bar chart is used for final ordering representation. The proposed software package is demonstrated on couple of illustrating examples of real life decision problems.

Before the ranking of the distress types, first the area and severity were determined for each distress occurred at each road as described above and the area and the severity of the distresses were used as an input in the decision analysis module for excel add-in.

To get the rank of each distresses occurred at the selected roads, a new decision problem were generated by clicking on "*New problem*" item in the main DAME menu, see figure 1.

In the top panel of the DAME software there are three basic settings named as number of scenarios, criteria and variants. In the second panel the methods that were used to compare scenarios/users and criteria were shown either using pairwise comparison matrix or set weights directly. The following figure shows the process of new problem creation and shows or illustrates how to define the number of scenarios, criteria and the number of variants used in this study.

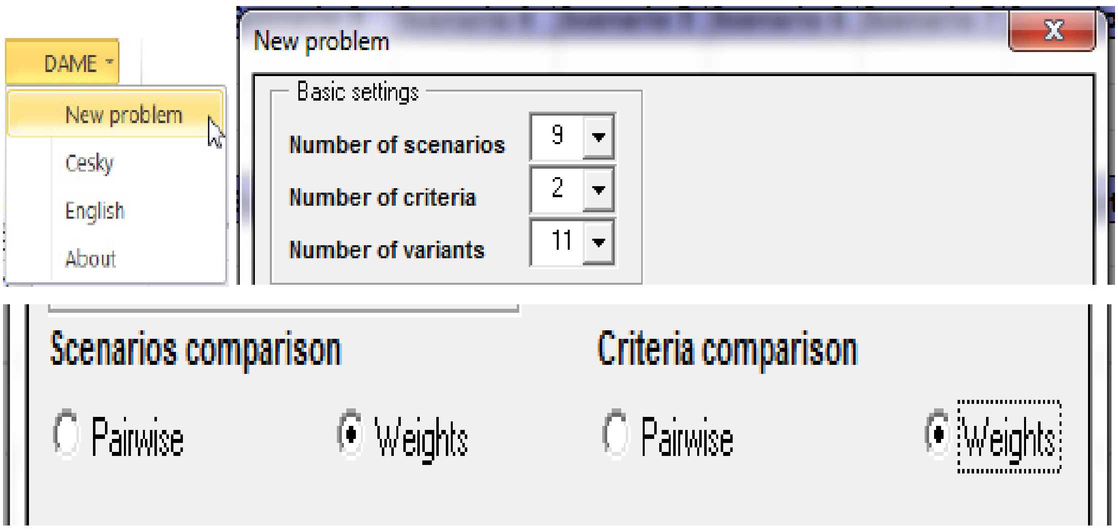


Figure 11: New problem characteristics.

For this research the numbers of scenarios were nine. This is done by assuming that one variant (distress) was occurred at nine roads among the total ten road samples. The two criteria's that were used in this research are the area and the severity of the distresses occurred at the sample roads. Prior to the ranking of the distresses, the severity of the distresses were determined from the field condition survey and the area of each distress that occurs at each sample roads were calculated by multiplying the length and width of the distress.

There are generally two methods for scenario and criteria comparisons, the first one is the pairwise comparison in which each pair of variants is compared individually and the second is weights in which the scenario's and the criteria's were compared based on the set of weights (value assigned for each scenarios and criteria) and this values were calculated in the DAME software. In this study the weights method is applied for both scenarios and criteria comparison.

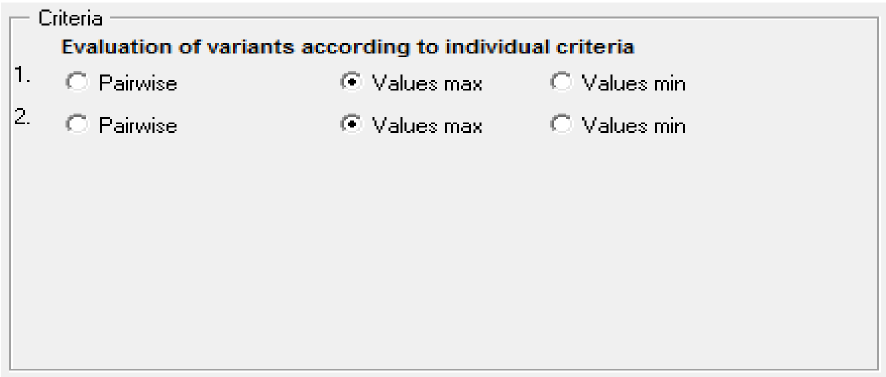


Figure 12 : Criteria evaluation options.

In the last panel (third panel) the criteria evaluation were done to evaluate variants according to individual criteria. For the criteria evaluation there are three options.

[1] Pairwise – each pair of variants is compared individually.

[2] Values max – indicates maximization criterion where each variant is evaluated by single value, e.g. price.

[3] Values min – indicates minimization criterion where each variant is evaluated by single value, e.g. costs.

At this study the values max option were selected for the criteria evaluation. This indicates that the distress with the higher severity and which covers large area (high extent) can have the higher influence (maximization) for maintenance on the criteria evaluation.

After the values max option is selected a new Excel sheet with forms is created as shown below. In this sheet the names of all elements were renamed and evaluate criteria and variants using weights as shown on table 29.

Table 29: Shows the scenarios, the criteria and variants.

Decision Analysis Module for Excel. Number of scenarios = 9, Number of criteria = 2, Number of variants = 11										
Names of scenarios:										
Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9		
Names of criteria:										
Area	Severity									
Names of variants:										
Pothole	Crocodile crack	Subsidence	Long.crack	Ravelling	Lacy edge	Shoving	Corrugation	Rutting	Delimnation	Low shoulder gravel

As shown in table 29, at this study the eleven variants/alternatives were compared based on the two criteria's for the nine scenarios. The results of each scenarios comparison based on the set of weights were discussed below.

Table 30: Evaluation of variants for scenario one.

Scenario 1

Criteria Comparison:

Criteria	Value	Criteria weights
Area		0.5
Severity		0.5

Evaluation of Variants According to Individual Criteria:

Area	Value	Severity	Value
Pothole	130	Pothole	2
Crocodile crack	130	Crocodile crack	2
Subsidence	150	Subsidence	3
Long.crack	20	Long.crack	2
Ravelling	230	Ravelling	2
Lacy edge	65	Lacy edge	1
Shoving	202	Shoving	2
Corrugation	21	Corrugation	3
Rutting	12	Rutting	1
Delimnation	250	Delimnation	3
Low shoulder gravel	256	Low shoulder gravel	2

Scenario one is about to compare the maximum combination of the distresses that occur at each roads. For each variants (distresses) in scenario one, the values of area and severity which is obtained from field condition survey were entered for each distresses in decision analysis module for excel as shown in table 30.

Table 31: Variants weight and rank for scenario one.

Variants weights

0.088677	0.086957
0.088677	0.086957
0.102319	0.130435
0.013643	0.086957
0.156889	0.086957
0.044338	0.043478
0.13779	0.086957
0.014325	0.130435
0.008186	0.043478
0.170532	0.130435
0.174625	0.086957

Evaluation of Variants According to Individual Criteria:

Zn=	Weight	Rank
Pothole	0.087816596	6
Crocodile crack	0.087816596	6
Subsidence	0.116377009	4
Long.crack	0.050299543	9
Ravelling	0.121923008	3
Lacy edge	0.043908298	10
Shoving	0.112373213	5
Corrugation	0.072379738	8
Rutting	0.0258319	11
Delimnation	0.150483421	1
Low shoulder gravel	0.130790676	2

As shown in table 31, the eleven distresses were compared based on their weight calculated for each distress types in DAME. Based on the severity and the area comparison for scenario one, the eleven distresses were ranked in the decision analysis module for excel (DAME) . The result of the comparison shows that the delimnation distress is ranked at the first level, the low shoulder gravel is at the second place, raveling is at the third place and the other distresses also ranked as shown in the tale 31.

Table 32: Evaluation of variants for scenario two.

Scenario 2			
Criteria Comparison:			
Criteria	Value		*Criteria weights*
Area			0.5
Severity			0.5

Evaluation of Variants According to Individual Criteria: Area	Value	Severity	Value
Pothole	250	Pothole	2
Crocodile crack	16	Crocodile crack	2
Subsidence	24	Subsidence	2
Long.crack	34	Long.crack	3
Ravelling	272	Ravelling	2
Lacy edge	210	Lacy edge	3
Shoving	397	Shoving	2
Corrugation	0	Corrugation	0
Rutting	141	Rutting	3
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

In scenario two, from the eleven distresses, the comparisons were done using the eight distresses data and the three distresses with zero occurrences. The area and severity values for each distress types were obtained from field condition survey. For each variant the values for area and severity were directly written in decision analysis module for excel add-in.

Table 33: Variants weight and rank for scenario one.

Variants weights		Evaluation of Variants According to Individual Criteria: Zn=	Weight	Rank
0.185597624	0.090909091	Pothole	0.138253358	4
0.011878248	0.090909091	Crocodile crack	0.051393669	8
0.017817372	0.090909091	Subsidence	0.054363231	7
0.025241277	0.136363636	Long.crack	0.080802457	6
0.201930215	0.090909091	Ravelling	0.146419653	2
0.155902004	0.136363636	Lacy edge	0.14613282	3
0.294729027	0.090909091	Shoving	0.192819059	1
0.00074239	0.045454545	Corrugation	0.023098468	9
0.10467706	0.136363636	Rutting	0.120520348	5
0.00074239	0.045454545	Delimnation	0.023098468	9
0.00074239	0.045454545	Low shoulder gravel	0.023098468	9

As shown in the table 33 the eleven distresses were compared based on their weight calculated for each distress types in DAME. Based on the severity and the area comparison for scenario two, the eleven distresses were ranked in the decision analysis module for excel (DAME). The result of the comparison shows that the shoving distress is ranked at the first level; the raveling is at the second place, lacy edge is at the third place and the other distresses are also ranked as shown in the tale above. The severity and the area of the distresses were also lower than the scenario one.

Table 34: Evaluation of variants for scenario three.

Scenario 3			
Criteria Comparison:			
Criteria	Value	*Criteria weights*	
Area		0.5	
Severity		0.5	

Evaluation of Variants According to Individual Criteria:

Area	Value	*Severity*	Value
Pothole	156	Pothole	2
Crocodile crack	47.5	Crocodile crack	2
Subsidence	3	Subsidence	1
Long.crack	0	Long.crack	0
Ravelling	285	Ravelling	1
Lacy edge	26.4	Lacy edge	2
Shoving	0	Shoving	0
Corrugation	0	Corrugation	0
Rutting	240	Rutting	3
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

In scenario three, from the eleven distresses, the comparisons were done using the six distresses data and the five distresses with zero occurrences. This values were used in decision analysis module for excel based on the maximization principle to obtain the weight for the area and severity for each variants which is known as variants weight. It is known fact that the distresses with the high severity and area should have the high priority that is why at this study the max value method were applied to evaluate variants according to individual criteria.

Table 35: Variants weight and rank for scenario three.

Variants weights		Evaluation of Variants According to Individual Criteria:		
		Zn=	Weight	Rank
0.204482894	0.125	Pothole	0.164741447	3
0.06226242	0.125	Crocodile crack	0.09363121	4
0.003932363	0.0625	Subsidence	0.033216182	6
0.001310788	0.0625	Long.crack	0.031905394	7
0.373574518	0.0625	Ravelling	0.218037259	2
0.034604797	0.125	Lacy edge	0.079802399	5
0.001310788	0.0625	Shoving	0.031905394	7
0.001310788	0.0625	Corrugation	0.031905394	7
0.314589068	0.1875	Rutting	0.251044534	1
0.001310788	0.0625	Delimnation	0.031905394	7
0.001310788	0.0625	Low shoulder gravel	0.031905394	7

As shown in table 35, the eleven distresses were compared based on their weight calculated for each distress types in DAME. Based on the severity and the area comparison for scenario three, the eleven distresses were ranked in the decision analysis module for excel (DAME). The result of the comparison shows that the rutting distresses were ranked at the first level; the raveling is at the second place, pothole is at the third place and the other distresses are also ranked as shown in the tale 35. The severity and the area of the distresses were also lower than the scenario one.

Table 36: Evaluation of variants for scenario four.

Scenario 4				
Criteria Comparison:				
Criteria	Value			*Criteria weights*
Area				0.5
Severity				0.5

Evaluation of Variants According to Individual Criteria:		*Severity*	Value
Area	Value		
Pothole	561	Pothole	3
Crocodile crack	315	Crocodile crack	2
Subsidence	0	Subsidence	0
Long.crack	0	Long.crack	0
Ravelling	888	Ravelling	2
Lacy edge	100	Lacy edge	2
Shoving	0	Shoving	0
Corrugation	0	Corrugation	0
Rutting	710.5	Rutting	2
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

In scenario four, from the eleven distresses, the comparisons were done using the five distresses data and the six distresses with zero occurrences. As discussed above, the area and severity values for each distress types were obtained from field condition survey. For each variants in scenario four, the values of area and severity were entered in decision analysis module for excel as shown in table 36. This values were used in decision analysis module for excel based on the maximization principle to obtain the weight for each variants which is known as variants weight.

Table 37: Variants weight and rank for scenario three.

Variants weights			Evaluation of Variants According to Individual Criteria:		
			Zn=	Weight	Rank
0.217399729	0.176470588		Pothole	0.196935158	2
0.122069366	0.117647059		Crocodile crack	0.119858213	4
0.000387522	0.058823529		Subsidence	0.029605526	6
0.000387522	0.058823529		Long.crack	0.029605526	6
0.344119357	0.117647059		Ravelling	0.230883208	1
0.03875218	0.117647059		Lacy edge	0.078199619	5
0.000387522	0.058823529		Shoving	0.029605526	6
0.000387522	0.058823529		Corrugation	0.029605526	6
0.275334238	0.117647059		Rutting	0.196490648	3
0.000387522	0.058823529		Delimnation	0.029605526	6
0.000387522	0.058823529		Low shoulder gravel	0.029605526	6

As shown in table 37, the eleven distresses were compared based on their weight calculated for each distress types in DAME. Based on the severity and the area comparison for scenario four, the eleven distresses were ranked in the decision analysis module for excel (DAME). The result of the comparison shows that the raveling distress is ranked at the first level; the pothole is at the second place, rutting is at the third place and the other distresses were also ranked as shown in the table 37.

Table 38: Evaluation of variants for scenario five.

Scenario 5

Criteria Comparison:

Criteria	Value	Criteria weights
Area		0.5
Severity		0.5

Evaluation of Variants According to Individual Criteria:

Area	Value	Severity	Value
Pothole	230.5	Pothole	3
Crocodile crack	3	Crocodile crack	3
Subsidence	0	Subsidence	0
Long.crack	0	Long.crack	0
Ravelling	686	Ravelling	2
Lacy edge	11.5	Lacy edge	3
Shoving	0	Shoving	0
Corrugation	0	Corrugation	0
Rutting		Rutting	0
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

In scenario five, from the eleven distresses, the comparisons were done using the four distresses data and the seven distresses with zero occurrences. The data for the area and severity were obtained from the field condition survey and entered for each distress types in decision analysis module for excel as shown in table 38. The values for area and severity were used in decision analysis module for excel based on the maximization principle to obtain the weight for each variants which is known as variants weight. The result of each comparison for scenario five is shown in table 38 below.

Table 39: Variants weight and rank for scenario five.

Evaluation of Variants According to Individual Criteria:

Variants weights		Zn=	Weight	Rank
0.245735608	0.166666667	Pothole	0.206201137	2
0.003198294	0.166666667	Crocodile crack	0.08493248	4
0.001066098	0.055555556	Subsidence	0.028310827	5
0.001066098	0.055555556	Long.crack	0.028310827	5
0.731343284	0.111111111	Ravelling	0.421227197	1
0.012260128	0.166666667	Lacy edge	0.089463397	3
0.001066098	0.055555556	Shoving	0.028310827	5
0.001066098	0.055555556	Corrugation	0.028310827	5
0.001066098	0.055555556	Rutting	0.028310827	5
0.001066098	0.055555556	Delimnation	0.028310827	5
0.001066098	0.055555556	Low shoulder gravel	0.028310827	5

As shown in table 39, the eleven distresses were compared based on their weight calculated for each distress types in decision analysis for module. Based on the severity and the area comparison for scenario five, the distresses were ranked in the decision analysis module for excel (DAME). The result of the comparison shows that the raveling distress is ranked at the first level; the pothole is at the second place, lacy edge is at the third place and the other distresses were also ranked as shown in the table 39.

Table 40: Evaluation of variants for scenario six.

Scenario 6		
Criteria Comparison:		
Criteria	Value	*Criteria weights*
Area		0.5
Severity		0.5

Evaluation of Variants According to Individual Criteria:			
Area	Value	*Severity*	Value
Pothole	382	Pothole	3
Crocodile crack	96	Crocodile crack	2
Subsidence	0	Subsidence	0
Long.crack	0	Long.crack	0
Ravelling	521.5	Ravelling	1
Lacy edge	42	Lacy edge	3
Shoving	0	Shoving	0
Corrugation		Corrugation	0
Rutting	0	Rutting	0
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

In scenario six, from the eleven distresses, the comparisons were done using the four distresses data and the seven distresses with zero occurrences. The values for area and severity were used in decision analysis module for excel based on the maximization principle to obtain the weight for each variants which is known as variants weight.

Table 41: Variants weight and rank for scenario five.

Variants weights	
0.364329995	0.1875
0.091559371	0.125
0.000953743	0.0625
0.000953743	0.0625
0.497377206	0.0625
0.040057225	0.1875
0.000953743	0.0625
0.000953743	0.0625
0.000953743	0.0625
0.000953743	0.0625
0.000953743	0.0625

Evaluation of Variants According to Individual Criteria:		
Zn=	Weight	Rank
Pothole	0.275914998	2
Crocodile crack	0.108279685	4
Subsidence	0.031726872	5
Long.crack	0.031726872	5
Ravelling	0.279938603	1
Lacy edge	0.113778612	3
Shoving	0.031726872	5
Corrugation	0.031726872	5
Rutting	0.031726872	5
Delimnation	0.031726872	5
Low shoulder gravel	0.031726872	5

As shown in table 41, the eleven distresses were compared based on their weight calculated for each distress types in decision analysis for module for scenario seven. Based on the severity and the area comparison for scenario seven, the distresses were ranked in the decision analysis module for excel (DAME). The result of the comparison shows that the raveling distress is ranked at the first level; the pothole is at the second place, lacy edge is at the third place and the other distresses were also ranked as shown in the tale 41.

Table 42: Evaluation of variants for scenario seven.

Scenario 7			
Criteria Comparison:			
Criteria	Value		*Criteria weights*
Area			0.5
Severity			0.5

Evaluation of Variants According to Individual Criteria:

Area	Value	*Severity*	Value
Pothole	116.1	Pothole	3
Crocodile crack	9	Crocodile crack	3
Subsidence	0	Subsidence	0
Long.crack	0	Long.crack	0
Ravelling	34	Ravelling	3
Lacy edge	270	Lacy edge	1
Shoving	0	Shoving	0
Corrugation	0	Corrugation	0
Rutting	0	Rutting	0
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

In scenario seven, from the eleven distresses, the comparisons were done using the four distresses data and the seven distresses with zero occurrences. The values for the area and severity were obtained from the field condition survey and entered for each distress types in decision analysis module for excel as shown in table 42. The values for area and severity were used in decision analysis module for excel based on the maximization principle to obtain the weight for each variants. The result of each comparison for scenario six is shown in table 42 below.

Table 43: Variants weight and rank for scenario seven.

Variants weights		Evaluation of Variants According to Individual Criteria:		
0.266223343	0.176470588	*Zn=*	Weight	Rank
0.020637468	0.176470588	Pothole	0.221346966	2
0.002293052	0.058823529	Crocodile crack	0.098554028	4
0.002293052	0.058823529	Subsidence	0.030558291	5
0.07796377	0.176470588	Long.crack	0.030558291	5
0.619124054	0.058823529	Ravelling	0.127217179	3
0.002293052	0.058823529	Lacy edge	0.338973792	1
0.002293052	0.058823529	Shoving	0.030558291	5
0.002293052	0.058823529	Corrugation	0.030558291	5
0.002293052	0.058823529	Rutting	0.030558291	5
0.002293052	0.058823529	Delimnation	0.030558291	5
		Low shoulder gravel	0.030558291	5

As shown in table 43, the eleven distresses were compared based on their weight calculated for each distress types in decision analysis module for scenario seven. Based on the severity and the area comparison, the distresses were ranked and the result of the comparison shows that the lacy edge distress is ranked at the first level; the pothole is at the second place, raveling is at the third place and the other distresses were also ranked as shown in the tale 43.

Table 44: Evaluation of variants for scenario eight.

Scenario 8			
Criteria Comparison:			
Criteria	Value		*Criteria weights*
Area			0.5
Severity			0.5

Evaluation of Variants According to Individual Criteria:

Area	Value	*Severity*	Value
Pothole	695	Pothole	2
Crocodile crack	1301	Crocodile crack	3
Subsidence	0	Subsidence	0
Long.crack	0	Long.crack	0
Ravelling	2664	Ravelling	2
Lacy edge	10.5	Lacy edge	2
Shoving	0	Shoving	0
Corrugation	0	Corrugation	0
Rutting	0	Rutting	0
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

In scenario eight, from the eleven distresses, the comparisons were done using the four distresses data and the seven distresses with zero occurrences. The values for the area and severity were obtained from the field condition survey and entered for each distress types in decision analysis module for excel as shown in table 44. The values for area and severity were used in decision analysis module for excel based on the maximization principle to obtain the weight for each variants. The result of each comparison for scenario six is shown in table 44 below.

Table 45: Variants weight and rank for scenario eight.

Variants weights		Evaluation of Variants According to Individual Criteria:		
		Zn=	Weight	Rank
0.148583645	0.125	Pothole	0.136791823	3
0.278140032	0.1875	Crocodile crack	0.232820016	2
0.000213789	0.0625	Subsidence	0.031356895	5
0.000213789	0.0625	Long.crack	0.031356895	5
0.569535008	0.125	Ravelling	0.347267504	1
0.002244789	0.125	Lacy edge	0.063622394	4
0.000213789	0.0625	Shoving	0.031356895	5
0.000213789	0.0625	Corrugation	0.031356895	5
0.000213789	0.0625	Rutting	0.031356895	5
0.000213789	0.0625	Delimnation	0.031356895	5
0.000213789	0.0625	Low shoulder gravel	0.031356895	5

As shown in table 45, the eleven distresses were compared based on their weight calculated for each distress types in decision analysis module for scenario eight. Based on the severity and the area comparison, the distresses were ranked and the result of the comparison shows that the raveling distress is ranked at the first level; the crocodile crack is at the second place, pothole is at the third place and the other distresses were also ranked as shown in the tale 45.

Table 46: Evaluation of variants for scenario nine.

Scenario 9			
Criteria Comparison:			
Criteria	Value		*Criteria weights*
Area			0.5
Severity			0.5

Evaluation of Variants According to Individual Criteria:

Area	Value	*Severity*	Value
Pothole	0	Pothole	0
Crocodile crack	0	Crocodile crack	0
Subsidence	0	Subsidence	0
Long.crack	0	Long.crack	0
Ravelling	170	Ravelling	2
Lacy edge	0	Lacy edge	0
Shoving	0	Shoving	0
Corrugation	0	Corrugation	0
Rutting	0	Rutting	0
Delimnation	0	Delimnation	0
Low shoulder gravel	0	Low shoulder gravel	0

Scenario nine is the last scenario for this study and it includes the least combination of distress occurrences among the above discussed scenarios. In scenario nine, from the eleven distresses, the comparisons were done using only one distress data and the ten distresses with zero occurrences. The value for the area and severity for raveling were obtained from the field condition survey and entered in decision analysis module for excel as shown in table 46. The values for area and severity were used in decision analysis module for excel based on the maximization principle to obtain the weight for each variants. The result of each comparison for scenario nine is shown in table 46 below.

Table 47: Variants weight and rank for scenario nine.

Variants weights		Evaluation of Variants According to Individual Criteria:		
		Zn=	Weight	Rank
0.005555556	0.083333333	Pothole	0.044444444	2
0.005555556	0.083333333	Crocodile crack	0.044444444	2
0.005555556	0.083333333	Subsidence	0.044444444	2
0.005555556	0.083333333	Long.crack	0.044444444	2
0.944444444	0.166666667	Ravelling	0.555555556	1
0.005555556	0.083333333	Lacy edge	0.044444444	2
0.005555556	0.083333333	Shoving	0.044444444	2
0.005555556	0.083333333	Corrugation	0.044444444	2
0.005555556	0.083333333	Rutting	0.044444444	2
0.005555556	0.083333333	Delimnation	0.044444444	2
0.005555556	0.083333333	Low shoulder gravel	0.044444444	2

As shown in table 47, the eleven distresses were compared based on their weight calculated for each distress types in decision analysis module for scenario nine. Based on the severity and the area comparison, the distresses were ranked and the result of the comparison shows that the raveling distress is ranked at the first place and the other distresses were ranked at the second place this is because the distresses except raveling has no value (this scenario comprises of the least combination with one distress and the others with no value of area and severity) as shown in the tale 47.

Table 48: Total weights and rank for the nine scenarios comparison.

Total evaluation of variants:		
CZn=	Weight	Rank
Pothole	0.065305173	3
Crocodile crack	0.039188854	5
Subsidence	0.025951328	8
Long.crack	0.021401435	10
Ravelling	0.079695903	1
Lacy edge	0.03867146	6
Shoving	0.040744799	4
Corrugation	0.017443236	11
Rutting	0.065987492	2
Delimnation	0.026121423	7
Low shoulder gravel	0.02393334	9

At this study the nine scenarios were created for the evaluations of eleven variants in decision analysis for excel to get the weight and the rank of each variant. Table 48 above shows the total evaluation result of each variant. This is done by assuming that one variant (distress) was occurred at nine roads among the total ten road samples. The two criteria's that were used in this research in DAME are the area and the severity that was determined from the field condition survey as discussed above. The result of the whole comparison of eleven variants (distresses) reveals that raveling distress were ranked in a first place, rutting distress type were at the second place, pothole were at the third place and the other distresses also were ranked as shown in table 48.

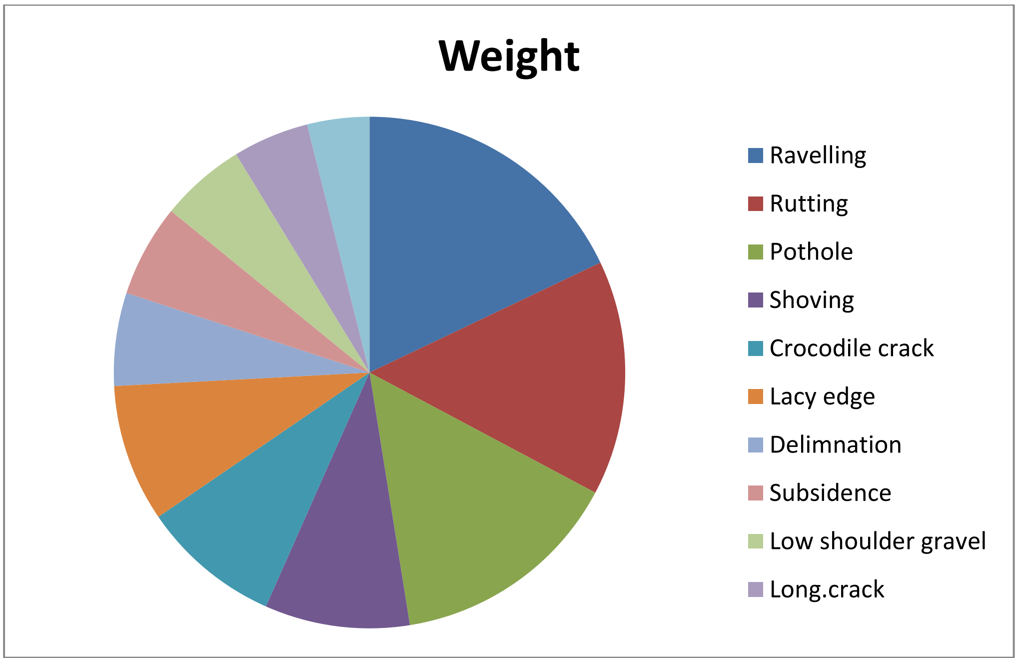


Figure 13: Total Evaluation of Variants.

Using the percentage damage of ranked distresses and road classification of sample roads the prioritization of roads were done on super decision software. The percentage damage for the ranked dominant distress was summarized as shown in table 49.

Table 49: Summary of percentage damage area for the ranked distresses.

Road Name Origen-Destn	PDA of Raveling	PDA of Rutting	PDA of Shoving	PDA of Corocodile	PDA of Pothole
sar bet -minaye biulding	17.5572519	-	-	9.923664122	9.92366412
Alemtsehay bridge-Wolega Hotel	22.5165563	-	36.0927152 3	1.324503311	20.6953642
Adissu Gebeya-Comercial Bank Powlos Branch	37.8737542	-	-	6.312292359	20.730897
Paster to Shewa Tsega (Mesalemiya)	47.639485	-	-	16.89914163	30.0965665
Berbere Tera -Mola Maru (Kebele Meznagna)	60.5472198	-	17.8287731 7	0.26478376	20.3442189
Debrezeit Menged -Sene Zetegn-Bhere Steige	49.361098	1.13582584	-	9.08660672	36.1571226
Leadership institute Jan Meda	-	8.80149812 7	-	0.561797753	72.4719101
Alert Roundabout -FM radio station	10.6750392	75.3532182 1	-	-	-
Asfaw Tekle Hotel to Ehil Berenda	54.2566191	-	-	26.49694501	14.1547862
Kolfe Coprative School to Filidoro School	11.0857515	46.3319204 4	25.8884903 8	-	-

4.3. Ranking of pavement sections on Super Decision Software

In this study a hierarchy was developed by considering a number of parameters at different levels of the structure. The first step on super decision software was creating clusters and nodes for each parameter and linking them as shown in the figure 14.

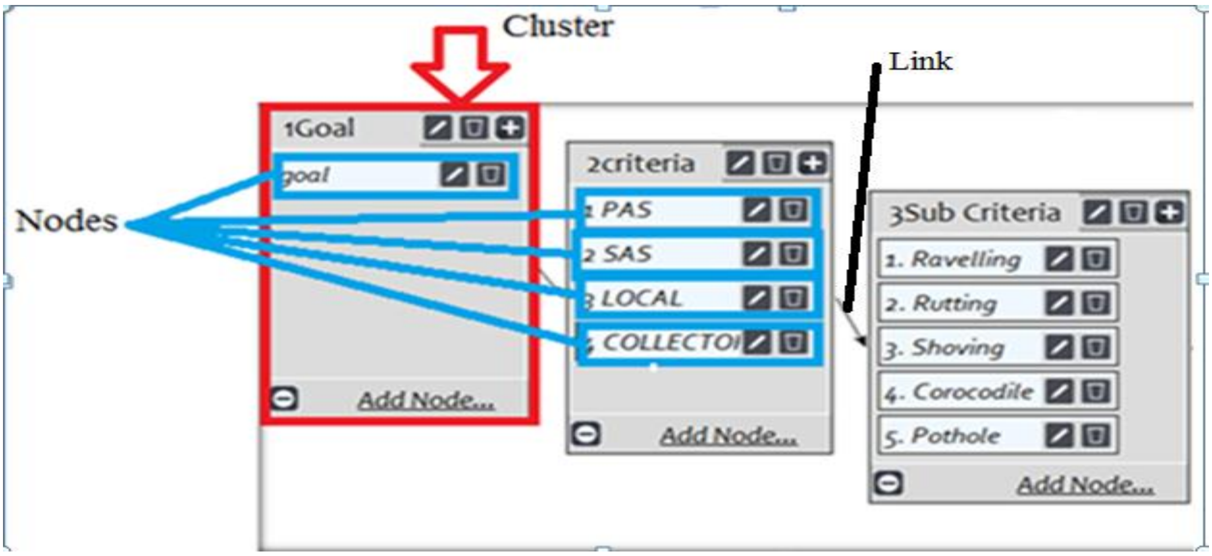


Figure 14: Cluster and nodes on super decision soft ware

Clusters are the collection of nodes that have some logical relationship in a frame. Nodes are elements in the cluster that were pair wisely compared with respect to the cluster (parental node) for importance, preference or likelihood. Clusters will not be compared pairwise in analytical hierarchy approach. Goal is a final judgment that was achieved. Criteria and sub criteria are decision factors considered during decision making. Both criterion and sub criterion are represented by node on a super decision model. By linking the goal nodes to criteria node, criteria to sub criteria and sub criteria to alternative the following hierarchy were obtained.

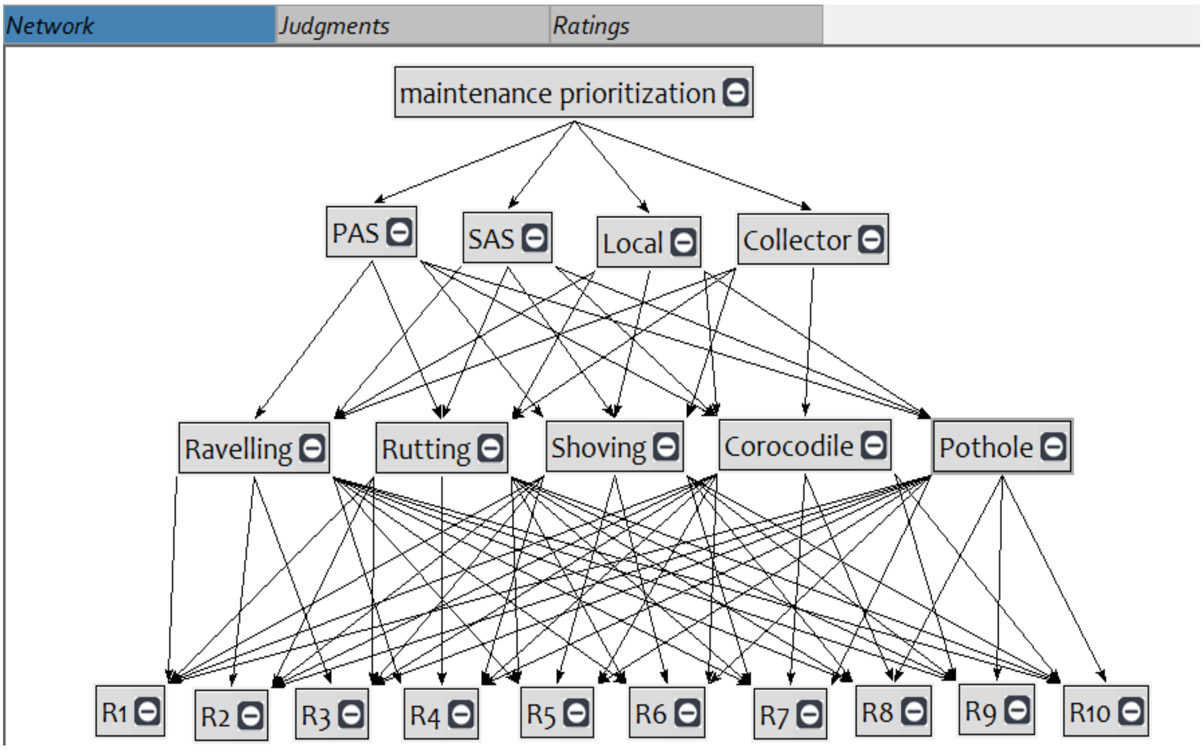


Figure 15: Decision tree on super decision software

The figure 15 above shows the network part of super decision software that express the flow from goal to criteria then criteria to sub criteria & last sub criteria to alternatives. Maintenance prioritization was put at the top level as major goal. Road type classification and pavement surface distresses are considered as the modeling parameters of criteria and sub criteria level respectively. The alternatives are the sample ten roads that were ranked. The road that has maximum priority rating value needs immediate attention. The ranking was done on the super decision software. After the hierarchy was done the second part were continued.

The second part of super decision software was the judgment it has also three parts. The first was the choose part shows the comparison to be made choose node is a parent node in which choose cluster contains a children node to compared with the parent node. The second part of judgments was the comparison there are 5 possible modes i.e. graphical, verbal, matrix questionnaire and direct for entering assessments. Judgments entered in one mode will appear as the equivalent judgment in any other mode except for the questionnaire that rounds off judgments from other modes. It is the important part of super decision so that output depends on. Each five parts was discussed below

4.3.1 Criteria comparisons

The graphical method of judgments comparison show the preferences as shown in the figure 16, the higher the graph the higher the preference and the lower gets lower preference with respect to the comparison criteria.

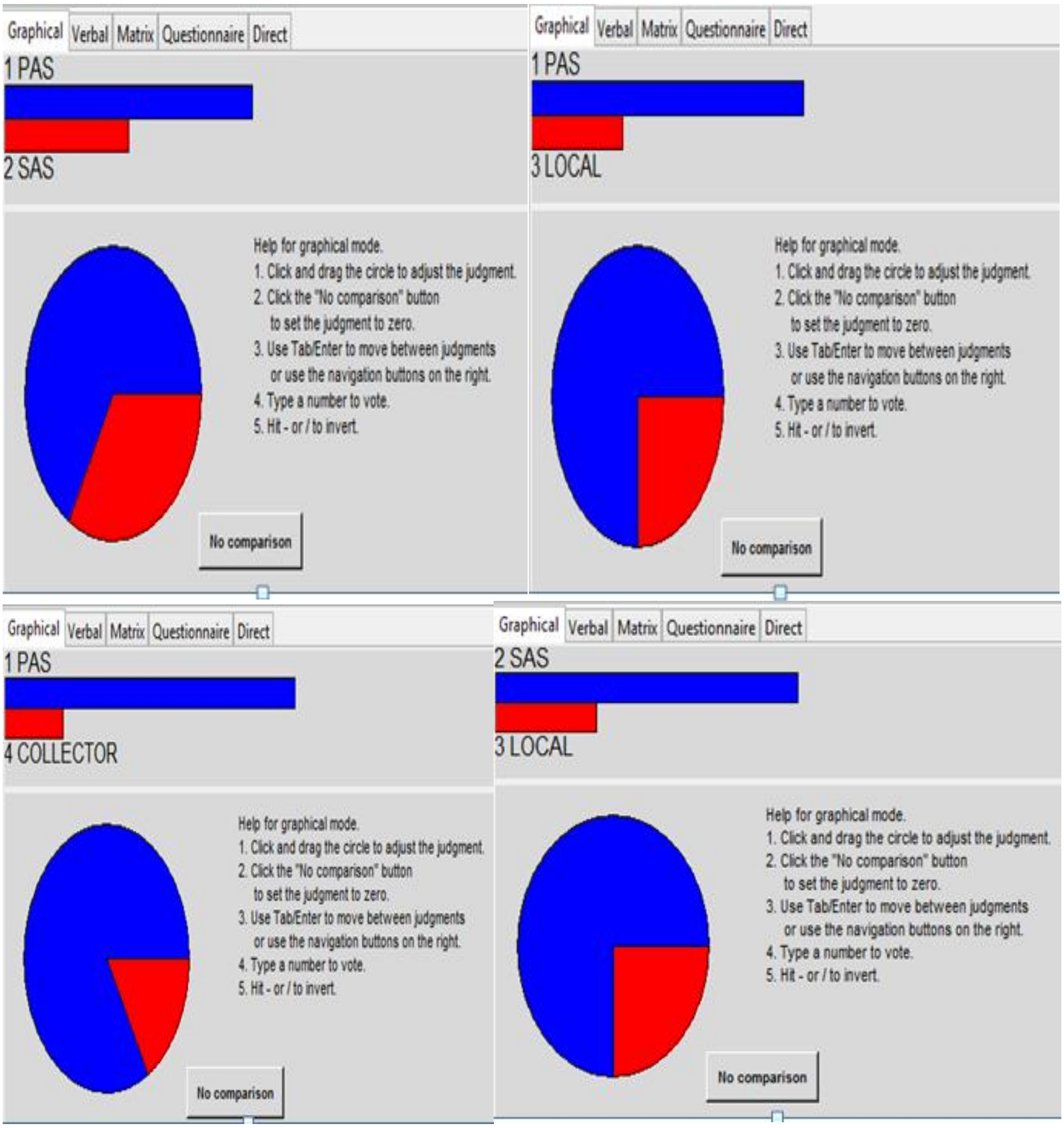


Figure 16: graphical representation of judgments

The more important, more preferred, or more likely, node or criteria entered. If they have the same value just simply toggling on the no comparison make it equal. In the graphical method of judgment only two criteria's can be compared at once.

The verbal method of judgments show the preferences as shown in the figure below based on the measures equal, moderately strongly very strongly and extremely preferences.

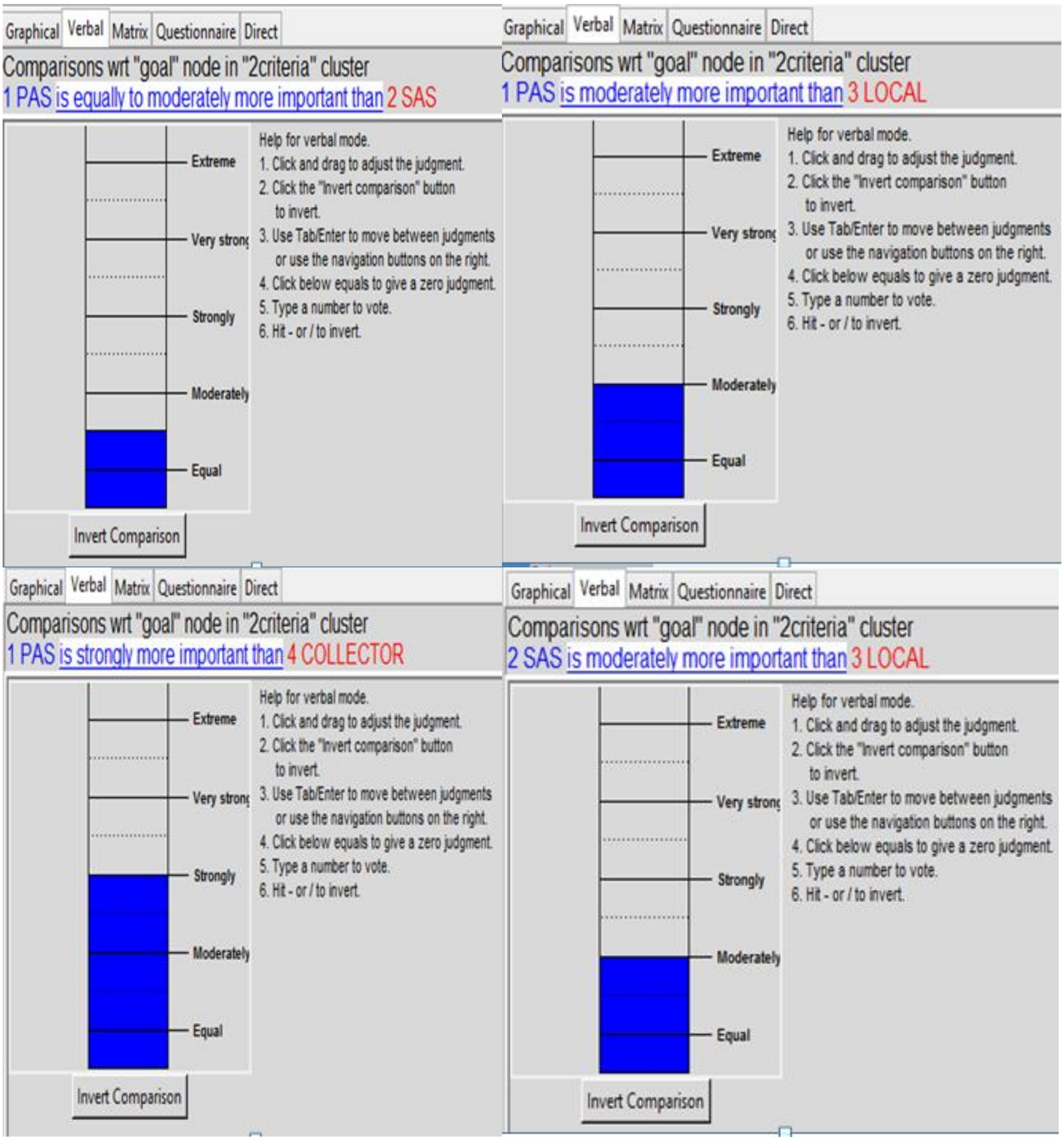


Figure 17: The verbal judgment representation

The more important, more preferred, or more likely, node or criteria entered. In the verbal method of judgment only two criteria's can be compared at once. By clicking on the invert comparison button it is possible to invert dominance. The comparison was written verbally on the above command.

The matrix judgments on the super decision software was done by entering judgments in cells by typing numbers from the Fundamental 1-9 Scale. The direction of the arrow indicates which criterion is more important. Double-click arrow to change the dominant element. In the phrase above the matrix the first element was dominant.

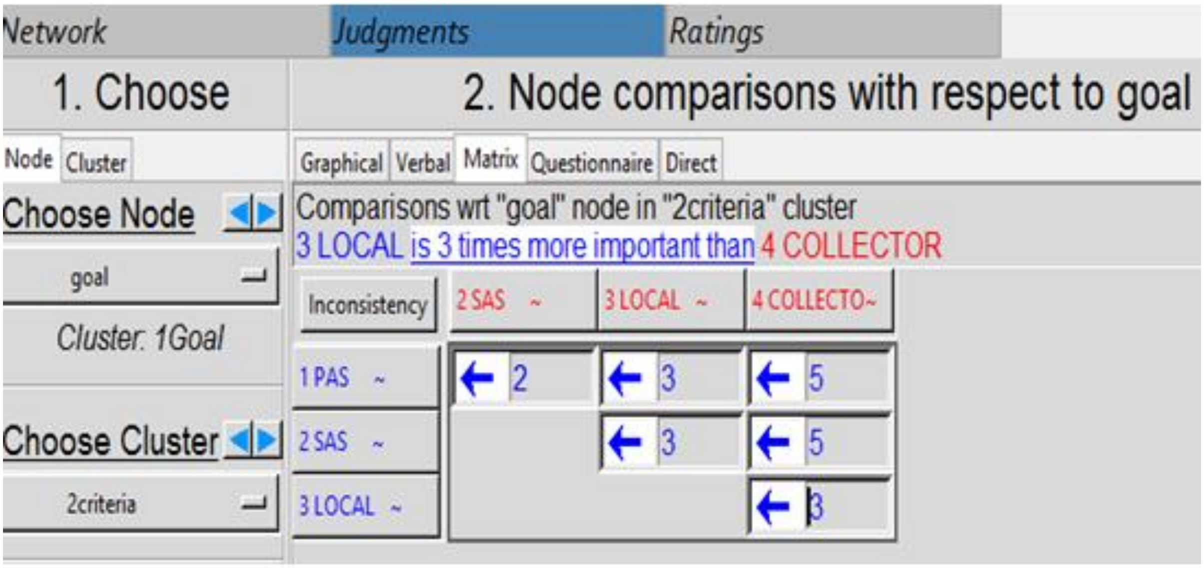


Figure 18: the matrix comparison representation of judgment

The current parent node is the Goal node and the Criteria nodes are being compared with respect to the Goal for importance. The matrix was done based on satty's nine rating scales as shown in the table 50 below.

Table 50: Scale for rating criterias.

Verbal Judgment of Preference	Numerical Rating
Extremely preferred	9
Very strongly to extremely	8
Very strongly preferred	7
Strongly to very strongly	6
Strongly preferred	5
Moderately to strongly	4
Moderately preferred	3
Equally to moderately	2
Equally preferred	1

The forth comparison judgment type was the questionnaire it was also done using the nine scales. The phrase above the questionnaire shows the first element was dominant. See the figure 19 below.

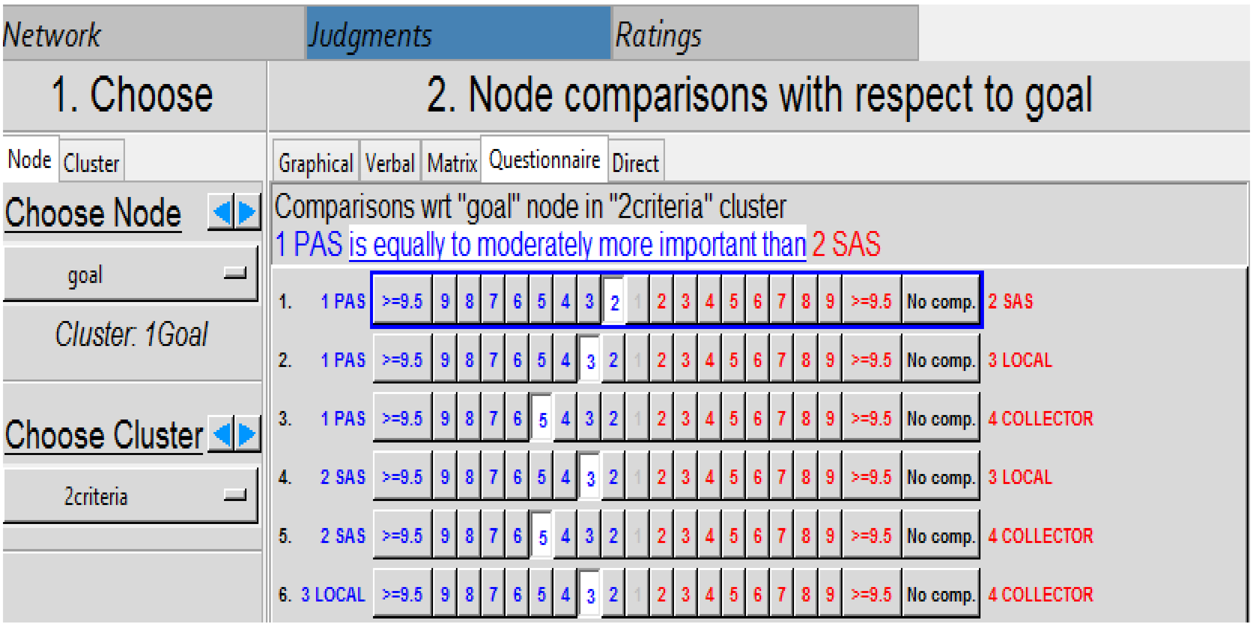


Figure 19: criteria node comparison with respect to goal.

In the questionnaire it was about to choose the judgment on the left or right side of the zero on the questionnaire line that is nearest to the more important, more preferred, or more likely, node. Then each node was pairwise compared with respect to goal on super decision media.

The fifth comparison judgment was the direct comparison of nods; it is a method of directly recording available real data's for the judgment comparison which was not used on this study.

The third part of judgment was the results which were obtained from the five comparison judgments. It is the percent influence weightage of criteria's with respect to the goal in order to prioritize the pavements. The weights of the criteria's were sum to be one. The figure 20 below shows the weightage for criteria's.

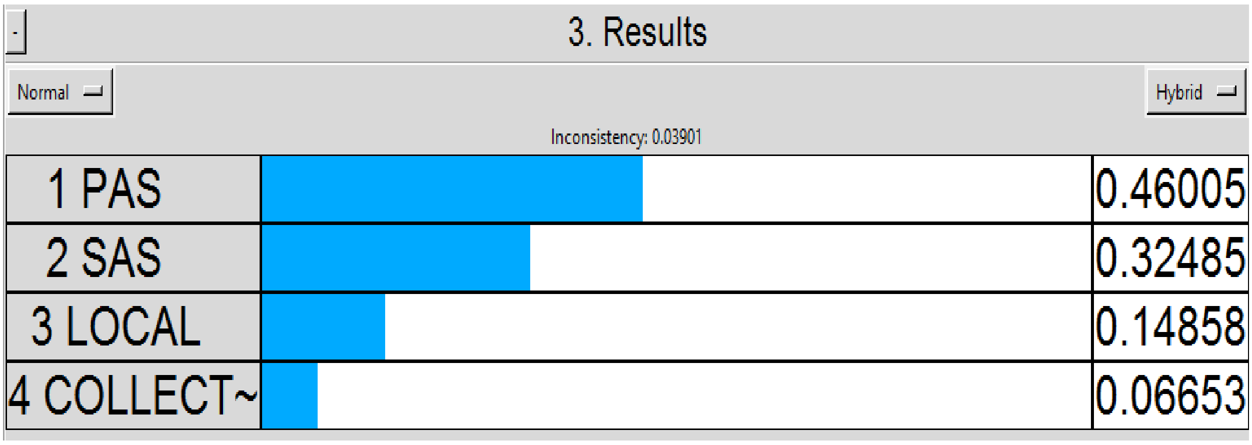


Figure 20: weights for the criteria's.

In the above figure it was shown that Principal Arterial Street has got the maximum score Sub Arterial Street the second local and collector got the third and the forth rank respectively. During the result the inconsistency should be less than 0.1 else the comparison should be revised in this study the inconsistency index was 0.0391 less than 0.1which implies the data was correct and fairly representative.

4.3.2 Sub criteria comparisons

As it was disused above the study has five sub criteria that was analyzed and obtained from decision analysis module for excel (DAME) these were raveling, rutting, shoving, crocodile cracking and pothole. Like the criteria comparison the sub criteria comparison was also done by taking the five sub criteria's. The questioners were disseminated for the responsible maintenance engineers and data collectors in the AACRA.

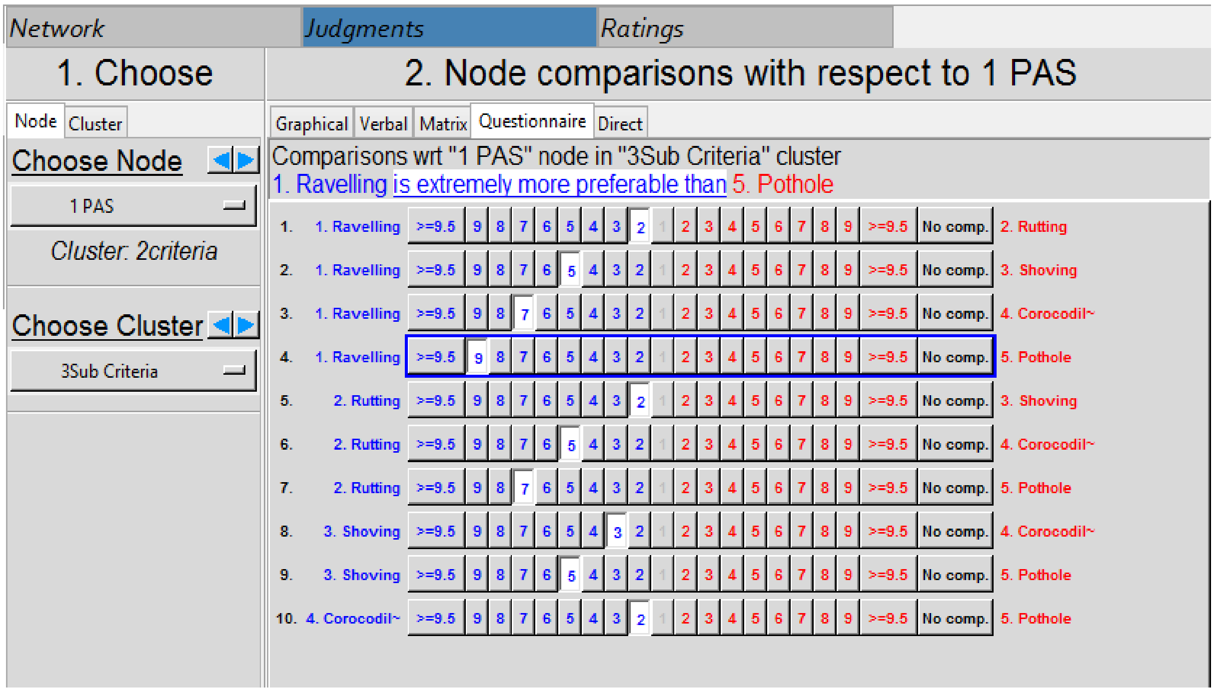


Figure 21: questionnaire format comparison for sub criteria.

In this study the questionnaire were filled by the maintenance engineers in the form of matrix as shown in figure 21 based on saaty's one to nine scale. In the questionnaire it was about to choose the judgment on the left or right side of the zero on the questionnaire line that is nearest to the more important, more preferred, or more likely, node. Then each node was pairwise compared on super decision.

The above figure shows the questionnaires data obtained from AACRA officials which has inconsistency index less than 0.1 was taken for this study since the more less the inconsistency the more the data reliable.

The following figure shows the result for the judgment which had an inconsistency index of 0.02278 that was less than 0.1, the more the percentage of the weight implies the higher preference with respect to comparison node.

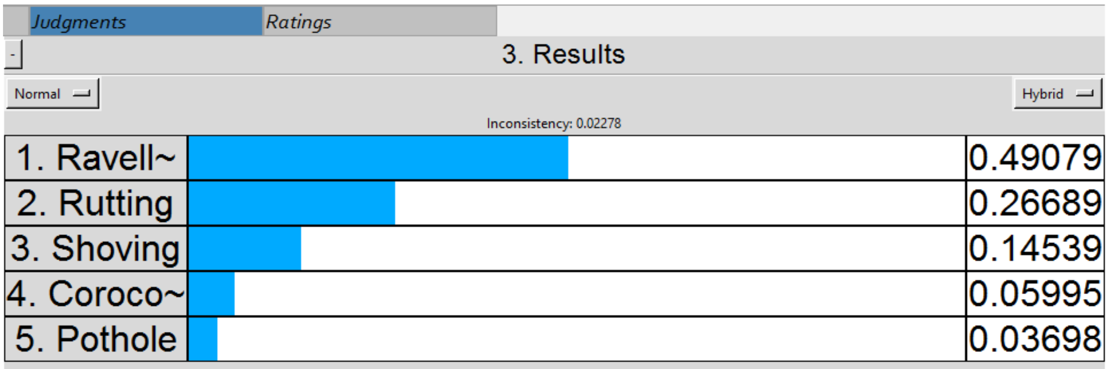


Figure 22: the result of weights for sub criteria.

The above figure shows how important is Criterion1 compared to Criterion2 with respect to the goal? In this case Raveling distress was having the maximum score 0.49079 out of 1 more important than the others. The second was Rutting and the third shoving distress. The forth and the fifth was crocodile cracking and pothole distresses respectively. The inconsistency was fairly representative the weights were used for rating the selected road samples.

4.3.3 Priority Rating

The final step after finding the weights for the criteria and sub criteria was rating the alternatives. In order to rate the alternatives (selected sample roads) there were three steps in general. The first part was about to choose the rating criteria. In this study both the criteria and sub criteria were used for the rating of road samples. As shown in the figure below.

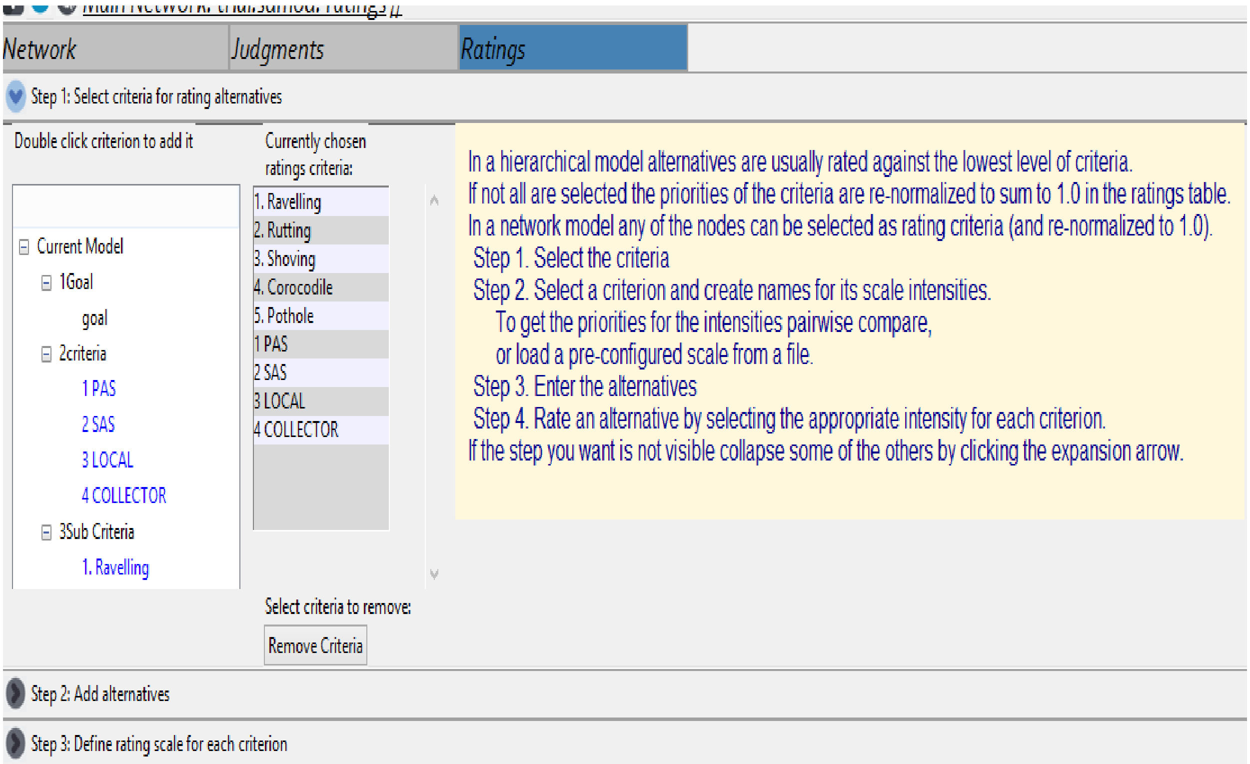
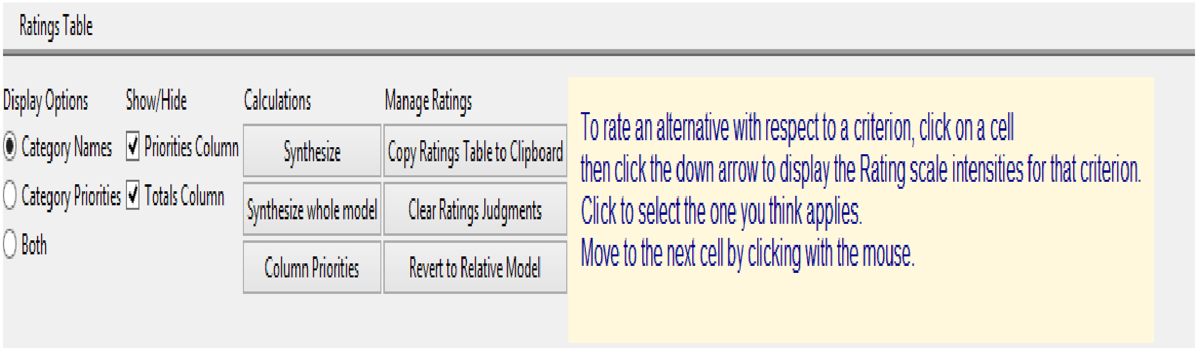


Figure 23: selecting the rating parameters.

In the hierarchical model most of the time the lowest criteria were used for priority rating but in this study both the criteria and sub criteria were used for priority rating because both has an influence directly to the goal. The super decision will re calculate and normalize the matrix weights to give 100% or sum to 1 since the criteria were pairwise compared before. Using the new re calculated and normalized matrix weights the corresponding data for each sample roads were entered in the super decision software.

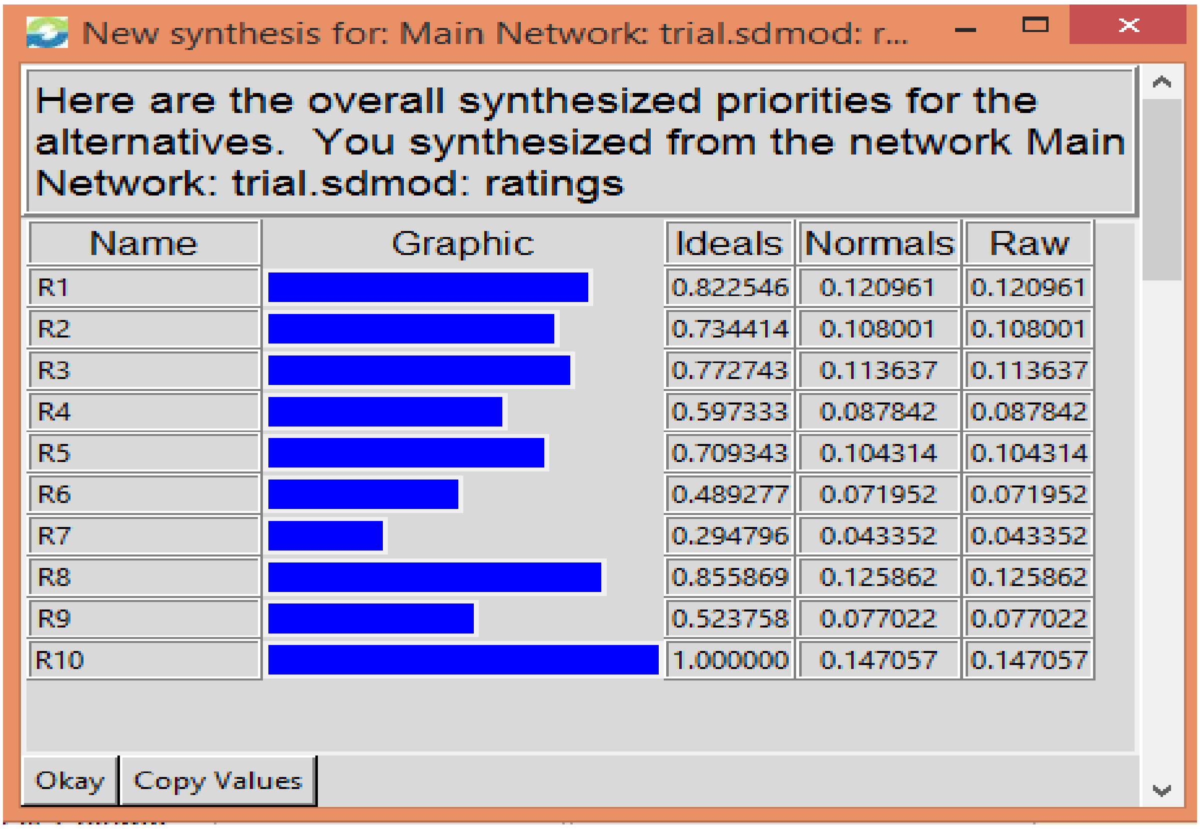


Alternatives	Priorities	Totals	1. Ravelling (0.1636)	2. Rutting (0.0890)	3. Shoving (0.0485)	4. Corocodile (0.0200)	5. Pothole (0.0123)	1 PAS (0.1533)	2 SAS (0.1083)	3 LOCAL (0.0495)	4 COLLECTOR (0.0222)
R1	0.1210	0.2779	0.1755725	No Value	No Value	0.0992366	0.0992366	1.0	No Value	No Value	No Value
R2	0.1080	0.2481	0.225166	No Value	0.36093	0.01325	0.20695	No Value	1.0	No Value	No Value
R3	0.1136	0.2611	0.37874	No Value	No Value	0.063123	0.20731	No Value	1.0	No Value	No Value
R4	0.0878	0.2018	0.476395	No Value	No Value	0.1689914	0.300966	No Value	No Value	1.0	No Value
R5	0.1043	0.2397	0.6054722	No Value	0.1782877	0.002648	0.20344	No Value	No Value	1.0	No Value
R6	0.0720	0.1653	0.4936	0.011358	No Value	0.0908661	0.36157	No Value	No Value	No Value	1.0
R7	0.0434	0.0996	No Value	0.088015	No Value	0.00561798	0.72472	No Value	No Value	1.0	No Value
R8	0.1259	0.2892	0.10675	0.7535322	No Value	No Value	No Value	No Value	1.0	No Value	No Value
R9	0.0770	0.1770	0.5425662	No Value	No Value	0.2649695	0.1415479	No Value	No Value	No Value	1.0
R10	0.1471	0.3379	0.11085752	0.4633192	0.258885	No Value	No Value	1.0	No Value	No Value	No Value

Figure 24: the rating of alternatives based on criteria and sub criteria.

In the above figure 24 shows the rating table format on the super decision software. It was shown that the data's for the criteria and sub criteria were recorded for the ten selected road samples. No value implies there is no data for that specific criteria or sub criteria. The super decision will calculate the total weights for the roads and give a priority based on the weights. The ratings were obtained from priorities. By synthesizing the new normalized weights of the criteria and sub criteria were obtained. Synthesizing the whole model was giving the possible priorities of alternatives.

The overall synthesis of the selected road samples were shown in the figure below with graphic form and priorities with three forms i.e. ideal, normal and raw sum. All forms show the same ranking of road samples means gave high value for R10, R8, R1, R3, R2, R5, R4, R9, R6 and R7.


New synthesis for: Main Network: trial.sdmod: r...

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Main Network: trial.sdmod: ratings

Name	Graphic	Ideals	Normals	Raw
R1		0.822546	0.120961	0.120961
R2		0.734414	0.108001	0.108001
R3		0.772743	0.113637	0.113637
R4		0.597333	0.087842	0.087842
R5		0.709343	0.104314	0.104314
R6		0.489277	0.071952	0.071952
R7		0.294796	0.043352	0.043352
R8		0.855869	0.125862	0.125862
R9		0.523758	0.077022	0.077022
R10		1.000000	0.147057	0.147057

Okay Copy Values

Figure 25: Synthesis of the whole model.

Synthesis of the whole model shows the importance of alternatives with respect to the goal. In this study there were ten alternatives. For the ten alternatives means for the ten road samples the priority with respect to maintenance were calculated and synthesized as shown in the figure 25. There were three priorities all will show the same priority rank with different values. The higher the priority implies the higher urgency need for maintenance the lower priority means low urgency need for maintenance. The normal synthesis weights are usually taken as a preference percentage weight for the alternatives. From the synthesis result it was concluded that the road sample ten have the higher weight and the road sample seven was have the lower weight preference with respect to prioritization. The rest R8, R1, R3, R2, R5, R4, R9, R6 and R7 will get the next highest urgency maintenance in a descending order respectively.

Since the road samples were having different combination of sub criteria and criteria values they had a different normal weightage values. After knowing the ideal, normal and raw priorities the next step was about finding the priority weightage for the final rank.

It was possible to rate the road samples since the recalculated weights of criteria and sub criteria were used as a comparison weights. The synthesizes and the ranking of the road are shown the figure 26 as bar chart to make more visible using a priority weightage values and also the total weights of the sample roads are shown.

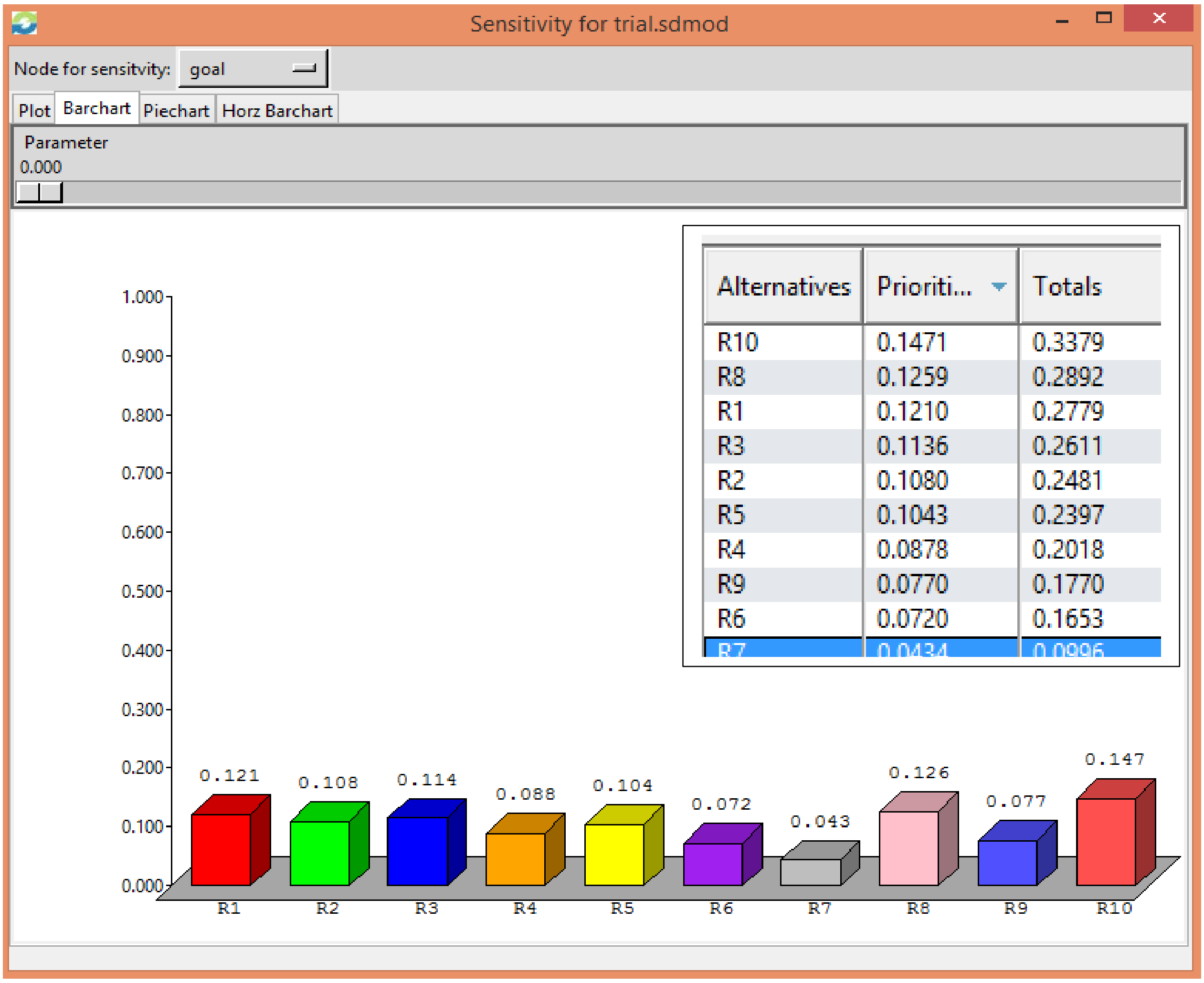


Figure 26: Bar chart for the priority

The sensitivity studies we mean to analyze how the priorities of the alternatives change as we vary the priority of a criterion. For this study the sensitivity analysis for the selected road samples were done with respect to goal as shown in the figure and there is no variation as the parameters varies therefore the road ranking was taken as the final ranking. The final ranking shows R10 needs maximum priority and ranked as first. The remaining R8, R1,R3,R2, R5, R4, R9, R6 and R7 got the next 2nd, 3rd,4th, 5th, 6th,7th, 8th 9th and 10th ranking of maintenance respectively.

4.4 Priority Rank Comparison

In this part the prioritization techniques utilized in the AACRA and AHP technique was compared. The following table 51 shows the prioritization ranking made in the AACRA and the prioritization of AHP techniques using super decision software for the selected ten sample roads. The prioritization of AACRA was not uniform which varies yearly therefore only the last prioritization technique used was taken for this study.

Table 51: Ranking of AHP Vs AACRA.

	Road Name Origen – Destination	Rank By AACRA Subjectively	Rank by AHP approach
R1	sar bet -minaye building	2	3
R2	Alemtsehay bridge-Wolega Hotel	7	5
R3	Adissu Gebeya-Comercial Bank Powlos Branch	10	4
R4	Paster to Shewa Tsega (Mesalemiya)	7	7
R5	Berbere Tera -Mola Maru (Kebele Meznagna)	4	6
R6	Debrezeit Menged -Sene Zetegn-Bhere Steige	9	9
R7	Leadership institute Jan Meda	3	10
R8	Alert Roundabout -FM radio station	3	2
R9	Asfaw Tekle Hotel to Ehil Berenda	3	8
R10	Kolfe Coprative School To Filidoro School	8	1

It is shown in the table that R4 and R6 were having the same ranking on both methods. But the remaining have different ranking. In the subjective rating of AACRA it was found that three road samples R7, R8 and R9 have the same ranking three but the roads have different classes R7 is a local R8 and R9 are SAS and collector respectively. As it was discussed in the previous sections of this paper this three road samples had different distress magnitude. The total percentage damage of distresses was 29.7%, 2.6% and 15.6% for R7, R8 and R9 respectively. Since the data obtained for these three road samples were not approximate each other it was expected to have different rankings priority or urgency maintenance therefore it shows that the prioritization was done subjectively. This was one of the draw back of the subjective priority ranking.

The subjective ranking used in the AACRA was dependent on severity and extent of distress and the ranking were computed subjective manner. In order to is overcome such problem the present study was done by incorporating an objective evaluation

Since the AHP method evaluates the pavement sections for maintenance in an objective manner rather than subjective manner, the priority list obtained through it can be considered as more accurate for implementation. The following table shows a prioritization method done in the AACRA. There are a condition matrix and priority matrix which is done subjectively. In the extent and severity relation 1 means low 2 means medium and 3 means high and the relation output the number from 1 – 5 implies the condition of the road i.e. 1- very good 2 – good 3 –

fair 4- poor and 5- very poor. The priority matrix shows the condition matrix output relation with the road class and road priority from 1 – 18. As shown the table below.

Table 52: AACRA prioritization.

Condition Matrix	Severity		
Extent	1	2	3
1	1	3	5
2	2	4	5
3	3	5	5

Priority matrix	Strategic	PAS	SAS	Coll/LOCAl
Condition	1	2	3	4
Very poor	1	2	3	4
Poor	2	5	6	7
Fair	3	8	9	10
Good	11	12	13	14
Very Good	15	16	17	18

Source: AACRA technical maintenance department

In the condition matrix for the values relating lower extent with high severity, medium extent with high severity high extent with medium severity and high extent with high severity got a value of 5 means ‘ very poor’. In this case it is really confusing to give the rank because all the four combinations got the same condition. It is subjective and will not make the ranking fair. Also, low extent with medium severity and high extent with low severity got the same condition 3 means fair but it is not also clear that which one is more deterministic for deciding the road condition. Therefore the judgment was subjective.

In the priority matrix also there are the same rankings. For example the strategic road in a poor condition and a principal arterial road in a very poor condition got a priority two do not show which one is more preferred there shouldn’t be the same raking for different road class since it may not be possible to maintain the road at the same time it needs a subjective judgment. The local and the collector roads were considered as same but it is not clear.

The other drawback of AACRA prioritization technique is that condition matrix does not clearly show for what distress. What if there is an occurrence of only one distress having a high severity and high extent on one road section and there is another road having different type of distresses having a high extent and high severity? It needs a subjective judgment leading to subjective prioritization. In the priority matrix the condition judgment were related with the road condition. In this case we can clearly see the subjectivity because when we see the rankings it shows that roads which were having a high road class will get a higher priority. There should be a combination effect consideration in order to make it a rational ranking.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

A simple, suitable and refined decision-making method is required for the road maintenance program which consists of databank availability and profitability. Due to shortfalls in annual budgets for pavement maintenance projects, decision makers unavoidably have to select prioritized sections for optimal pavement maintenance work. In this research the Analytic Hierarchy Process was found to be one of the simplest and most useful methods in multi-criteria decision making process. This method was based on pairwise comparisons which facilitate calculations and judgments.

That literatures were reviewed regarding the distresses occurred on flexible pavements, road maintenance prioritization and causes of late maintenance operation and also about Analytical Hierarchy Process and also Super Decision Software.

In this chapter the conclusion and recommendation of the research are summarized as follows.

5.1 Conclusion

Addis Ababa City Road Authority is the main governmental authority which is responsible for the construction and maintenance of the roads found in the city. Prioritization of pavement sections is very crucial for the proper budget allocation and pavement maintenance management activities. As observed during the study period, the maintenance activities were done mainly based on the engineers subjective judgment and also it is difficult to obtain the data recorded for the previous prioritized roads. The other challenge is that the prioritization methods they used is not fixed and vary timely and situations. If the maintenance were not done without considering multi criteria's and having a fixed maintenance prioritization technique, it is difficult to maintain the roads fairly and will lead the road section to further damage and unexpected maintenance expenses.

In this research the percentage damage and damage area calculation were done for each distresses observed on the ten sample roads. The percentage damage shows the amount of distress quantified from 100 percent, which means the coverage of single distress type from the total damage calculated based on the data obtained from the field condition survey. The total damage area was the sum of the areas of individual distresses and done in order to determine the coverage of all distresses from the total area of the sample road. The percentage damage was obtained by dividing the individual distress area to the total damage area. For this study only five distresses was analyzed on the decision analysis module for excel for the further analysis in the prioritization process.

5.1.1 Conclusion on Decision Analysis Module for Excel (DAME)

The decision analysis module for excel were used to determine the maintenance priority governing distresses. The DAME was done by taking nine scenario's means by taking the maximum occurrence of distresses. In this research Raveling got the maximum occurrence it occurs on the nine roads among the ten road samples. There were eleven variants means there were eleven different types of distresses occurred on the ten sample roads. After taking the scenarios and variants the comparison was among the two criteria's i.e. area and severity. The DAME analyzes all the data and was possible to rank the most governing distresses. The software uses maximization principle means combines the maximum of the criteria's for the dominancy. In this research top five ranked distresses were taken as the dominant distresses for the maintenance these were Raveling, Rutting, Pothole, Shoving and Crocodile Cracking.

5.1.2 Conclusion on the Super Decision Software

Considering the multi criteria's to prioritize the pavement sections for maintenance can have great benefit for the decision maker (Pavement Administrator). It was observed that the developed analytic hierarchy process (AHP) model works sufficiently and yields adequate results as well as providing accurate decisions.

In this research, the super decision software was used for the prioritization of the sample ten roads. The super decision uses Analytic Hierarchy Approach technique that the alternatives were prioritized by considering four important indices (criteria) and also five important sub-indices (sub criteria) selected objectively. The criteria's were the road classification data Principal Arterial Street, Sub Arterial Street, Local and collector type of roads that were taken from AACRA road classification and the sub criteria's were obtained from the field condition assessment and decision analysis module for excel result these were Raveling, Rutting, Pothole, Shoving and crocodile cracking. All the criteria's and sub criteria's were pair wisely compared in order to know the influence weighs of the criteria's and sub criteria's.

The comparison of more than one criteria application in the same decision can determine the best outcome if there are resources to achieve this. In this research the ranking shows how the alternatives are important to the goal by considering different criteria's and sub criteria's. The higher the priority shows the higher the urgency need for maintenance. The priority weights of R10 was high there for it has got the first priority of maintenance the remaining road samples R8, R1,R3,R2, R5, R4, R9, R6 and R7 got the next 2nd, 3rd,4th, 5th, 6th,7th, 8th 9th and 10th priority rankings for maintenance respectively.

5.1.3 Conclusion on the AACRA Prioritization Technique

The prioritization technique that was used in the AACRA was not uniform and varies yearly. The prioritizations were done subjectively. There were same rankings given for the roads having different types of distresses and road classes make the technique vague and also the prioritization ranking were not meet the available budget. This leads the roads not to be maintained for the several years these are the drawbacks for the maintenance technique used by the AACRA. In this paper the prioritization of AACRA compared with the prioritization technique done by super decision software applying Analytic Hierarchy Process.

5.2 Recommendation

This research can be taken as initiation for making uniform maintenance prioritization technique. Since the maintenance prioritization technique uses an objective based prioritization technique it can be accepted and further analysis can be added.

It is recommended the data collection should be done by skilled persons since it the basis for prioritization. During the data collection it was observed that some of the distresses were skipped and some distresses were recorded as other type. There were in convenience among the data collectors. This lead to record wrong data leads to wrong ranking prioritization.

The other it is recommended to classify the distresses as dominant and non-dominant this helps to maintenance urgency need distresses before reaching to sever condition that may lead to the pavement to fail. In this research using Decision Analysis Module for Excel the dominant distresses were ranked.

It is recommended to have a clear prioritization technique that wills not varied yearly and a prioritization technique that should have to be

- Easy to conduct: As it does not need special equipment for measuring which is neither expensive nor complicated.
- Widely used: As many researchers have adapted it.
- Comparable: Its result can be compared to some international prioritization technique.

In this research a widely used Analytical Hierarchy process approach technique using super decision software were discussed and recommended to be used.

Since AHP is easier to understand and it can effectively handle both qualitative and quantitative data it was possible to capture the expert's knowledge. The technique is used to solve problems having multiplicity of criteria for judging the alternatives is pervasive. Finally it is recommended to rank the pavement based on the budget available due to luck of that there were roads which are planned before years and not maintained yet. The data's for that road were recorded once and it is not going to be re-collected after those years it leads to roads with different distress data to be maintained with the wrong data.

In the AACRA ranking method the distress types were not considered as a determined and better to create an indicator of the road with the number values known classifications. The use of AHP does not involve cumbersome mathematics. AHP involves the principles of decomposition, pairwise comparisons, and priority vector generation and synthesis. Based on this study result, It is recommended to use the objective based Analytical Hierarchy Process to reduce the subjective decision making and also it is very important to record the previous prioritization result for each road section. This is helpful in managing the road sections and it minimizes the wastage of resource.

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APPENDIX-A

DISTRESS SEVERITY AND METHOD OF MEASUREMENTS

Table 53: Distress Severity and Method of Measurements

		Severity	

No.	Type	Low(L	Medium (M)	High(H)	How to Measure
1	Alligator Cracking	Fine, longitudinal hairline cracks running parallel to each other with no, or only a few interconnecting cracks. The cracks are not spalled	Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled	Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges. Some of the pieces may rock under traffic	Alligator cracking is measured in square meters of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately; however, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity present. If alligator cracking and rutting occur in the same area, each is recorded separately as its respective severity level.
	Bleeding	Bleeding only has occurred to a very slight degree and is noticeable only during some part of the year. Asphalt does not stick to shoes or	Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of	Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year	Bleeding is measured in square meter of surface area. If bleeding is counted, polished aggregate should not be counted.
3	Block-Crack	1. Unfilled cracks ≤ 13 mm, or 2. Filled cracks of any width with the filler in satisfactory condition. No faulting exists	1. Unfilled crack with a width >13 and ≤50 mm. 2. unfilled crack of any width ≤50 mm with faulting of <10 mm, or	1. unfilled crack with a width >50 mm, or 2. filled or unfilled crack of any width with faulting >10 mm	Block cracking is measured in m2 of surface area. It usually occurs at one severity level in a given pavement section; however, if areas of different severity levels can be distinguished easily from one another, they should be measured and recorded separately
4	Upheaval & settlemen	Causes low-severity ride quality	Causes medium-severity ride quality	Causes high severity ride quality	Measured in linear meters. If the bump occurs in combination with a crack, the crack also is recorded.
5	Corrugation	Corrugation produces low- severity ride quality	Corrugation produces medium- severity ride quality	Corrugation produces high- severity ride quality	Corrugation is measured in square meters of surface area
6	Depression	13 to 25 mm	25 to 50 mm	More than 50 mm	Depressions are measured in square meters of surface area.
7	Edge Cracking	Low or medium cracking with no breakup or raveling	Medium cracks with some breakup and raveling	Considerable breakup or raveling along the edge	Edge cracking is measure in linear meters.

No.	Type	Severity Levels			How to Measure
		Low (L)	Medium (M)	High (H)	
8	Lane / Shoulder Drop-off	The difference in elevation between the pavement edge and shoulder is > 25 mm and< 50 mm	The difference in elevation is >50 mm and < 100 mm	The difference in elevation is >100 mm	Lane/shoulder drop-off is measured in linear meters.

N	Type	Severity levels			How to Measure
		L	Medium (M)	High (H)	
9	Longitudinal / Transverse Cracking	1. Filled crack width is Less than 10 mm, or 2. filled crack of any width (filler in satisfactory condition).	1. .non- filled crack width is greater than or equal to 10 mm and less than 75 mm; 2. non-filled crack is less than or equal to 75 mm surrounded by light and random cracking; or, 3. filled crack of any width surrounded by light cracks	1. any crack filled or unfilled surrounded by medium- or high-severity random cracking; 2. unfilled crack greater than 75 m; or, 3. a crack of any width where approximately 100 mm of pavement around the crack is severely broken.	Longitudinal and transverse cracks are measured in linear meters. The length and severity of each crack should be recorded. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately.
10	Patching	Patch is in good condition and satisfactory. Ride quality is rated as low severity or better	Patch is moderately deteriorated, or ride quality is rated as medium severity, or both	Patch is badly deteriorated, or ride quality is rated as high severity, or both; needs replacement soon	Patching is rated in m2 of surface area; however, if a single patch has areas of differing severity, these areas should be measured and recorded separately. For example, 2.5 m2 patch may have 1 m2 of medium severity and 1.5 m2 of low severity

No.	Type	Severity levels	How to Measure

<table>
<tr><td>11</td><td>Polishin g</td><td colspan="4">No degrees of severity are defined; however, the degree of polishing should be clearly evident in the sample unit in that the aggregate surface should be smooth to the touch</td><td>Polished aggregate is measured in square meters of surface area. If bleeding is counted, polished aggregate should not be counted.</td></tr>
<tr><td rowspan="5">12</td><td rowspan="5">Potholes</td><td rowspan="2">Max. depth of pothole</td><td colspan="3">Average diameter</td><td rowspan="5"></td></tr>
<tr><td>100 – 200 mm</td><td>200 - 450m</td><td>450 to 750 mm</td></tr>
<tr><td>13 to ≤</td><td>L</td><td>L</td><td>M</td></tr>
<tr><td>> 25 and ≤50 mm</td><td>L</td><td>M</td><td>H</td></tr>
<tr><td>> 50 mm</td><td>M</td><td>M</td><td>H
If the pothole is more than 750 mm in diameter, the area should be determined in square meter and divided by 0.5 m^2 find the equivalent number of holes. If the depth is 25 mm or less, the holes are considered medium-severity. If the depth is more than 25 mm, they are considered high-severity</td></tr>
</table>

	Type	**Severity levels**			**How to Measure**
		Low (L)	**Medium (M)**	**High (H)**	
13	Rail-Road Crossings	Railroad crossing causes low-severity ride quality	Railroad crossing causes medium-severity ride quality	Railroad crossing causes high-severity ride Quality	The area of the crossing is measured in square meters of surface area. If the crossing does not affect ride quality, it should not be counted. Any large bump created by the tracks should be counted as part of the crossing

14	Raveling	Aggregate or binder has started to wear away. In some areas, the surface is starting to pit. In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.	Aggregate or binder has worn away. The surface texture is moderately rough and pitted. In the case of oil spillage, the surface is soft and can be penetrated with a coin.	Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 10 mm in diameter and less than 13 mm deep; pitted areas larger than this are counted as potholes. In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.	Raveling are measured in square meters of surface area

No.	Type	Severity levels			How to Measure
		Low (L)	Medium (M)	High (H)	
15	Reflection Cracks	1.Unfilled crack width is less than 10 mm , or 2. Filled crack of any width (filler L satisfactory condition).	1.Unfilled crack width is greater than or equal to 10mm and less than 75 mm; no 2. filled crack less than or equal to 75 mm surrounded by light secondary cracking; or, filled crack of any width surrounded by light	1.Any crack filled or unfilled surrounded by medium or high-severity secondary cracking; unfilled cracks greater than 75 mm or, 2. a crack of any width where approximately100 mm of pavement around the crack are	Reflection cracking is measured in linear meters. The length and severity level of each crack should be identified and recorded separately. For example, a crack that is 15 m long may have 3 m of high severity cracks, which are all recorded separately. If a Bump occurs at the reflection crack, it is
16	Rutting (mean rut depth)	6 to 13 mm	>13 to 25 mm	>25 mm	Rutting is measured in square meters of surface area, and its severity is determined by the mean depth of the rut. The mean rut depth is calculated by laying a straight edge across the rut, measuring its depth along the length of the rut to compute its mean depth in
17	Shoving	Shove causes low-severity ride quality	Shove causes medium-severity ride quality	Shove causes high-severity ride quality	Shoves are measured in square meters of surface area. Shoves occurring in patches are rating with the patch, not as a separately

No.	Type	Severity levels			How to Measure
		Low (L)	Medium (M)	High (H)	
18	Slippage Cracks	Average crack width is < 10 mm	One of the following conditions exists average crack width is ≥ 10 and < 40 mm, or the area around the crack is moderately spalled, or surrounded with secondary cracks.	One of the following conditions exists the average crack width is > 40 mm,or the area around the crack is broken into easily removed pieces.	The area associated with a given slippage crack is measured in square meters and rated according to the highest level of severity in the area.
19	Swelling	Swell causes low severity ride quality. Low severity swells are not always easy to see but can be detected by driving at the speed limit over the pavement section. An upward motion will occur at the swell if it is present.	Swell causes medium-severity ride quality.	Swell causes high-severity ride quality.	The surface area of the swell is measured in square meters

APPENDIX-B

QUESTIONNAIRE

This questionnaire is prepared for Road Engineers who works at Addis Ababa City Road Authority and the consultant Engineers.

Dear respondent,

First of all I would like to express my deepest gratitude in advance for taking your time in willfully participating by responding to this questionnaire.

This questionnaire is concerned about prioritizing the road sections for maintenance and rehabilitation activities & the focus area is on pavement maintenance management, for research purpose **Designed to Fulfilling the Requirement for M.Sc. Degree in Highway Engineering, Jimma University Institute of Technology**.

The specific objectives of this research are;

1. To determine the percentage damage of distresses for the sample roads using visual condition assessment survey.
2. To rank the most dominant distresses that governs the selection of maintenance priority for the selected roads using decision analysis module for excel.
3. To determine the rank of sample roads for maintenance based on the weights of each criterion's and sub criterion's using AHP approach in supper decision software.
4. To compare the current prioritization technique of AACRA with the study result and recommend the appropriate and systematic prioritization approach based on the study result.

Since the information you provide could prove to be essential in elaborating the most important factors for selecting road sections for maintenance activities and designing a framework on how to prioritize the rod section for maintenance in budget constraint and also how the pavement maintenance sector of your organization/authority could be improved, I believe your answer will be direct and frank.

This questionnaire has one part is about comparing each factors identified pair wisely.

Your response will be kept strictly confidential. It will be used exclusively for academic and research purposes only.

Thank you

Use this scale for comparing

Verbal Judgment of Preference	Numerical Rating

Extremely preferred	9
Very strongly to extremely	8
Very strongly preferred	7
Strongly to very strongly	6
Strongly preferred	5
Moderately to strongly	4
Moderately preferred	3
Equally to moderately	2
Equally preferred	1

1. For the road classes please put your preferences the left side is for the left side lists and the right preference is for the right sided lists one is the middle center equal preference.

PAS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	SAS
PAS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Local
PAS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Collector
SAS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Local
SAS	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Collector
Local	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Collector

2. For the selected distresses below please put your preferences the left side is for the left side lists and the right preference is for the right sided lists one is the middle center equal preference.

Raveling	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Rutting
Raveling	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Shoving
Raveling	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Corocodile
Raveling	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Pothole
Rutting	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Shoving
Rutting	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Corocodile
Rutting	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Pothole
Shoving	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Corocodile
Shoving	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Pothole
corocodile	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	Pothole