JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

BENEFIT-COST ANALYSIS OF HIGHWAY MAINTENANCE USING FOAMED BITUMEN: A CASE OF AMBO TO GEDO ROAD SEGMENT

A Research is Submitted to School of Graduate Studies of Jimma University as a Partial Fulfillment for the Requirements of Masters of Science in highway Engineering

By:

Ayantu Bayisa

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Advisor: Fikadu Fufa (PhD)

Co- advisor: Basha Fayissa (MSc)

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Faculty of civil and environmental engineering

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Benefit-cost analysis of highway maintenance using foamed bitumen: A case of Ambo to Gedo road segment

By

Ayantu Bayisa

Approved by Board of Examiners

1. Dr. Rohoboam Solomon External Examiner	Signature	23 / 06 / 2022 Date
2. Engr. Biruk Yigezu Internal Examiner	Signature	23 / 06 / 2022 Date
3. Engr. Teyba Wedajo Chairperson	Signature	23 / 06 / 2022 Date
4. Dr-Ing. Fekadu Fufa Main Advisor	Signature	23 / 06 / 2022 Date
5. Engr. Basha Fayissa Co-Advisor	Signature	25 / 06 / 2022 Date

Benefit –Cost Analysis Of Highway Maintenance Using Foamed Bitumen

DECLARATION

I hereby declared that the research entitled as "benefit-cost analysis of highway maintenance using foamed bitumen: A case of ambo to gedo road segment "is my original work and has not been presented as a requirement for the award of any degree at jimma university and elsewhere.

Candidate:	Signature:	Date:
Ayantu Bayisa		23 / 06 / 2022

As Masters Research advisor, I here by certified that I have read and evaluated this MSc thesis prepared under my guidance by Ayantu Bayisa entitled as "benefit-cost analysis of highway maintenance using foamed bitumen: A case of ambo to gedo road segment''. Thus, I recommended for its evaluation.

Fikadu Fufa (PhD)		23 / 06 / 2022
Advisor	Signature	Date
Basha Fayissa (MSc)		23 / 06 / 2022
Co-Advisor	Signature	Date

Highway Engineering Stream, JIT 1

ABSTRACT

Highway maintenance is one of the major tasks to provide safety and comfort for road users. It comprises an activities such as keeping pavement slopes, drainage facilities, patching, filling joints and all structures and property. Foamed bitumen is sprayed into the mixing drum where it the surface (typically 0.075mm) and a soft material having complex behavior which consists hot bitumen, quantities of water 2-5% and it produced when the water and air is injecting into hot bitumen at 150-180^{o}C. Lack of regular maintenance of road create a rapidly fall into disrepair and preventing realization of the longer term impacts of road improvement on development. The road surface types of Ambo to Gedo road is paved road and trunk road (A_4). On Ambo to Gedo road segment a significant rising of vehicle operating costs, travel time and their associated human and property costs are happened due to lack of proper and regular maintenance. These problems were identified through assessing existing conditions of road, to estimating the maintenance cost of road using foamed bitumen and to determining the benefit gained of road maintenance using foamed bitumen by present worth analysis.

A vehicles, passengers, drivers and engineers are the population of the study. The study followed purposive sampling method and employed mixed analytical and descriptive research approach. The maintenance cost and travel fare were collected from Ethiopian Road Authority and transport authority respectively. The travel time were measured and counted directly on road segment. The maintenance cost, travel time saving, vehicle operating saving and travel fare saving were analyzed using the present worth of benefit and cost. The entire road segment revealed that 40%poor, 33.85%good and 26.15%fair conditions. The total benefit and maintenance cost were 951,393,933.9ETB and 295,824,304.1ETB. Finally the result of analysis, B/C is greater than 1 which is 3.216 using foamed bitumen and 2.71, without foamed bitumen, means were the maintenance cost pay back and there is additional saving of benefit which show maintenance cost is less than the benefit gained, so the maintaining road periodically saves and it reduce the reconstruction of road cost and one contribute role to increase the economic activity of the area. Recommend to the road authorities need to give more emphasis on road maintenance activity, period and quality of maintenance using foamed bitumen.

Keywords: benefit-cost analysis, foamed bitumen, maintenance cost, travel time cost, vehicle operating cost, pavement condition

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TABLE OF CONTENTS

Contents **Pages**

LISTS OF FIGURES

LISTS OF TABLES

ACRONMYS

AADT	Average annual daily traffic
AASHTO	American association of state highway and transportation officials
BCA	Benefit cost analysis
BCR	Benefit cost ratio
CRS	Condition rating system
DOH	Department of highway
ERA	Ethiopian road authorities
ERCC	Ethiopian road construction corporation
ERDP	Ethiopian road development program
ETB	Ethiopian birr
LCCA	Life cycle cost analysis
MRA	Municipal road authorities
NPV	Net present value
PASER	Pavement surface evaluation system rating
PCR	Pavement condition rating
PSR	Present serviceability rating
RCV	Remaining condition value
RRA	Regional road authorities
RSDP	Road sector development program
TTS	Travel time saving

VC	Vehicle classification
VHT	Vehicle hours travel

CHAPTER ONE

INTRODUCTION

1.1. Background

Road plays a vital role in the socio economic development of the country by providing easy transportation for agriculture, industrial products and public transportation with tremendous reduction of travel cost and time. Long-lasting pavements that are safer, smoother, environmentally sensitive and cost-effectively constructed and maintained are an important part to modernize the Ethiopian transportation system. In Ethiopia, billions of money is spent every year to construct road but the trend and budget allocation attention for pavement condition improvement, comparing with new projects is very poor. To address the constraints, the Ethiopian government is implementing the maintenance of the road network under the Road Sector Development program (RSDP).

A well-developed transportation network is vital to the economic development of the country. High quality road network increases the potential of any economic investment by helping both consumer and producer. A high quality road network is important for high level of economic performance. It helps to sustained economic growth, increases productivity, helps in increment regional development and increases competitiveness. Highway maintenance is one of the major tasks for the department of highways (DOH) to provide safety and comfort users (Lertworawanich, 2018).

One of the problems seen from Ambo to Gedo road segment is due to lack of maintaining the properly and regularly using foamed bitumen. The road is trunk road (A_4) and the surface type of the road is paved road, it was constructed before 10 years and has lost its designed period. Due to prolong service year and the increasing number of traffic, the road deteriorates, and has defects like potholes, failures, cracking and its lost camber. Road without regular maintenance ,road with easily fall into disrepair ,preventing the long term effect of road construction on development as well as the well social and economic growth country and constructing new roads cost but without maintaining the existing road properly they deteriorate very quickly. This deterioration in return will affect the road efficiency and eventually increase the cost of maintenance or replacement if nothing is done in long run. (Kabeto, 2018).

Road maintenance comprises the activities to keep pavement slopes, drainage facilities, patching, filling joints and all structures and property as near as possible to their as constructed or renewed condition. The maintenance of roads famously known could enhance the economic growth and social benefits though road system that poorly maintained destructs mobility, upsurges the accidents rate and worsens other main aspects. A benefit-cost analysis is need for evaluating and comparing different alternatives. Benefit-cost analyses of a highway maintenance using foamed bitumen have been used as a tool to evaluate preliminary. The elements of primary transportation can be monetized are travel time costs, vehicle operating costs, safety costs, ongoing maintenance costs , remaining capital value (a combination of capital expenditure and salvage value) and foamed bitumen for highway maintenance (Yitages, 2017).

Foamed bitumen is sprayed into the mixing drum where it coats the surface of the some particles(typically less than 0.075mm in diameter),making the agglomerations of loosely packed mortar that adhere to the larger particles. Consequently, these coated fines together with the secondary binder (i.e. cement of lime) improve the performance of the parent material. Foamed bitumen uses to improve the strength of granular materials while retaining flexible pavements. It allows to evently distributed throughout soil materials and it can mix on site or in plants and It is essentially a mixture of air, water and bitumen. When small quantity of cold water is injected into hot bitumen, the bitumen expands by approximately 15 times its original volume with low viscosity. The large surface areas and low viscosity of foamed bitumen facilities the greater dispersion of bitumen in the aggregates skeleton and successfully formed by the presence of a surfactant which is primarily contained in asphaltiness. Foamed bitumen to prevent water because it’s bind course aggregate and asphalt, so foamed bitumen is one of the major binder of asphalt (Sarvesh Kumrawat1, 2018).

Foamed bitumen is a hot bituminous binder that has been temporarily converted from state of liquid into a foam state by addition of a small percentage of water and pressurized air. It consists of hot bitumen, small quantities of water between 2–5% by weight of bitumen and air. The foamed bitumen produced when water and air are injecting into hot bitumen at 150–180°C (Sarvesh Kumrawat1, 2018). Maintenance using foamed bitumen is successfully due to its ease and speed construction, it is compatibility with a wide range of aggregate types and relative immunity the effects of weather (Khalid, 2013).

Results from benefit-cost analysis using foamed bitumen, along with public input and environmental documentation, can be used to evaluate the monetized and to identify benefit of foamed bitumen for highway maintenance, effects and impacts of alternatives when a decision needs to be made.

1.2. Statement of Problem

Roads play a vital important in order to make a nation grow and develop. Especially in the third country good maintained roads also will enhance poverty reduction by improving access between regional and rural communities and ultimately enhancing socio economic growth and development. In the history of Ethiopia Road Development Program (ERDP), almost all of the road pavements are flexible, high amounts of budget allocated every fiscal year planning period and it demands high foreign currency for asphalt material importing from abroad. Since the cost comprises of a large portion of government investment, a careful evaluation of the alternatives is importance to make the right choice for a particular project (Kabeto, 2018).

A key principle of road maintenance is that spending money now saves future costs. As the assets deteriorate, so the cost to restore their condition increases and as the condition gets worse, so the costs to society usually become more significant. The problem of Ambo to Gedo on road segment occurs due to lack of maintaining using foamed bitumen the road properly and regularly. The road surface affected by distresses like potholes, cracks, raveling due to these lack safety to travel, dust disturb the movement of travel and take long travel time (Kabeto, 2018).

Without regular maintenance using foamed bitumen, roads can rapidly fall into disrepair, preventing realization of the longer term impacts of road improvement on development, such as increased agricultural production and growth in school enrollment. If nothing is done, roads with a design life of decades can need major repair work after just a few years. Poorly maintained roads constrain mobility, significantly raise vehicle operating costs, travel time and their associated human and property costs, which again will infect the economy of transporters. As the road network deteriorates, the whole country loses major assets created with vast amounts of money, time and effort. In this study the research carried out benefit-cost analysis to evaluate the fundamental advantages and disadvantages of highway maintenance using foamed bitumen affect the user's benefit and cost (Stankevich, 2005).

1.3. Research questions

I. What are the problem existing conditions of the road segment?
II. How much maintenance cost is incurred to maintain the road using foamed bitumen?
III. How much is benefit saved due to road maintenances using foamed bitumen?

1.4. Objectives of the study

1.4.1. General objective

The general objectives this study is to analysis the benefit cost of highway maintenance using foamed bitumen. A case of ambo to gedo road segment.

1.4.2. Specific objectives

I. To assess existing conditions of the road segment
II. To estimate the maintenance cost of the road using foamed bitumen by present worth analysis
III. To determine the saving benefit of road maintenance using foamed bitumen by present worth analysis

1.5. Significance of the study

- ✓ To be recognized today in a changed context and with a changed concept.
- ✓ To providing improved service to road users and contributing to environmental quality.
- ✓ The implementing authority (ERA), which use the information to give more emphasis on maintenance of road activity.
- ✓ Educational institutions, which use the information for academic purpose.

1.6. Scope and Limitations of the Study

The scope of this study is to analysis of benefit cost of highway maintenance using foamed bitumen and restricted to the analysis of travel time saving, vehicle operating cost saving, transport fare saving and non-monetary aspect like environmental concern and economic analysis using primary and secondary data. The limitation of this study to limited environmentally impact, societal benefits from road maintenance would not be fully quantifiable in this study, because of technological differences and data availability limitations in our country in vehicle operating cost saving only consider fuel and tire cost for small bus but if considering oil, depreciation of vehicle and other factor the result would be increase due to difficulty to estimate.

1.7. Plan for dissemination of findings

Dissemination of findings is important so that results can be used to improve engineering and technological industries. A dissemination plan would be designed by implementing the following points effectively.

- ✓ Orient toward the needs of the audience, using official language (English language), and if needs other appropriate languages can be used at information levels.
- ✓ Include various dissemination methods: written text including illustrations, graphs and figures; electronic and web-based tools; and oral presentations at community meetings and scientific conferences.
- ✓ Leverage existing resources, relationships, and networks fully.

CHAPTER TWO

LITERATURE REVIEW

2.1. General description

Benefit cost analysis counts all the negative and positive economic effects of an investment, regardless how they are paid. It treats all negative effects as costs and all positive effects as benefits. The important in benefit cost analysis is the concepts of incrementally to quality as economically worthwhile; a project must generate benefits over and above the forth coming from the base case. The base case should represent as closely as possible the most efficient and productive use of existing assets, if expenditures are required to achieve it (Inc., 2006).

Highway maintenance is defined as the function of preserving, repairing, and restoring a highway and keeping it in condition for safe, convenient, and economical use. Maintenance includes both physical maintenance activities and traffic service activities (John Ireland Blvd, 2020).Highway maintenance programs are designed to offset the effects of weather, vandalism, vegetation growth, and traffic wear and damage, as well as deterioration due to the effects of aging, material failures, and construction faults (Yong Bai, 2009).

The purpose of maintenance is to ensure that the road remains serviceable throughout its design life.it important to prolongs the life of the road by reducing the rate of deterioration, thereby safeguarding previous investments in the construction and rehabilitation, to lowers the cost of operating vehicles on the road by providing a smooth running surface, to keeps the road open for traffic and contributes to more reliable transport services and to sustains social and economic benefits of improved road access (Girmay, 2016).

2.2. Road maintenance

Road maintenance is an activity that designed to keep a road network serviceable by reducing the deterioration of pavements. The main purpose of road maintenance is to preserve the asset, not to upgrade it. Unlike major road works, maintenance must be done regularly. The major activities in road maintenance are keeping pavement, shoulders, slopes, drainage facilities and all other structures and properly with in the road margins as near as possible to their as constructed.it helps to make minor repairs and improvements to eliminate the causes of defects and to avoid excessive repetition of maintenance efforts (Gorfu, 2017)**.**

Road maintenance is preserving and keeping each types of roadway, roadside, structures as nearly as possible in its original conditions as constructed or as subsequently improved an the operational of road facilities and services to provide, satisfactory and safe transportation. Almost every day is affected by the use of roads.in most countries roads are the major transport mode of passengers and freight. Road networks facilities transport services and reduce the cost of travel and trade, individuals' roads enhance accessibility to markets and services. To achieve continuity of road transport benefits, road assets need to be maintained in good condition. The condition of a road will deteriorate over time through use because of the wear and tear of expected and unanticipated traffic, climate change and construction materials quality. It refers to the process and resources that are combined to manage road conditions as well as to protect the road assets. It is part of the activities required to ensure an affordable and efficient road system for the sustainability of road transport services. It keeps a road network and transport services operating (G/Mariam…, 2019).

Road maintenance is essential in order to:-

- ✓ Preserve the road in its originally constructed condition.
- ✓ Project adjacent resources and user safety
- ✓ Provide cost effective, shortest time and environmentally friendly travel on the routes.

For management and operational convenience, road maintenance activities are categorized as routine, periodic, and urgent.

2.2.1. Routine maintenance

Route maintenance is work performed in relation to event; season or overall deterioration of the transportation asset. It Comprises small-scale works conducted regularly, aims "to ensure the daily pass ability and safety of existing roads in the short-run and to prevent premature deterioration of the roads. Frequency of activities vary but is generally once or more a week or month. Typical activities include cleaning of silted ditches and culverts, patching, and pothole repair. It is the preliminary maintenance activities applied to highway assets to maintain them in good, clean and safe conditions. It also includes some minor modification and improvement to the existing conditions (Lertworawanich, 2018).

Table 2.1.Pavement Routine maintenance schedule (Yonas Ketema, 2016)

Frequency in a year	Month of a Year	Routine Maintenance Activities	Remarks
1st	March	Activity Code 210-215,18 &19	Twice (2) a year before and after the rainy season
	April		
	May		
2nd	October		
	November		
	December		

2.2.2. Periodic maintenance

Periodic maintenance is a set of activities to the performed periodically to strength pavement structures and to extend service life of the highways with to serve existing and future traffic (Lertworawanich, 2018). The Periodic Maintenance is to be conducted once a year before the rain comes as per the experience of the Ethiopian Road Construction Corporation (ERCC) and Ethiopian Road Authority (ERA) **(**Yonas Ketema, 2016). Covers activities on a section of road at regular and relatively long intervals, aims “to preserve the structural integrity of the road. These operations tend to be in large scale, requiring specialized equipment and skilled personnel. They cost more than routine maintenance works and require specific identification and planning for implementation and often even design. Activities can be classified as preventive, resealing works, overlay, and resurfacing and pavement reconstruction (Gorfu, 2017).

Preventive: It includes fog sealing and rejuvenation. When preventive treatment is performed, any surface distress and preventive treatment age are reset to zero. It has effects of delaying the initiation of cracking and raveling, but the pavement structure and strength remains unaltered. **Resealing Works:** Resealing without shape correction can repair surface distress but cause little change to roughness or structural strength of the pavement. However, resealing with shape correction can achieve some reduction in roughness through the filling of depressions and repair of damaged areas. Resealing works resets surface distresses, surfacing age, and preventive treatment ages to zero, and thereafter the pavement condition is considered to be new.

Overlay: It is specified using new surfacing thickness, layer strength coefficient, surface material, and construction defect indicator for bituminous surfacing. Overlay work resets surface distresses to zero, and thereafter the pavement condition is considered to be new.

Resurfacing: It involves the removal of all or part of the existing bituminous surfacing and replacing it with a new bituminous surfacing. It is usually performed to correct defects that have occurred mainly due to poor construction quality and the bituminous material being too rich or brittle, or where the road surface levels need to comply with some requirements related to drainage facilities. Information on new surfacing thickness, layer strength coefficient, surface material, and depth of milling are required to specify mill and replace works.

Pavement Reconstruction: It refers to all works that require the re-specification of the surfacing and road base types. It may be specified either as a maintenance standard or as an improvement standard if the works involve the minor widening of the carriageway.

Table 2.2.Schedule of Periodic maintenance for flexible pavement (Yonas Ketema, 2016)

Frequency in a year	Month of a year	Periodic maintenance Activities	Remarks
Once a year	March	Activity code 309-216	Once every three years before rainy season
	April		
	May		

2.2.3. Urgent maintenance

Is undertaken for repairs that cannot be foreseen but require immediate attention, such as collapsed culverts or landslides that block a road clearly put that the strategic aim of road maintenance should focus on performing the right types of maintenance activities (i.e. routine, periodic, or emergency maintenance), at the right time on a road so as to optimize the total benefit-cost relationships of a road over its lifetime (Gorfu, 2017).

2.3. Benefit -cost analysis

Benefit Cost Analysis (BCA) is a tool that state transportation agencies can use to perform economic comparisons of infrastructure improvement projects across transportation modes to determine if a project is a justified investment. Benefit-cost analysis is systematic evaluation of the economic advantages (benefits) and disadvantages (costs) of the sets of investment alternatives (Wallace, 2016). The objective of a benefit-cost analysis is to translate the effects of an investment into monetary terms and to account for the fact that benefits generally accrue over a long period of time while capital costs are incurred primarily in the initial years. The primary transportation related elements that can be monetized are travel time costs ,vehicles operating costs ,safety costs, ongoing maintenance costs, and value (a combination of capital expenditure and salvage value) (John Ireland Blvd, 2020).

Benefit cost analysis is a systematic process for calculating and comparing the benefits and costs of project alternatives. Using benefit cost analysis, transportation professionals can compare present value costs and benefits among alternatives for a given analysis period. A BCA differentiates cost and benefits by projects costs (or agency costs), project benefits (or user costs) and project benefits include cost avoided such as increased crashes or air emission (Michael Lawrence, 2018).

Table 2.3 benefits and cost categories (Michael Lawrence, 2018)

Project benefits(user costs)	Project costs(agency costs)
✓ Reduced travel time and delay ✓ Improved travel time reliability ✓ Reduced crash frequency ✓ Reduced vehicle operating cost	✓ Design and engineering ✓ Routine maintenance ✓ Construction ✓ Reconstruction

According to the transportation economic committee the benefit cost analysis is most applicable projects are a large enough to justify the price of through analysis, improve transportation system rather than altering them to the meet legal requirements and have environmental costs which are insignificant or can be monetary values.

2.4. Asphalt pavement surface distress

Distress is the deterioration of a pavement apparent by various external signs and indicators. Pavement deterioration is the processes of distress (defect) develop in the pavement under the combined effects of traffic loading and environmental conditions due to weathering and aging. The four major categories of common asphalt pavement surface distress (Girmay, 2016).

A. Cracking: Cracks in flexible pavements are caused by deflection of the surface over an unstable foundation, shrinkage of the surface, thermal expansion and contraction of the surface, poorly constructed lane joints or reflection cracking. The common types of cracking: fatigue cracking, longitudinal cracking, transverse cracking, block cracking, slippage cracking and edge cracking.

Alligator or fatigue cracking:-It is a series interconnected cracks creating small, irregular shaped pieces of pavement.

It is caused by failure of the surface layer due to repeated traffic loading or fatigue and little pavement thickness. It usually associated with drainage problems.

Possible measures:-

- ✓ Small may be fixed with patch or repair
- ✓ Large areas require reclamation or reconstruction
- ✓ Drainage must be carefully examines in all cases
- ✓ For cracking from overloading a properly designed overlay will correct condition

Figure.2.1.Alligator or fatigue cracking

longitudinal cracking:-Longitudinal cracks are long cracks that run parallel to the center line of the roadway. These may be caused by frost heaving or joint failures or they may be load induced. Understanding the cause is critical to selecting the proper repair. Multiple parallel cracks may eventually form from the initial crack. This phenomenon, known as deterioration, is usually a sign that crack repairs are not the proper solution.

Figure .2.2. Longitudinal Cracking

Transverse crack:-Transverse cracks from at approximately right angles to the centerline of the road way. They are regularly spaced and have some of the same causes as longitudinal cracks. Transverse cracks will initially be widely spaced. They usually begin as hairline or very narrow cracks and widen with age. If not properly sealed and maintained, secondary or multiple cracks develop, parallel to the initial crack. The reasons for transverse cracking, and the repairs, are similar to those for longitudinal cracking. In addition, thermal issues can lead to low-temperature cracking if the asphalt cement is too hard.

Figure . 2. 3. Transverse crack

Block cracking is an interconnected series of cracks that divides the pavements into irregular pieces. This is sometimes the result of transverse and longitudinal cracks intersecting. They can also be due lack of compaction during construction. Low severity block cracking may be repaired by a thin wearing course.as the cracking gets more severe overlays and recycling may be needed. If base problems are found, reclamation or reconstruction may be needed.

Reflective cracking is occurring when a pavement is overlaid with hot mix asphalt concrete and cracks reflect up through the new surface.

Edge cracking is the result from lack of support of the shoulder due to weak material or excess moisture they may occur in a curbed section when subsurface water causes a weakness in the pavement.

B. **Surface deformation** Pavement deformation is the result of weakness in one or more layers of the pavement that has experienced movement after construction. The deformation may be accompanied by cracking. Surface distortions can be traffic hazard (GIRMAY, 2016).Basic types of surface deformation: rutting, corrugation, shoving, and depression, swell.

Rutting is the displacement of pavement material that creates channels in the wheel path. It is usually a failure in one or more layers in the pavement. The width of the rut is a sign of which layer has failed. A very narrow rut is usually a surface failure, while a wide one in indicate of a subgrade failure.

Corrugation is referred to as wash boarding because the pavement surface has become distorted like a wash board.it usually occur at places where vehicles accelerate or decelerate.

Shoving it also form of plastic movement in the asphalt concrete surface layer that creates a localized bulging of the pavement. Locations and causes of shoving are similar to those for corrugations.

Depressions are small, localized bowl shaped areas that may include cracking. Depressions cause roughness, are a hazard to motorists and allow water to collect. Depressions are typically caused by localized consolidation or movement of the supporting layers beneath the surface course due to instability.

Swell is a localized upward bulge on the pavement surface. Swell are caused by an expansion of the supporting layers beneath the surface course or the subgrade. The expansion is typically caused by frost heaving or moisture. Reconstruction may be required for extensive swelling.

C. Disintegration is the progressive breaking up of the pavement into small, loose pieces. If the integration is not repaired in it is easily stages, complete reconstruction of the pavement may be needed. The common types of disintegration: potholes and patches.

Potholes a pothole is a depression in a road surface, usually asphalt pavement, where traffic has removed broken pieces of the pavement.it is usually the result of water in the underlying soil structure and traffic passing over the affected area.

Caused by the localized disintegration of the pavement surface:

- ✓ Expansion and contraction of ground water after the water has entered into the ground under the pavement, when water freezes, it expands
- ✓ Weak spots and poor mixtures in the subgrade
- ✓ Appears when appropriate maintenance is not promptly applied once a distressed conditions have been detected and Heavy rains

Remedial measures

- ✓ Temporary patching and repair through filling it with a pre mixed material. Permanent repair through filling it with new base and surface material.

Figure .2. 4. Potholes caused by poor drainage

Patches A patch is defined as a portion of the pavement that has been removed and replaced. Patches are usually used to repair defects in a pavement or to cover a utility trench. Patch failure can lead to a more widespread failure of the surrounding pavement. Some people do not consider patches as a pavement defect. While this should be true for high quality patches as is done in a semi-permanent patch, the throw and roll patch is just a cover. The underlying cause is still under the pothole. To repair a patch, a semi-permanent patch should be placed. Extensive potholes may lead to area repairs or reclamation. Reconstruction is only needed if base problems are the root source of the potholes.

D. Surface defects related to problems in the surface layer. The most common types of surface defects (Girmay, 2016). Raveling, bleeding, polishing and delamination.

Raveling is the loss of material from the pavement surface.it is result of insufficient adhesion between the asphalt cement and the aggregates. Raveling can be accelerated by traffic and freezing weather.

Bleeding is defined as the presence of excess asphalt on the road surface which creates patches of asphalt cement.

Polishing is the wearing of aggregate on the pavement surface due to traffic.it can result in a dangerous low friction surface. A thin wearing course will repair the surface.

Delimitation is a failure of an overlay due to a loss of bond between the overlay and older pavement common causes of delimitation include: wet or dirty surface during paving of the overlay, failure to use a tack coat or poor compaction of the overlay

2.5. Pavement condition rating (PCR)

The condition rating systems can be grouped into two main groups namely estimated condition ratings and measured condition ratings. The estimated condition rating systems are based on observed physical conditions of the pavements while the measured condition rating systems are not only based on observations by trained raters but are also backed by physical measurements such as roughness and mathematical expressions. Most of the state agencies use the measured rating systems since they provide a more objective rating of the performance of the pavements (Adarkwa, 2013).Examples of pavement rating condition in the two categories.

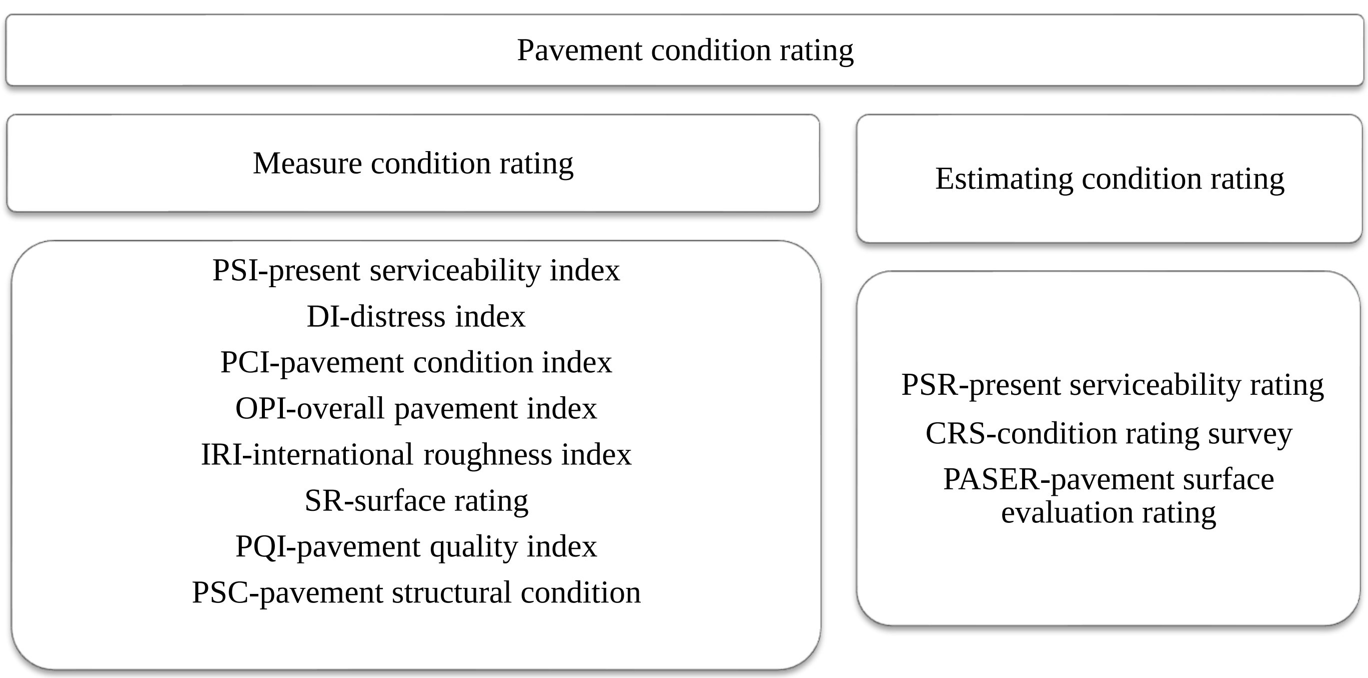

Figure .2 . 5. Pavement condition rating systems

2.5.1. Present serviceability rating [PSR]

The most common and fundamental pavement condition rating index is present serviceability rating [PSR].This is from AASHTO and based on the ride quality as experienced by a panel of observers riding in a vehicle on a particular section pavement. The rating scale used is from 0 to 5.

Table 2.4.Present serviceability rating (Adarkwa, 2013)

PSR Rating	Description
5	Very good; distress free, newly constructed pavements are in this category
4	Good; few sign of deterioration
3	Fair; ride quality inferior to a new pavement, tolerates high speed traffic
2	Poor; distress over 50%surface,deep crack, large potholes
1	Very poor; large potholes, deep cracks, only passable at reduced speeds, distress over
0	75%of surface

2.5.2. Condition rating survey [CRS]

The CRS is also types of estimated condition rating system used by the Illinois Department Of Transportation [IDOT].The scale is a 1 to 9 scale with increments of 0.1.a value of 1.0 represents total failure while a value of 9.0 represents a newly constructed pavement (Adarkwa, 2013).

2.5.3. Pavement surface evaluation system (PASER)

PASER is the one of estimating condition rating system; it is also visual rating of the pavement conditions based on a 1-10 scale. There is a manual photographs and description that guides inspectors to choose the appropriate value on the scale that captures the conditions accurately.

Table 2.5**.**PASER rating and description maintenance requirements (Adarkwa, 2013)

PASER rating	Description of maintenance
9-10	No maintenance needed
8	Little maintenance

7	Routine maintenance, crack sealing, minor patching
5-6	Seal coating
3-4	Overlay
1-2	Reconstruction

2.6. Transport development and maintenance in Ethiopia

Development in Ethiopia is the responsibility of the Ministry of Transport and the Ministry of Urban Development and Construction. Road sector development and maintenance is mainly executed by the Ethiopian Road Authority (ERA), Regional Road Authorities (RRAs), Municipal Road Authorities (MRAs) and the Woreda Road Desks (RSDP4, 2012).

2.6.1. Road transport

Ethiopia's classified road network increased on the average by 5% per annum from its 1997 base of about 26,500 km to 37,018 km up to 2005 of which about 13.0% is paved. The ten-year Road Sector Development Program (RSDP) launched in 1997 has continued to address both the past neglect and the present capacity constraint in the road sector (TOURE, 2006).

To execute such a very crucial project, large amount of budget will be allocated for the surfacing of pavements. In the last 17^{th} years (1997-2014 G.C) the total length of rigid pavement constructed was only 2.3 kilometers while about 99.8% or 12640 kilometers are flexible pavement. Over the past 17^{th} years 41.2% of the total Ethiopian road sector development program(RSDP)expenditures was allocated for the rehabilitation and upgrading roads,28.8% for construction of link roads,5.7% for maintenance of federal roads,8% of regional road and 11.7% of wereda roads,2.8% of institutional) support projects and other activities at the federal level. During the last four years (2010-2014 G.C) RSDP accomplishment expenditure showed that 4.8 billion for periodic and 0.7billion for routine maintenance were utilized to federal and regional flexible pavement roads (Yonas Ketema, 2016).

2.6.2. Ambo road network

Ambo Road Network Management Branch Directorate is currently responsible for administering eight sub section of paved and unpaved road segments having a total length of 372.00Km, which are located in the west shewa zone of the oromia region, west of Addis Ababa .Out of the total road networks 268.40 Km are Paved road and 103.60Km are unpaved .The terrain classification of the road network coverage is dominantly flat and steep slopes (ERA, 2016).

2.6.3. Heavy-Vehicle impact on pavement damage

Commonly identified pavement distress associated with heavy vehicles can be characterized as fatigue cracking and rutting. On rigid pavements damage includes transverse cracking, corner breaking, and cracking on the wheel paths. Flexible pavements and granular roads are most susceptible to rutting. In all cases, cracking and rutting increase pavement roughness and reduce pavement life. Trucking has become the most popular mode of freight transportation because of its efficiency and convenience, and this preference has resulted in increased highway maintenance costs (Yong Bai, 2009).

2.6.4. Pavement Deterioration Prediction

Many of the analysis packages used in a PMS require pavement performance prediction models. A condition prediction model allows agencies to forecast the condition of each pavement segment from a common starting point. The pavement performance prediction element involves the estimation of future pavement conditions under specified traffic loading and environmental conditions. Reliable pavement performance prediction models are crucial for identifying the least-cost rehabilitation strategies that maintain desired levels of pavement performance (Yong Bai, 2009).

2.6.5. Time-Related Deterioration of Pavements

A pavement will deteriorate over time due to environmental factors in the absence of truck traffic. Thermal cracking, differential heaving due to swelling subgrade or frost penetration, disintegration of surface materials due to freeze-thaw cycles, and other climatic aging effects on materials are largely a function of the environment and will result in a loss of pavement serviceability (Yong Bai, 2009).

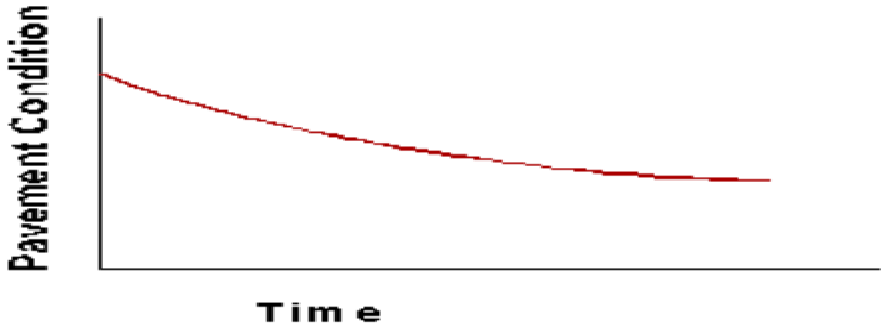

Figure.2. 6.Theoretical relationship between loss of pavement serviceability and time

This figure is depicts likely form the negative exponential function. This function suggests that pavement condition declines rapidly when initially exposed to the environmental elements, but then deteriorates at a decreasing rate over time. This type of decay process is similar to other natural and man-made phenomena, not just highways (Yong Bai, 2009).

2.6.6. Traffic Volume Growth

As traffic levels grow, the need for maintenance is only increased. Even for many developed countries, where the long term rate of traffic growth has slowed, attempts to maximize capacity on congested networks and to maintain mobility at higher traffic flows have led to use of increasingly complex assets to ease traffic flow. Such assets require more frequent interventions on the networks drive increased maintenance costs (Kabeto, 2018).

2.7. Average Annual Daily Traffic (AADT)

AADT is the average of 24-hour counts collected every day of the year. It is necessary to obtain data continuously. However, it is not feasible to collect continuous data on all roads because of the cost involved. To make reasonable estimates of annual traffic volume characteristics on an area wide basis, different types of periodic counts, with count durations ranging from 15 minutes to continuous, are conducted, the data from these different periodic counts are used to determine values that are the employed in the estimation of annual traffic characteristics (Kabeto, 2018).

AADTs are used in several traffic and transportation analyses for:

- ✓ Estimation of highway user revenues
- ✓ Establishment of traffic volume trends

- ✓ Evaluation of the economic feasibility of highway projects
- ✓ Development of freeway and major arterial street systems
- ✓ Development of improvement and maintenance programs

2.7.1. Vehicle Classification (VC)

VC records volume with respect to the type of vehicles, for example, passenger cars, two-axle trucks or three-axle trucks.

VC is used in:

- ✓ Design of geometric characteristics with particular reference to turning-radii requirements, maximum grades, lane widths, and so forth
- ✓ Capacity analyses, with respect to passenger-car equivalents of trucks
- ✓ Adjustment of traffic counts obtained by machines
- ✓ Structural design of highway pavements, bridges, and so forth (Kabeto, 2018)

2.8. Highway maintenance benefits

Every nations benefit from a well performing transportation network, Road is essential for economic development of a country. For speedy transportation of commodities and quick movements, a good road network is essential. In highway benefit cost analysis, the usual procedure is that benefits are first estimated in physical terms and then valued in economic terms. The benefit cost analysis measures the capital cost in monetary terms, and the benefits that accrue in the form of travel time and the vehicle operating cost savings on the other. The major considerations in the measurement of costs and benefits are: the travel that incurs costs to road users such as the time spent on travelling; costs arising from the direct costs of fuel, maintenance and depreciation (Kabeto, 2018).

2.8.1. Travel-Time Savings

Travel-time savings typically generate the greatest amount of benefit share of people’s personal time is devoted to transport. These savings are calculated based on the difference in travel time between the base case and alternatives. Travel time is often expressed as vehicle hours traveled (VHT).The estimation of travel time savings should include both the driver and passengers in the vehicle (i.e., vehicle occupancy rates). In many cases, vehicle occupancy rates vary between peak and off peak hours as well as between alternatives. The valuation of travel time savings is calculated using standardized cost per hour per person for different vehicles (auto truck) (John Ireland Blvd, 2020).

2.8.2. Vehicle Operating Cost saving

When transportation improvements are made, the cost of operating vehicles along a particular facility or set of facilities can change. Operating costs can change because the number of miles driven changes, as in the case of a shorter by pass or a reduction in circuitry or diversion of trips, or it can change because of changes in the number of stops or speed-cycle changes .The number of vehicle miles traveled (VHT) is the most common variable that affects vehicles operating costs. Once the change in vehicle miles is estimated is the valuation of vehicle operating costs calculated using standardized cost per mile figures for different vehicles (auto or truck] (John Ireland Blvd, 2020).Vehicle operating cost saving includes; the costs associated with fuels, tires, maintenance, repairs and mile age dependent depreciation (Alqadhi, 2018).

2.9. Highway life-cycle costs

In economic terms; the cost of a transportation investment is the value of the resources that must be consumed to bring the project about. The total value of construction and any additional maintenance costs must be estimated. Transportation cost is a major expenditure that is accounted after expenditure on housing. Thus reduction of fuel consumption due to maintenance of roads helps the peoples to spend less money on transportation expenditure (John Ireland Blvd, 2020).

2.9.1. Capital Costs

Capital costs make up the total investment required to prepare a highway improvement for service, from engineering through landscaping. When possible capital costs should be grouped into similar life cycle. These including; engineering right of way, major structures, grading and drainage, sub base and base, surfacing and miscellaneous items. Estimates of capital cost, ranging from detailed engineer's estimates to planning-level cost estimates, should be as refined as appropriate for the project's stage in the project development process (John Ireland Blvd, 2020).

2.9.2. Routine Annual Maintenance Costs

When evaluating transportation investments, it is important to account for the future operating and maintenance costs of the facility. In the case of an upgraded roadway, it is necessary to estimate the additional maintenance costs that would be required for the alternative as compared to the base case (John Ireland Blvd, 2020).

2.9.3. Remaining Capital Value (RCV)

Many components of a project retain some residual useful life beyond the benefit-cost analysis period (typically 20 years). At the end of the analysis period, the infrastructure that has been put in place generally has not been completely worn out, and will continue to provide benefits to drivers and travelers into the future. It is important to reflect this value in the analysis. The remaining capital value is calculated by determining the percentage of useful life remaining beyond the analysis period, and multiplying that percentage by the construction cost for that component. The estimate of the remaining capital value at the end of the analysis period is then converted to a present value and subtracted from the initial capital cost (Sharad.S.Adlinge, 2016).

2.10. Benefit-Cost Ratio

As its name implies benefit cost compares expected benefits of a project to the expected costs over the life of the project. Because the benefits and costs occur over time, standard financial procedures are used to create a "present value" of both costs and benefits. In this method all costs and benefits are discounted to their present worth and the ratio of benefit to cost is calculated.

Benefits:-

- ✓ Travel time savings
- ✓ Vehicle operating cost savings
- ✓ Travel fare savings
- ✓ Safety improvement
- ✓ Emission reduction

Costs:-

- ✓ Initial costs (planning, design, engineering and construction)
- ✓ Continuing costs (operation and maintenance)

- ✓ Road-user costs during construction
- ✓ Maintenance cost

2.10.1.Net Present Value (NPV)

The NPV can be used in all decision contexts and should be reported for all evaluations. One disadvantage of the NPV is that it tends to place a higher priority on larger projects any project with positive NPV is treated as acceptable. In comparing more than one project, a project with higher NPV should be accepted. Any project with positive NPV is treated as acceptable. In comparing more than one project, a project with higher NPV should be accepted. The NPV of investments is adjusted to constant terms using a discount rate.

2.10.2.Present worth method

Combines all investment cost or benefit and all annual expenses into a single present-worth sum, which represent the sum necessary at the time zero to finance the total disbursement over the analysis period. This present sum when multiplied by capital recovery factor will give the equivalent uniform annual cost or benefit.

2.10.3.Discount Rate in Cost Analysis

For most transportation investments costs are incurred in the initial years, while the benefits from the investment accrue over many years into the future. When assessing the costs and benefits of a project. It is necessary to take into account the time value money by the converting the costs and benefits that take place in different years into a common year. Discount rate is used to converts the future costs and benefits of a project into present value.it is the rough difference between the interest and inflation rates and it indicates the real value of money over time. A real discount rate reflects only the effects of the time value of money and results in a lower, current number when multiplied by a higher future value (John Ireland Blvd, 2020). A discount rate of 10.23% was used in this study as recommended by Ethiopian ministry of finance and economic development for evaluation of project feasibility in Ethiopia (Kabeto, 2018).

2.11. Introduction to foamed bitumen

Foamed bitumen can be produced by injecting pressurized air and a small quantity of cold water into a hot bitumen phase in an expansion chamber. Soon after spraying into a special container, the bitumen foam expands rapidly to its maximum volume followed by a rapid collapse process and a slow, asymptotic return to its original bitumen volume. For 500g of hot bitumen injected using 10g of cold water (2% of bitumen mass) normally results in foam with a maximum volume around 15-20 times that of the bitumen. The ratio between maximum foam volume achieved and the volume of original bitumen is termed the maximum expansion ratio (ERm). The ERm value is mainly dependent upon the amount of water added, namely the foaming water content (FWC). ERm increases with higher FWC. After reaching its maximum volume, the foam dissipates rapidly accompanied by steam gas escaping. The time that the foam takes to collapse to half of its maximum volume is called the half-life (HL). HL would normally be between 20-30 seconds and after a particular time (around 60 seconds), the foam volume reduces very slowly and asymptotically. During this phase, foam bubbles still survive even though the bitumen has become harder (Sri Sunarjono, 2008).

Regarding the generating process of foamed bitumen, it is supposed that foamed bitumen comprises air, steam gas, liquid bitumen and a little remaining water. When foam is investigated in a measuring cylinder, steam gas is seen clearly forming bubbles which are wrapped by liquid bitumen. The gas bubbles appear to be rising to the surface boundary (looking like water boiling) whilst the liquid bitumen descends during foam dissipation due to the gravity effect. Foam bubbles appear larger when foam volume reduces. It is also understood that bitumen temperature during foaming reduces significantly to around the boiling point of water. Thus, foam properties change in several ways with elapsed time, i.e. temperature drops, gas content reduces; volume decreases, density increases, and bubbles expand & collapse. The bitumen state also changes from liquid to foam, returns back to liquid, and then moves to a viscous and solid condition. Thus, foamed bitumen is an unstable material with complex properties. During the foaming process, the key properties of bitumen change from bulk properties to surface properties. Molecules of surfactant (primarily contained in asphaltiness) are transported from the bulk of bitumen to the interface (between liquid bitumen and air gas), and form an adsorption layer on the interface foam structures can be divided into two groups, i.e. wet and dry, depending on the proportion of liquid in the foam. Wet foam is foam with liquid volume fraction typically between 10-20%, whereas dry foam is foam with liquid volume fraction less than 10%. Bubble shapes in wet foam are approximately spherical, while in dry foam, the bubbles are more polyhedral. The bubbles structure significantly affects the foam rheology. Dry foam tends to have higher apparent effective viscosity and elastic modulus than wet foam (Sri Sunarjono, 2008).

Recycling with foamed bitumen is emerging as a proven technique for new road design as well as pavement maintenance and rehabilitation with secondary materials such that re-use in asphalt layers. The technology behind the method, based on adding foamed bitumen to aggregate materials is already well established and highway authorities are increasingly latching onto the economic and environmental benefits (Ben, 2014).

Foamed bitumen (foamed asphalt, expanded asphalt) is a mixture of air, water and bitumen. It can be used with a variety as materials, ranging from conventional high quality graded materials and recycled asphalt to marginal materials. Such as those having a high plasticity index (Ben, 2014).When the water contacts the hot bitumen it rapidly changes to steam and the volume of bitumen expands many times. When using foamed bitumen as a binding agent for road construction the fines content in the mineral aggregate (i.e. passing a 0.075 mm sieve) is very important (Khalid, 2013).

Foamed bitumen has been used successfully in many countries such as New Zealand and South Africa. Experience from these countries shows that's pavements with foamed bitumen have performed very well and in some cases beyond exceptions. The techniques is becoming increasing popular in these and other countries due to its low energy requirements, in situ application and the ability to stabilize low quantity materials with high fines content. These advantage are attractive to the Ethiopian road sector since currently there is a huge program for rehabilitation and expansion of road network. In Ethiopia, the first use of foamed bitumen was in the road construction of the 65km section of Ambo –Gedo on the A_4 trunk road, which connects Addis Ababa to the western part of country (Endale, 2015).

Figure .2.7.Foamed bitumen (Source: (S K Rahman*1, 2019))

2.11.1.Preparation of Foamed Bitumen for highway maintenance

The production of foamed bitumen is a continuous process where small amounts of water is injecting into hot bitumen in high temperature of 150°C to 180°C which is supported by air. It makes the mixture to expand up to 20 fold volumetrically when released through nozzles and the volume of water between 2% to 5% is added to the bitumen during mixing.

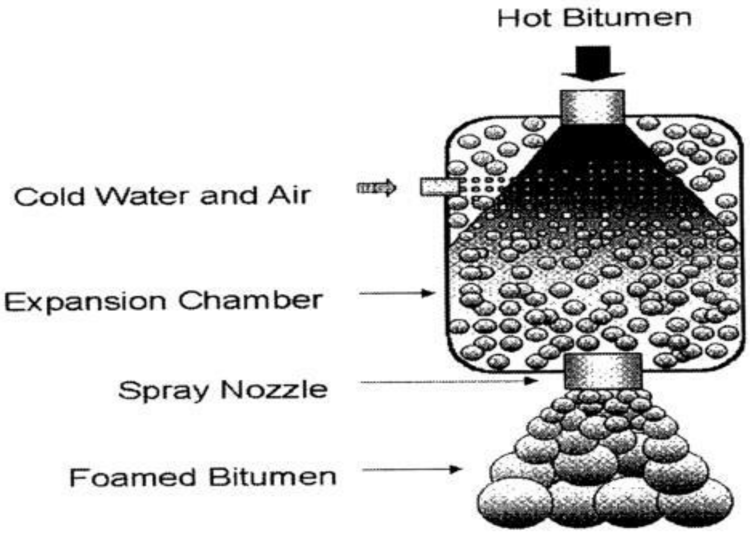

Figure .2.8.Preparation of Foamed Bitumen

(Source: (S K Rahman*1, 2019)

2.11.2.Properties of foamed bitumen for high maintenance

Foamed bitumen is known n as expanded bitumen; it is hot bitumen which is transformed from a liquid state to a foam state when small water 2 -5 percentages is added. The foamed bitumen in terms of expansion ratio and half-life are determined, the half-life is the time in seconds between the time when foam reaches the maximum volume and the time it disperses to half its maximum volume. The expansion ratio is the ratio between the maximum volumes reached in the foam has dispersed. The foamed properties of bitumen have an important role in the mixing stage of foamed bitumen asphalt production. A maximized expansion ratio and half-life within the mix would give better binder dispersion (Khalid, 2013).

The volume of produced foam, the temperature and the quantity of water affect the expansion ratio and half-life. When high temperatures are used for foaming, increasing the quantity of water the results of expansion ratio increasing and at the same time results in a decreasing half-life.in the laboratory, the foam parameters are affected by the size of the container and it suggested limits for the half-life at least 20 seconds and for an expansion ratio 8-15 times.it possible to produce highly expanded foamed bitumen with greater than 60seconds half-life and expansion ratio greater than 15times by using surface active additives. When foamed bitumen with high expansion ratio (15:1) was used the cohesion and compressive strength of mixture would be greater. Also it showed that better aggregate coating and mix properties resulted from high expansion ratio foamed bitumen (Khalid, 2013).

The main properties of foamed bitumen for highway maintenance as follows:-

- ✓ Ductility: for a good road there should be good interlocking between the different layers of materials. It is found that foamed bitumen is more ductile and hence it has good binding properties.
- ✓ Viscosity: foamed bitumen has a low viscosity and hence easily binds the aggregates due to maintenance
- ✓ Softening point: in the case of foamed bitumen, a slight softening will occur after foaming process relative to the unformed condition.

- ✓ Traffic volume: The road construction using foamed bitumen can be opened to traffic earlier
- ✓ Economy: The maintenance cost is less for foamed bitumen
- ✓ Weather condition: Not susceptible to heavy rainfall and is efficient in tropic condition (S K Rahman, 2019).

2.11.3.Design of foamed bitumen for highway maintenance

When designing a foamed bitumen mixture, the aggregate gradation and an amount of bitumen should be mixed economically to the amount of bitumen is required to guarantee an appropriate level of resistance and durability fatigue cracking, to resist deformation by traffic loading, the mixture stiffness and stability should be taken into consideration, the percentage of voids in the mixture to allow compaction under traffic loading without any of loss of stability or bleeding and improved moisture susceptibility during mixing ,placement and compaction (Khalid, 2013).

2.11.4.Foamed bitumen content for highway maintenance

The possible amounts of bitumen content in the foamed bitumen mixture cannot be dictated clearly, but can be fixed hot mix asphalt. The binder content range can be fixed by the loss of stability of the mix at the upper end and the water content at the lower end. The ratio of binder content to fines contents is the most important parameters. The suitable binder content can be selected based on the fines content of the mix. The use of binder fines proportion to choose the binder content was suggested by akeroy and hicks. It is in the range from 3.5% binder content for 5% fine content to 5% binder content for 20% fines content probably this process may be not suitable for all types of materials because of the different binder absorbing characteristics of the fines depending on the material source (Khalid, 2013).

Table 2.5.foamed bitumen content (source**:** (Khalid, 2013)**)**

%passing 4.75 mm sieve	%passing 0.075mm sieve	% foamed bitumen
<50(gravels)	3-5	3
	5-7.5	3,5
	7.5-10	4
	>10	4,5
	3-5	3,5

>50(sands)	5-7.5	4
	7.5-10	4,5
	>10	5

2.11.5.Using of foamed bitumen for highway maintenance

The use of foamed bitumen in road maintenance using a cold system can be achieved either by 'in-plant (ex-situ)' or 'in-place (in-situ)' technology. In neither system is it necessary to heat the aggregate materials (either recycled or fresh aggregates) prior to mixing with foamed bitumen. In-plant mixing enables control of input materials and mixing quality and also the material produced can be stored for later use, whereas in place treatment offers a cost effective and rapid form of road rehabilitation with relatively lower quality than in-plant mixing method. The in-plant mixed process produces a material known as Foamix. The plant consists of hoppers for aggregate with a conveyor belt feeding into a pug mill. Spray bars are fitted for addition of water (Sri Sunarjono, 2008).

Foamed bitumen is sprayed as the aggregate drops from the conveyor belt and proceeds to mixing in the pug mill to ensure that foam distribution within the mix is homogenous. The Foamix then drops onto a conveyor belt where it can be transported to a loading truck or to a stockpile. Currently, progress in the production technology for Foamix has led to the development of mobile mixing plants which can be located close to site in order to reduce the transport cost of materials. The feed materials may be virgin aggregates, road planning's, marginal construction materials or combinations. The produced Foamix material appears as moist particles that consists of coated fine aggregate and partly coated coarse aggregate. The in-place process, also known as Foam stab, consists of recycling a distressed pavement by milling the road to certain depth (100mm to 300mm) using a heavy duty rotovator. The Foam stab process can be used to recycle distressed asphalt pavement and granular base and/or sub-base layers. The pulverized pavement is then injected with water followed by foamed bitumen sprayed into the recycler's mixing chamber (Sri Sunarjono, 2008).

The bitumen is continuously supplied to the rotovator from a road tanker and the two vehicles move in tandem along the site. The appearance of the materials after mixing is similar to Foamix.

The mixed material can then be leveled, shaped and compacted to obtain a new flexible pavement. Foamed bitumen can also be produced in a small mobile plant under laboratory conditions. The foamed bitumen produced by this unit is similar to that produced by the foamed bitumen systems mounted on large recycling machines. The role of mixing in the process of generating foamed asphalt material is important since foamed bitumen collapses rapidly in seconds. Foamed bitumen should be produced at the best quality to ensure that the foam disperses as much as possible in the mixture. Aggregate moisture content should be predetermined properly to ensure foamed bitumen is able to distribute onto the aggregate surface. Mixer capabilities (power, speed and agitator type) should be designed to guarantee the most homogenous foam dispersal in the mixture (Sri Sunarjono, 2008).

During the mixing process, foamed bitumen properties play an important role in helping to produce the optimum end product performance. FAM has most potential when used as a base course layer and placed between an asphaltic surface and granular layers in a road pavement. There are three important mechanical properties related to the base course, namely: (1) stiffness, which is to ensure good load spreading ability; (2) fatigue strength, which is to prevent cracking under repeated traffic loading; and (3) resistance to permanent deformation, which is to eliminate rutting. Thus, it is necessary to characterize foamed asphalt in terms of those three fundamental properties for base application (Sri Sunarjono, 2008).

Road maintenance versus road maintenance using foamed bitumen

Durability layers, road maintenance is found to have less durability layers and high cost of maintenance compare with using foamed bitumen. While road maintenance using foamed bitumen have highly durable, opened to traffic earlier and less maintenance cost compared with road maintenance without foamed bitumen. As the uses of foamed has increased, so have the different areas of application perceived foamed bitumen means of improving the quality of marginal aggregate such as loess, to enable them to be used in road maintenance. Foamed bitumen can be produced through the injecting of small quantities of water of cold moleculised water as a fine moist into hot penetration grade bitumen in an expansion chamber. It is a one of innovative technologies that have been applied pavement construction.

- ✓ The use of foamed bitumen solutions saves time in construction, since can compact it and instantly carry traffic.
- ✓ The change in weather conditions, like cold weather or slight rain, will not affect the performance and quality of the foamed bitumen, We can construct layers of foamed bitumen in all-weather conditions
- ✓ Use foamed bitumen with various kinds of aggregates, mostly mixing small diameter aggregate with bitumen an ideal option
- ✓ Energy savings during the mix processing and Improved workability
- ✓ It attains rapid strength and can take traffic loads at the earliest and to improve the quality of marginal aggregates to a standard acceptable for use in road maintenance (S K Rahman, 2019).

2.11.6.Application of foamed bitumen for highway maintenance

When we consider a foamed bitumen application:

- ✓ When pavements has myriad of patches that more repair will not be efficient
- ✓ If there is overloading and can no longer control it easily
- ✓ When asphalt overlays can longer solve flushing issues
- ✓ As the usage of foamed bitumen increases in road industry, the variety of application increases too.
- ✓ The road can be repeatedly patched to the extent that road repairs are no longer cost effective

2.11.7.Why use foamed bitumen on highway maintenance

If have to remove and replace a road, cost will increases. It might need to strip the road back completely before putting down new materials to create a more solid surface. As a result, the costs will be relatively high and rebuild takes time. Have to prepare the subgrade and lay it down ,then have to lay the new top surface .The more time spend on the project and more labour costs increase, but if we use foamed bitumen on road maintenance ,the work fast and all costs reduce. It might not have to pull up the road .If subgrade is sound on maintenance, leave it leave in place. Foamed bitumen fixes work on existing base surfaces. The foaming nature of the bitumen helps it bind with other materials effectively and helps the surface of the road stick to the subgrade.

CHAPTER THREE
RESEARCH MATERIALS AND METHODOLOGY

The methodology followed in this paper is more inductive in nature. It looks at relevant factors, which are essential for the benefit-cost analysis of highway maintenance using foamed bitumen. This research is a systematic investigation to find answer to the problem. To give sufficient and realistic answer for problems arises the research would be carried out by Review the pertinent domestic and foreign literatures, ongoing researches, books, the internet leading to highway engineering journals related to benefit-cost analysis of highway maintenance using foamed bitumen.

3.1. Study area

The study area is found in West Shewa Zone, Oromia regional state, Ethiopia which is located at the western part of Addis Ababa. The investigated road segment is part of Addis Asosa Trunk road which passes through Ambo and Gedo towns. The studied road segment connects Ambo to Gedo. The geological location of Ambo town is 8^{o}59'N latitude, 37^{o}51'E longitude and elevation of 2093.89m.The elevation difference between Ambo and Gedo is 404.05m.The surface type of road is paved, the pavement condition is poor and the types of maintenance are routine and periodic along Ambo to Gedo road segments. The road was constructed before 10 years and currently, showing failure before its ended design period.

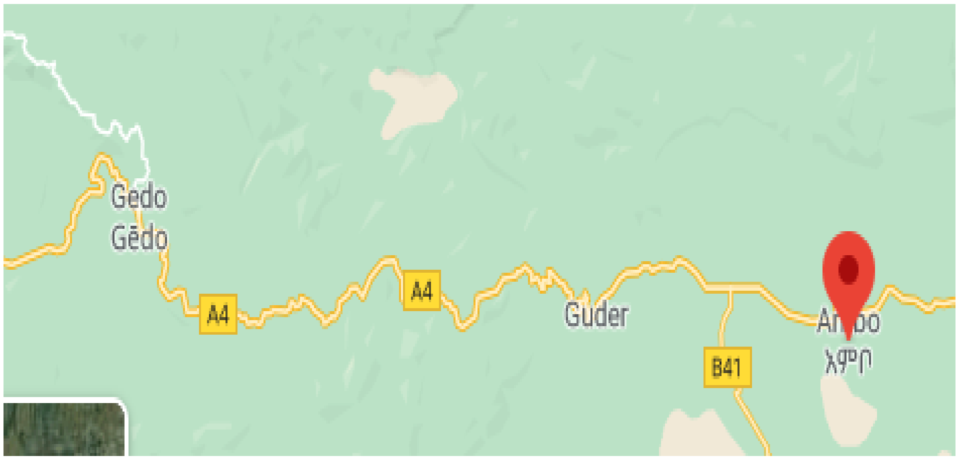

Figure.3. 1.Map of study area (source: Google Map)

3.2. Study design

The research was conducted by using both descriptive and analytical methods.

- ✓ Literature review
- ✓ Field observation, data collection and review of documents
- ✓ Evaluating the benefit and costs by net present worth method
- ✓ Benefit cost analysis by benefit-cost ratio method

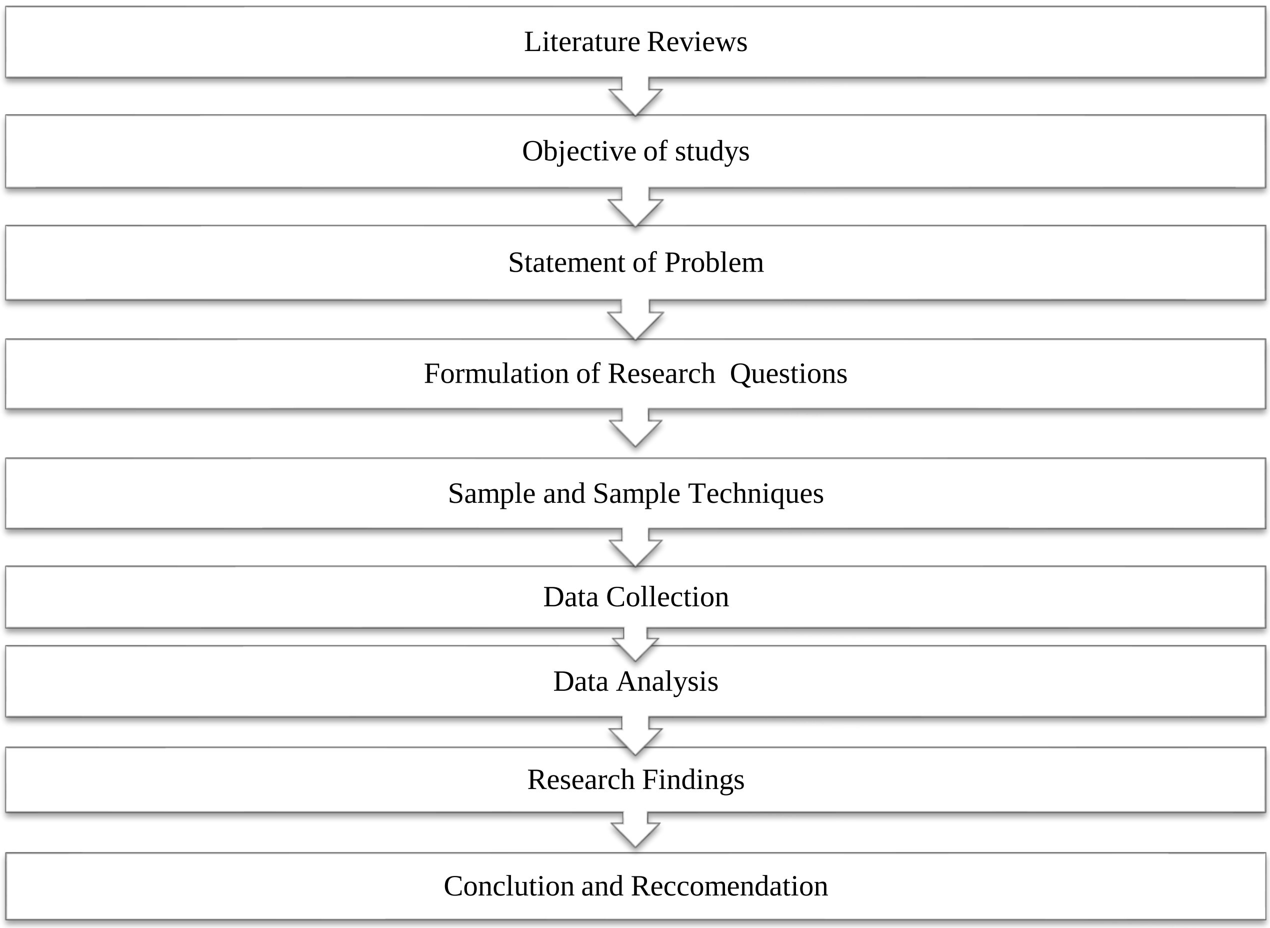

Figure .3.2. Flow chart of study

3.3. Study of variables

There are two types of study variables; these are independent and dependent variables.

3.3.1. Independent variables

Maintenance cost

Travel time saving

Vehicle operating cost saving

Benefit cost analysis

Transport fare saving

3.3.2. Dependent variables

Effect of foamed bitumen on benefit-cost analysis of highway maintenance

3.4. Population

The population under study was vehicles, passengers and drivers on the road segment. The impacts of the population and their values for results of finding have been conducted. The population enabled to obtain the necessary data for the study.

3.5. Data source and collection processing

The data were gathered from engineers, passenger and drivers on road safety, travel time cost and vehicle operating cost through interview and questionnaires. The output of the study was used to improve the cost benefit analysis of road maintenance using foamed bitumen. Both primary and secondary data were used for this research. The primary data for this study were the travel time which was measured directly from small bus between Ambo Bus station and Gedo bus station, the data collected from engineers, drivers and passengers through questionnaires and travel fare data which was obtained from Ambo road transport authority and those which were collected from journal, book, website and manuals.

3.6. Sample size and sampling

This study was performed on a purposive sampling selection process and employed mixed research approach both analytical and descriptive. It was selected by some arbitrary method because it is known that it was produce well matched groups. The idea is to pick out the sample in relation to some criterion which is considered important for the particular study. It was enabled to choose participants of own interest based on education and experience. Then the existing condition of pavement identified, effects and their impacts on the benefits-costs are prepared as questionnaires to get information as a sample size. Sample taken 10 engineers, 42 passengers and 15 drivers to gather data.

3.7. Data Processing and Analysis

After determination of cost of highway maintenance, travel time saving, vehicle operating cost saving and transport fare saving the net present worth and AADT analysis was calculated.

The formula of net present worth is shown below:-

A_b=TTS+VOC+TFS

$$NPW_B=A_b\,[(\frac{(1+i)^n-1)}{i(1+i)^n}]$$

Where NPW_B=net present worth of benefit

A_b=annual benefit

TTS=travel time saving

VOC=vehicle operating cost

TFS=transport fare saving

$$NPW_c=A_c\,[(\frac{(1+i)^n-1)}{i(1+i)^n}]$$

NPW_C=net present worth of cost

M_C=maintenance cost, A_c=annual cost

$$\frac{B}{C}=[\frac{NPWb}{NPWc}]$$

Where $\frac{B}{C}$ =Benefit cost ratio

i=discount rate

n=period of design

Total yearly volume of vehicles=sum of daily volume of vehicles*365/7)

Total weekly volume of vehicles=the sum of daily volume of vehicles in the week

$$AADT=\frac{\text{Total Yearly Volume of Vehicles}}{365}$$

Vehicle operating cost saving=the summation of cost fuel and cost of tire for small bus vehicle

Cost of tire for small vehicles=number of tire*the price of one tire*count number of vehicles*number of tire change

Travel time analysis: travel time amount is the time measured from Ambo to Gedo bus station without deducting the time of stop during travel. After measuring the travel time deduct (DDT) the average stopping time which is duration of stop in time of travel.

3.8. Ethical Considerations

Ensuring the confidentiality of the data obtained.

- ✓ The research has to be approved by an ethics review committee to make sure the study is not violating any of the above considerations.
- ✓ Do not taking advantage of easy-to-access groups of people.
- ✓ When reporting results, to be sure that it accurately represent on what is observed.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Pavement Condition Existing

Pavement condition surveys play a vital role in the management of pavements network. It refers to activities performed to give an indication of serviceability and physical conditions of road pavements. Pavements form a greater part of our society infrastructure system whose proper functioning is essential for development and similar to other types of infrastructure assets, pavements deteriorate over time, helps agencies to schedule of maintenance and rehabilitation works efficiently and enable to estimate the level of repair and rehabilitation required in terms of costs and extent of deterioration. This is because the condition ratings reflect the current condition of the pavement. Data obtained from condition surveys can be used for long term budget planning and used to project future conditions and this serves as a guide for management decisions. The road condition survey like visualization of the carriageway, shoulder showed that is affected by pavement distress like potholes, raveling, rutting, corrugation and fatigue cracks although no safety to travel and dustiness affect the drive and the passengers to travel.

PASER uses visual inspection to evaluate pavement surface conditions. When assessed correctly, PASER ratings provided a basis for comparing the quality of roadway segments. The PASER assessment method does not require measurements of individual distress and specific require distress types. The advantage of PASER is that roads may be assessed quickly. The key to a useful evaluation is identifying different types of pavement distress and linking them to a cause. Recognizing defects and understanding their causes helps us rate pavement condition and select cost effectiveness repairs (Barrette, 2011).

The rate at which pavement deteriorates depends on its environment, traffic loading conditions, original construction quality and maintenance procedures. Poor quality materials or poor construction procedures can significantly reduce life of pavement. As a result, two pavements constructed at the same time may be having significantly different lives, or certain portions of a pavement may deteriorate more rapidly than others. On the other hands timely and effective maintenance can extend a pavement life. With all of these variables, it is easy to see why pavements deteriorate at various rates and why we find them in various stages of disrepair (Barrette, 2011).

Period inspection is necessary to provide current and useful evaluation data. To evaluate an individual pavement segment, first determine its general conditions. It relatively new, toward the top end of the scale? In very poor condition and the bottom of the scale? Or somewhere in between? Then , record the defects on the road segment, after that in sample areas captured photo to differentiate the distress and to know more severe areas(some photos there in appendix 5).

Next, review the individual pavement distress and select the appropriate surface rating. Individual pavements will not have all of the types of distress listed for any particular rating. They may be having only one or more types. Using these factors judgments used to give pavement rating. The existing pavement condition is summarized and presented in the table 4.1.

Table 4.1.Existing pavement condition

Location	Length in km	Visible Distress	Pavement condition index (PCI)	Pavement rating condition	General condition/treatment measures
Ambo to Guder	12	Potholes, Severe distress with extensive loss of surface integrity.	3	Poor	Needs patching and repair prior to major overlay. Re-compact, scarify
Guder to Goro sole	22	Fatigue cracking showing the beginning of potholes, fatigue cracking showing the potholes.	7	Good	First signs of aging. Maintain with routine crack filling.
Goro sole to Babich	14	potholes, fatigue cracking	3	Poor	Needs patching and repair prior to major overlay

					Milling and removal of deterioration extends the life of overlay.
Babich to Gedo	17	Potholes on residential road after heavy rains, potholes as a result of fatigue cracking	4	Fair	Significant aging and first signs of need for strengthening. Would benefit from a structural overlay (2" or more).

From table 4.1,the existing pavement condition along Ambo to Gedo using pavement rating condition and pavement condition index ,26 km in poor condition, 22 km in good condition and 17 km in fair condition and pavement condition in percentages 40% poor, 33.85% good and 26.15% fair and the figure of pavement condition rating showed below.

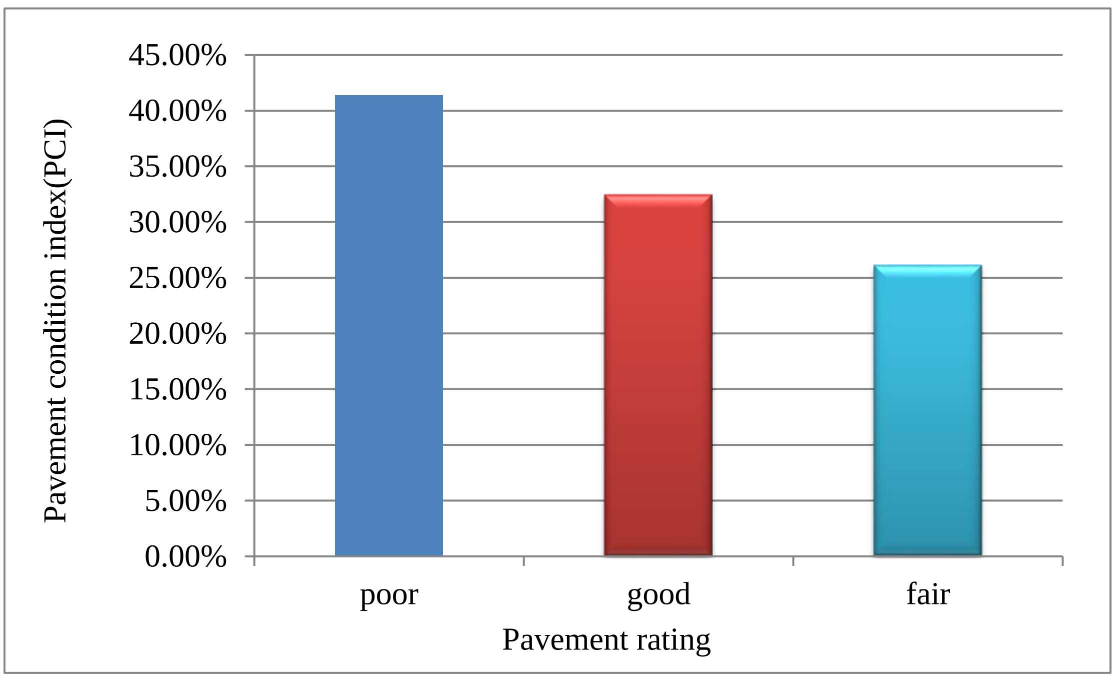

Figure .4.1.pavement condition rating

4.2. AADT analysis

AADT is the average of 24 hours counts collected every day of the years. It is necessary to obtain data continuously. It is not feasible to collect continuously data on all roads because the cost involved, making reasonable estimates of annual traffic volume characteristics on an area wide basis, different types of periodic counts, count durations ranging 15 minutes are conducted, the data values in the estimation of annual traffic characteristics. The periodic counts usually conducted are continues, coverage counts.

AADTs are used in several traffic and transportation analyses for:-

- ✓ Development of improvement and maintenance programs
- ✓ Development of freeway and major arterial street system
- ✓ Estimation of highway user revenues
- ✓ Establishment of traffic volume trends
- ✓ Evaluation of economic feasibility of highway projects

Table.4.2. AADT Analysis

Date	Daily volume of vehicles	Total weekly volume of vehicles	Total yearly volume of vehicles	AADT
Monday 18/2020	1224	8340Vehs	434871Vehs	1191vehs/day
Tuesday 19/2020	1272			
Wednesday 20/2020	1056			
Thursday 21/2020	1224			
Friday 22/2020	**1020**			
Saturday 23/2020	**1392**			
Sunday 24/2020	1152			

From table 4.2, the maximum daily volume of vehicles on Saturday is 1392vehs and the minimum daily volume of vehicles on Friday is 1020vehs in Ambo to Gedo station count and AADT values is 1191vehs/day (there are in appendix 1).

Table 4.3.Composion of vehicles

Types of vehicles	Number of vehicles	Percentage composition of vehicles
Car	76	11.16%
Small bus	403	59.18%
Medium truck	90	13.27%
Heavy truck	112	16.44%
Total	681	100%

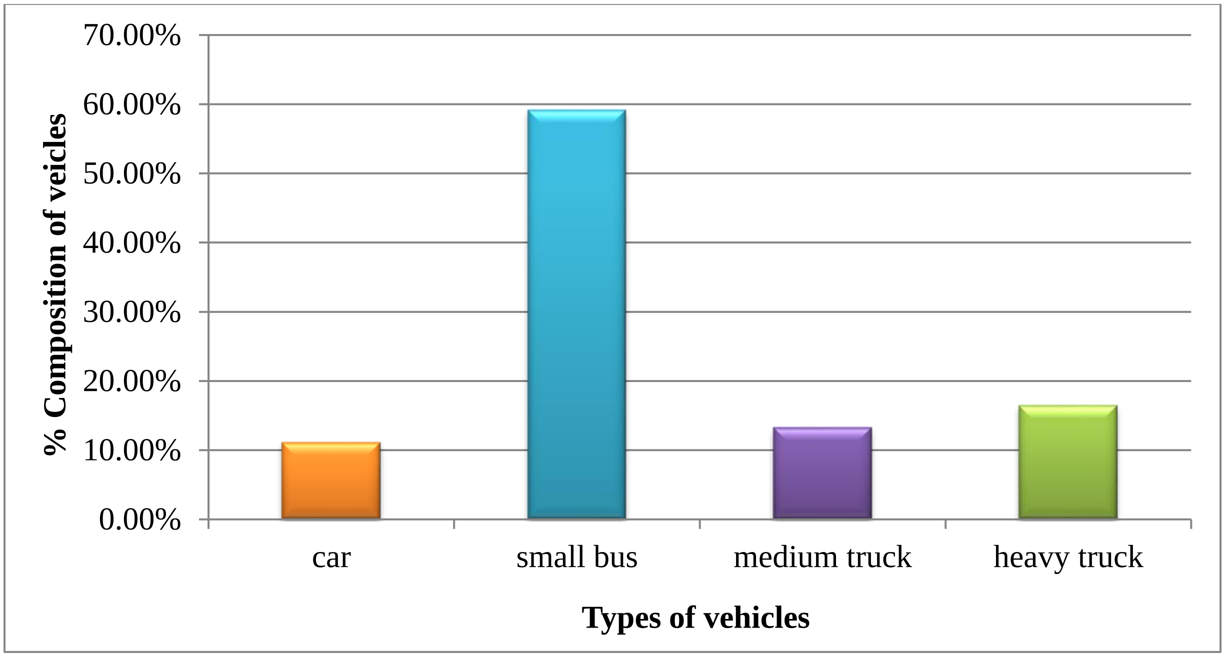

Figure .4.2. Composion of vehicles

4.3. Travel time saving analysis

This is the benefit of pavements gained after the condition of the pavement is improved. The data taken directly measured from small bus Ambo to Gedo direction. The direction of travel from Ambo to Gedo, the small bus begins to travel from Ambo to Gedo bus station and the small bus begins to travel from Gedo to Ambo bus station. On the table as shown describe travel time saving analysis and the smallest number of passengers including driver is 14, it showed that table 4.4.

Table.4.4.Average travel time analysis

Travel time analysis							
A	B	C	D	E	F	G(DDT)	H
Direction	vehicle types	Number of passenger	Number of stops	Average stopping time(sec)	travel time amount	(D*E)	F-G
Ambo-Gedo	small bus	14	3	30	1hr:30min(90min)	90sec(1.5min)	88.5min
Gedo-Ambo	small bus	16	5	50	1hr:33min(93min)	250sec(4.17min)	88.83min
Ambo-Gedo	small bus	14	2	20	1hr:30min(90min)	40sec(0.67min)	89.33min
Gedo-Ambo	small bus	17	5	50	1hr:33min(93min)	250sec(4.17min)	88.83min
Ambo-Gedo	small bus	16	5	50	1hr:33min(93min)	250sec(4.17min)	88.83min
Gedo-Ambo	small bus	16	3	30	1hr:30min(90min)	90sec(1.5min)	88.5min
Ambo-Gedo	small bus	14	3	30	1hr:30miin(90min)	90sec(1.5min)	88.5min
Gedo-Ambo	small bus	14	5	50	1hr:35min(95min)	250sec(4.17min)	88.83min
Ambo-Gedo	small bus	17	6	60	1hr:45min(105min	360sec(6min)	99min
Gedo-Ambo	small bus	14	2	20	1hr:30min(90min)	40sec(0.67min)	89.33min
Ambo-Gedo	small bus	18	4	40	1hr:32min(92min)	160sec(2.67min)	89.33min
Gedo-Ambo	small bus	17	4	40	1hr:32min(92min)	160sec(2.67min)	89.33min
Ambo-Gedo	small bus	17	2	20	1hr:30min(90min)	40sec(0.67min)	89.33min
Gedo-Ambo	small bus	16	5	50	1hr:33min(93min)	250sec(4.17min)	88.83min
Ambo-Gedo	small bus	16	4	40	1hr:32min(92min)	160sec(2.67min)	89.33min
Gedo-Ambo	small bus	14	3	30	1hr:30min(90min)	90sec(1.5min)	88.5min
Ambo-Gedo	small bus	14	4	40	1hr:32min(92min)	160sec(2.67min)	89.33min
Gedo-Ambo	small bus	15	4	50	1hr:33min(93min)	200sec(3.33min)	89.67min
average travel time in minute is 90min 1hr:30min							

The table 4.4 indicates, the travel time amount is the time measured from Ambo to Gedo which is from Ambo bus station to Gedo bus station without deducting the time of stop during travel. After measuring the travel time deduct (DDT) the average of stopping time which is duration of stop in time of travel due to reason like to take the person, to take things, to gain things and so on.

The minute of small bus taken to travel from Ambo to Gedo which is the time vehicles travel without stop it means travel time in minute minus the travel time deduct value. The average travel time in minute got from take the average of column H which is the time of small bus take to travel without stop in travel. The average travel time in minute is 90min or 1hr: 30min.

4.4. Questionnaire analysis

Out of the total study population, the engineers, the passengers and the drivers are to be selected for questioning. Accordingly, the sample size taken 10 engineers, 42 passengers and 15 drivers firms (such that a total of 67 firms) have been found to have being involved.

A. Engineers

From 10 engineers 7 male and 3 female. Their responsibility on organization or their work status 3consultant, 4 office engineer, 1plan manager and 2 site manager.

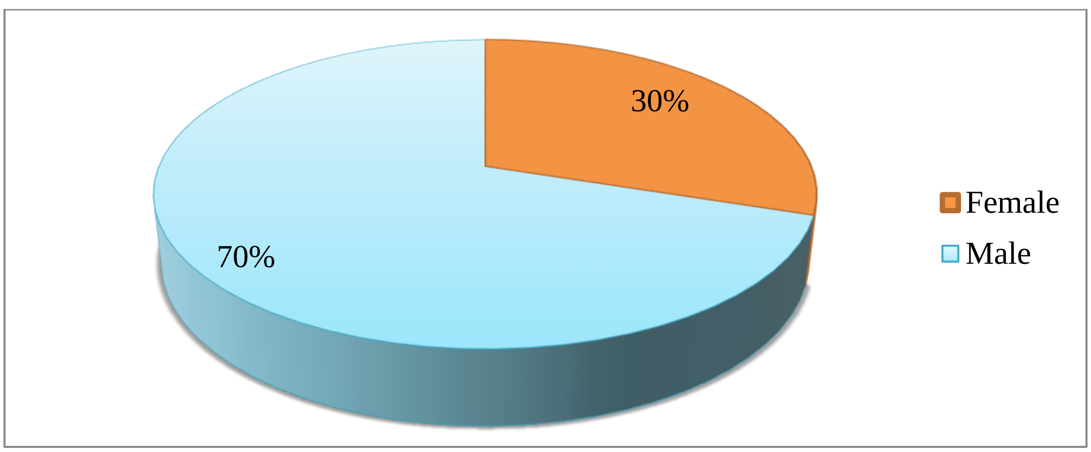

Figure .4.3. Gender status

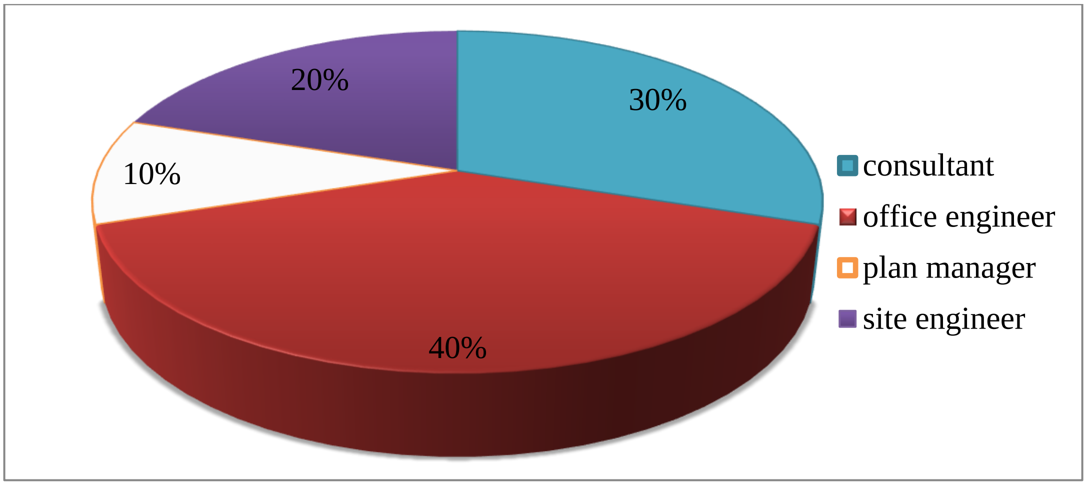

Figure .4.4. Work status

Purpose of road maintenance from Ambo to Gedo road, from 10 engineers asked,3 of them to save time,2 of them for safety,1 of them says to communicate easily and fast trade market and 4 of them confortable for passengers and reduce damage for traffic.

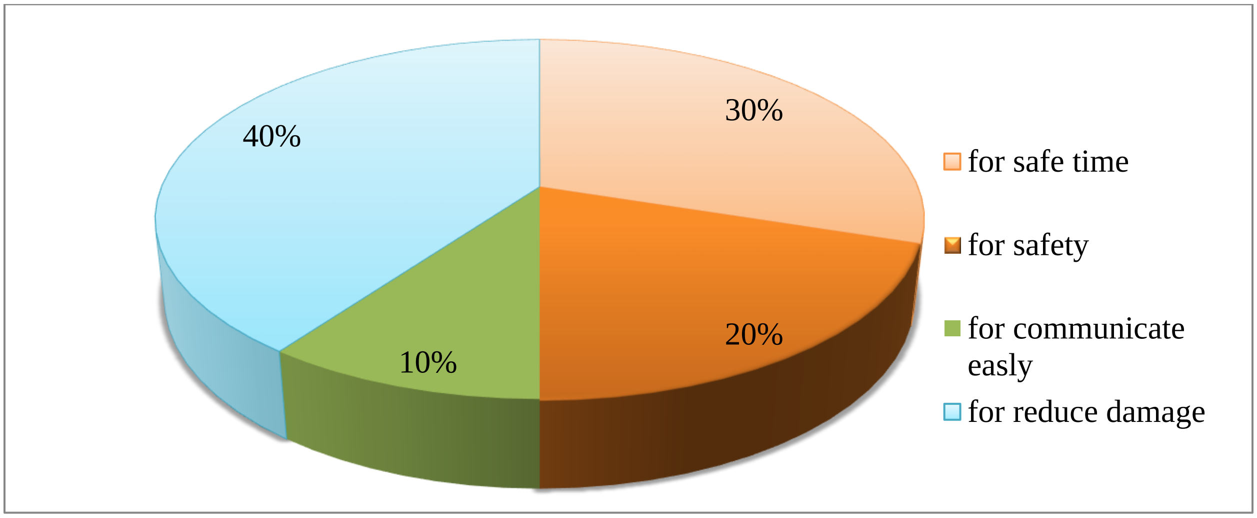

Figure .4.5. Purpose of road maintenance

B. Drivers

From 15 drivers 13 male and 2 female. The make trips in ambo to gedo direction per day, 10 of them said twice and 5 of them said once.

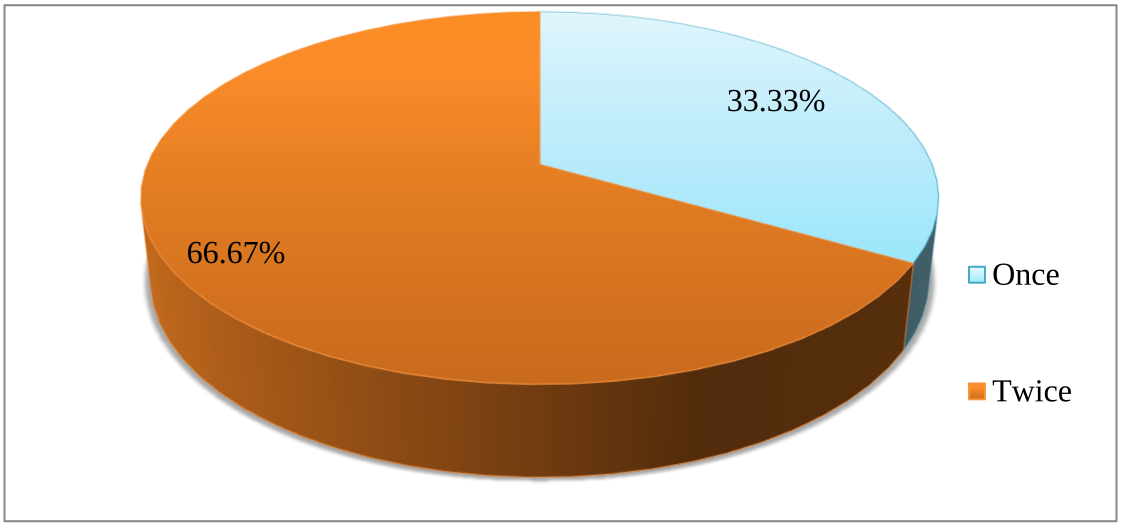

Figure .4.6. Trips along ambo to gedo direction

C.Passengers

From 42 passengers gender status 28 male and 14 female.Their work status 18 merchant,8 government employed,10 going to home and 6 working in private.

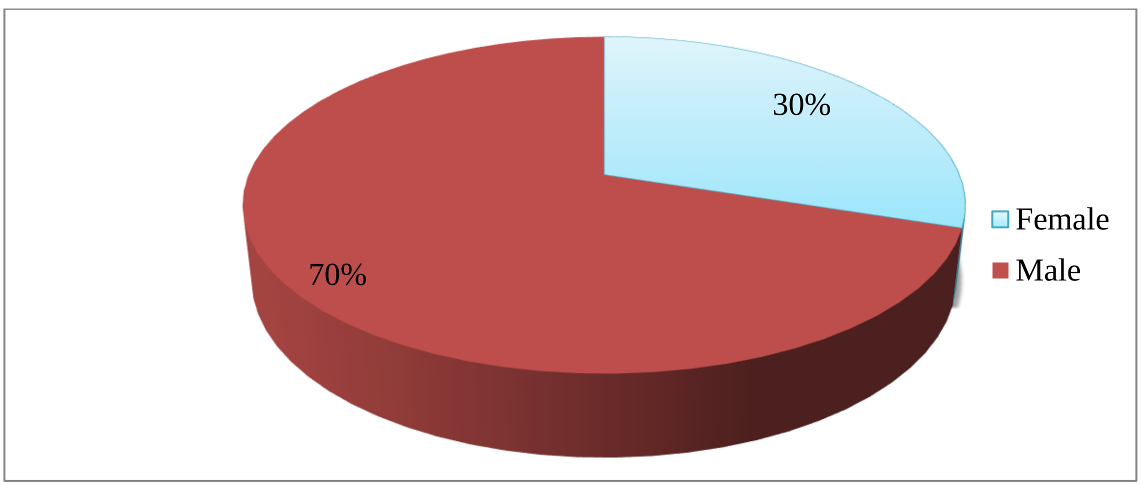

Figure .4.7.Gender status

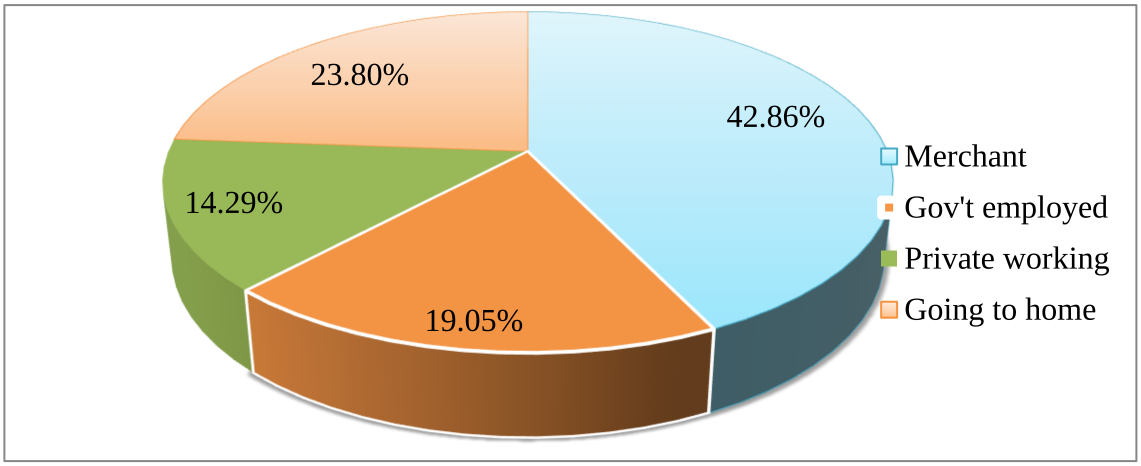

Figure .4.8. Work status

The purpose of trips from Ambo to Gedo road segment, 14 for work, 8 for meeting, 10 for business and 10 for going to home.

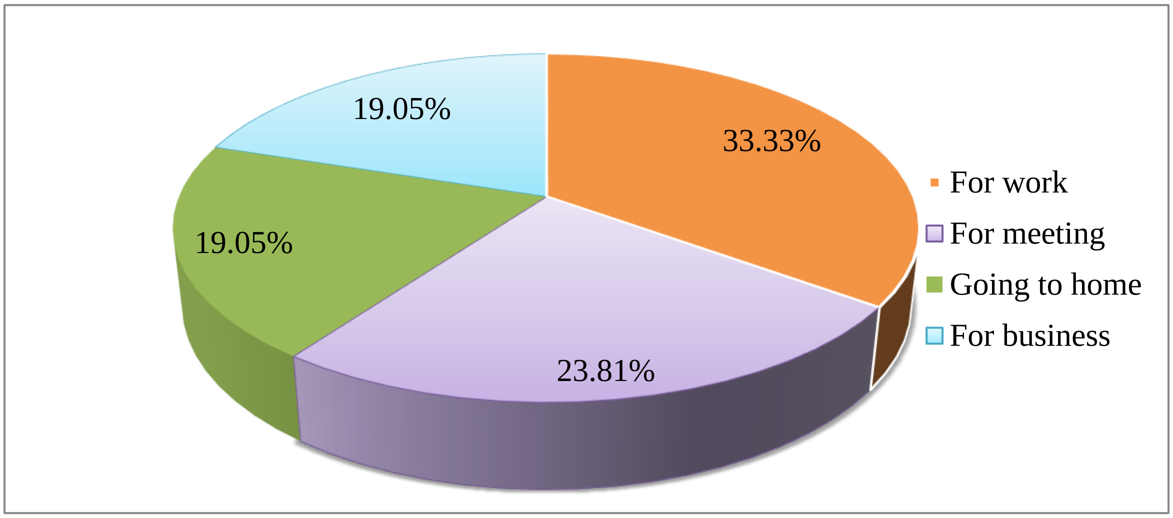

Figure.4.9. Advantage of trips along ambo to gedo direction

Daily working from 42 passengers, 12 of them 2-4hr in work, 15 of them 8-12hr in work, 9 of them 4-6hr in work, 6 of them 12-16 hour in work and Monthly income of passenger from 42, 8 of them gain 800-1500 birr/month, 15 of them gain 1500-4000 birr/month, 13 of them gain 4000-6000birr/month, 6 of them gain 6000-10000birr/month.

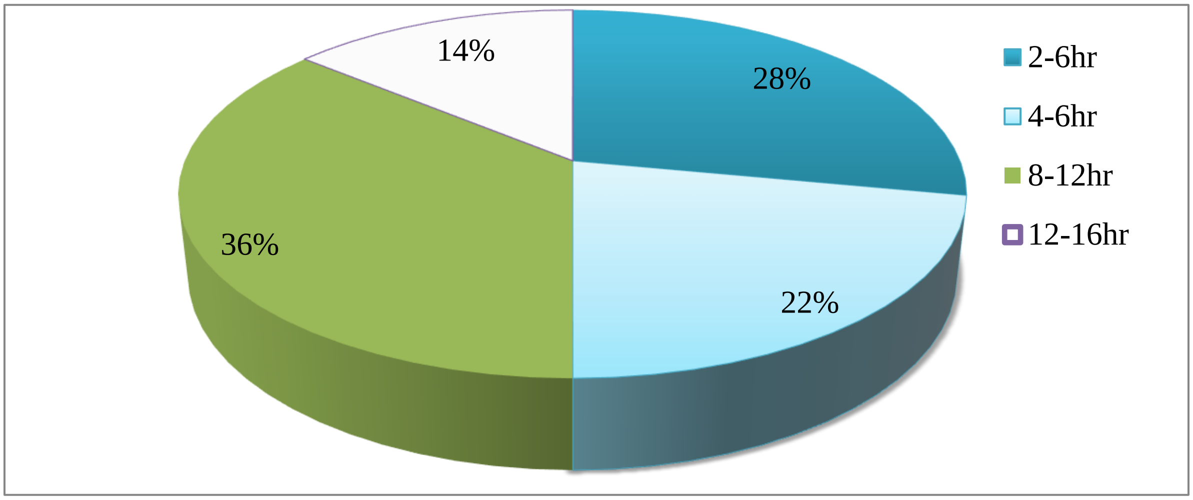

Figure .4.10.Daily working per hour

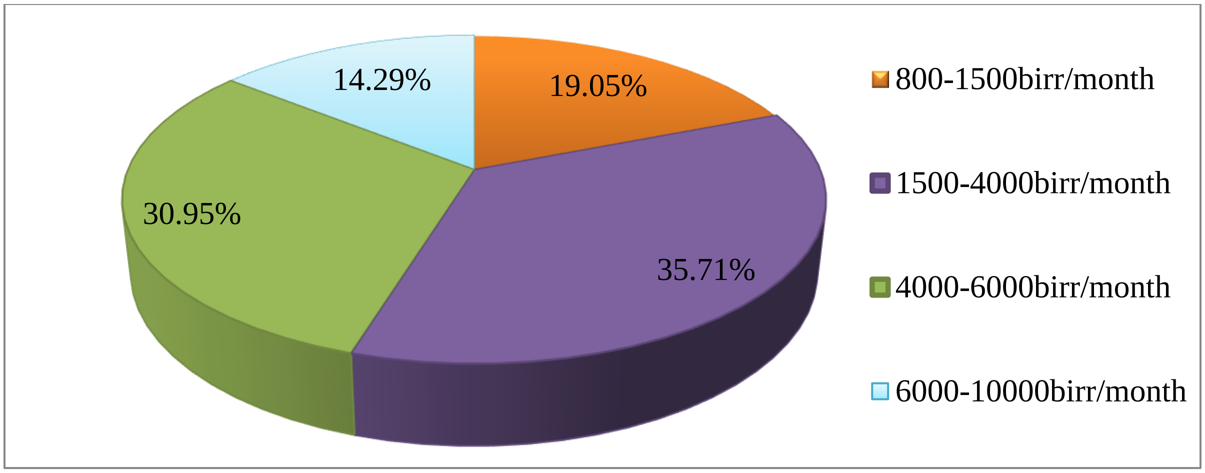

Figure .4.11. Monthly income

From table 4.4 the average travel time from Ambo to Gedo station, 1hr:30min=90min,from distancesto.com travel time calculator total travel time from Ambo to Gedo 50min which is the amount of time can expect to travel to destination. Note that road work weather conditions and other factors can affect this estimate. After improvement of road the travel time is reduce =90min-50min=40minute, then the average income in birr 0.26cent/min*40min=10.4birr (0.26cen/min is average income per minute already calculated in appendix 4). Based on after improvement of road the total travel time saving in birr for each vehicle is the number of each vehicles * number of passengers * average income in birr * 365 it gives 24,104,600birr/year, there is in table 4.5.

Table 4.5.Total travel time saving for each vehicle

Types of vehicles	Number of vehicles	number of passengers	Total travel time saving for each vehicles
car	76	4	1,153,984
small bus	403	14	21,417,032
medium truck	90	2	6,83,280
heavy truck	112	2	8,50,304
Total travel time saving			24,104,600 birr/year

4.5. Vehicle operating saving analysis

Ethiopia's consumption of fuel is largely attributed to transport industries rather than some other economic sectors in the country.

4.5.1. Cost of fuel for vehicles

Most of the types of fuel that are being used for all types of vehicles are petrol and diesel. Ethiopia's consumption of fuel is largely attributed to transport industries rather than some other economic sectors in the country. From questionnaires the average daily small bus use of Fuel is 25liter per day for 65km and the price of one liter fuel is18 ETB, because along Ambo to Gedo road is not comfortable to drive. From this assume the efficiency all vehicles are equal and Vehicles consume an average of 0.386 liters/km.

Cost of fuel for small bus vehicles=0.386lit/km*(1km*1191)*18birr/lit*365

=3,020,399.82birr/year

4.5.2. Cost of tire for vehicles

From informal interview with drivers all of them said the tire once changed after two month usage at bad condition of road along Ambo to Gedo and the price of one tire is 3000birr, because the road along Ambo to Gedo is not safety for travel.

Cost of tire for small bus vehicles=3000*4tire*403*6

=29,016,000birr/year

Therefore, the values vehicle operating cost saving based on cost of fuel and cost of tire for small bus vehicles is 32,036,399.62birr/year, which means the summation value of cost of fuel and cost of tire for vehicles.

4.5.3. Transport fare saving analysis

Transport fare is a fee paid by passenger for use of a public transport system. The fare paid is a contribution to the operational costs of the transport system involved. From informal interview with passengers all of them said the transport fare of small bus tariff is 30birr, but the price paid for travel due to bad condition road the cost transportation is 50 birr for one person travel. The additional cost transportation payment taken from passenger by vehicle owner due to bad road condition is 20 birr.

The total transport fare saving in year is 41,186,600 birr/year, which means the count number of small bus *number of passengers * the additional payment taken from passenger * 365)

4.6. Benefit- Cost ratio

Benefit-cost analysis compares the expected benefits of a project to the expected costs over the projected life of the project. Because the benefits and costs occur over time, standard financial procedures are used to create a "present value" of both costs and benefits. In this method all costs and benefits are discounted to their present worth and the ratio of benefit to cost. Benefit cost analysis places a value on each incremental benefit and costs of each option. The results of benefit cost analysis can be shown as benefit cost ratio or net present value. The viability of system or compared several is to calculate the net present value of the costs and the benefits and obtain the benefit cost ratio (B/C).

The Benefit-Cost Ratio (BCR) is defined as the present value of benefit divided by the present value of costs. If the result of Benefit Cost Ratio is greater than one or equal to one the infrastructure improvement is viable and economically justified while a Benefit Cost Ratio less than one indicates that a project is not viable and economically not justified.

Benefit-Cost Ratio (B/C) =Net Present worth of Benefits (NPW_B) / Net Present worth of Costs (NPW_C).The following economic rules apply when interpreting and using the decision criteria:-

If the B/C≥1, the project is viable and economically justified

If the B/C<1, the project is not viable and economically not justified

4.7. Maintenance cost for highway maintenance using foamed bitumen

The maintenance cost data were taken from ERA maintenance project, the maintenance project begins from Ambo to Gedo road and maintenance cost estimated for analysis of period currently practiced by ERA indicates is 30,262,826.69 ETB.

Table 4.6.Parameters considered for the benefit cost analysis

Parameters	Remarks
Traffic direction	Two lane
Analysis period(years)	10 years
Beginning of analysis period	2017
Discount rate (%)	10.23%
Interest rate (%)	5% ,commercial bank of Ethiopia
Surface type	Asphalt(HMA)

The maintenance cost of the road by present worth analysis and saving benefits of road maintenance by present worth analysis ,the values of annual benefit, the values of cost and the benefit cost ratio for highway maintenance using foamed bitumen by present worth analysis are 951,393,933.9 ETB and 295,824,304.1 ETB, 30,262,826.69 ETB and 3.216 respectively(there are in appendix 3) and benefit saved, maintenance cost incurred and benefit cost ratio without foamed bitumen by present worth analysis are 374,351,288.17 ETB,137,931,578.4 ETB and 2.71 respectively(there are in appendix 4).

Based on this benefits and costs for highway maintenance, if the benefit cost ratio is greater or equal to one, the project is viable economically justified and discount rate applied. It indicates the time period required for benefit repay investment. After the future streams of benefits and costs are discounted the benefit cost ratio are got the sum of discounted benefit divided by the sum of discounted cost. The benefit cost ratio with or without foamed bitumen (B/C) > 1 accept the project is economically acceptable for the estimates and discount rate applied, but the benefit cost ration using foamed bitumen is best, because the maintenance cost is less and B/C is greater which means 3.216 >2.71.These results show if the alternative is economically justified compared to the base case. After the futures streams of costs and benefits are discounted, the sum of the discounted benefit is divided by the sum of discounted of cost.

Therefore the benefit cost ratio with foamed bitumen is 3.216 or greater than benefit cost ratio without foamed bitumen means the maintenance cost after pay back and there is additional saving of benefit which show the maintenance cost is less than the benefit gained, so the maintaining road periodically and regularly saved the values of passengers, drivers and engineers gained benefit and road maintenance using foamed bitumen is that spending money now saves future costs. As the asset deteriorate, so the cost to restore their condition increases and as the condition gets worse, the costs to society usually become more significant maintained road significantly increase economic productivity and development, increased quality of life, less dust, cleaner environment, lower vehicle operating expenses for users, saving in time to people ,goods and vehicles increased safety and skid resistance, positive economic development, people want to live, work and drive on paved roads, so increased economic activity will follow them.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

This study presents benefit cost analysis of highway maintenance using foamed bitumen, it was found that conclude the maintenance cost incurred, the benefit saved due to road maintenance and quality of road using foamed bitumen. Foamed bitumen is sprayed into the mixing drum where it coats the surface typically less than 0.075 mm in diameter is very important and soft material with complex behavior. It is essential a mixture of air, water and bitumen and successfully formed by the presence of a surfactant which is primarily contained in asphaltiness. When small quantity of water is injected into hot bitumen at 150-180 ^{0}C, the bitumen expands by approximately 15 times its original volume with low viscosity.

The existing pavement condition using pavement rating system showed that from the total length ,the pavement condition in percentages 40% poor,33.85% good and 26.15% fair, so the percentage result shows that the existing road condition needs more improvement. The tire cover and fuel use increase as roads deteriorates reduction of fuel uses due to maintenance of roads helps the peoples to under pay less money on transportation consumption. The benefit saved due to road maintenance of road using foamed bitumen from travel time saving, vehicle operating saving and transport fare saving and the maintenance cost incurred to maintain road using foamed bitumen after using net present worth analysis along ambo to gedo road segment are 951,393,933.9 ETB and 295,824,304.1 ETB respectively.

Based on the benefit saved and maintenance cost incurred using foamed bitumen, the benefit cost ratio of road maintenance using foamed bitumen is greater than the benefit cost ratio of road maintenance without foamed bitumen, because the maintenance cost is less for foamed bitumen. Therefore, the benefit cost ratio using foamed bitumen or without foamed bitumen is greater than one which is 3.216,2.71 respectively and the maintenance cost less than benefit gained, the maintaining road periodically and regularly saves the values of engineers, passenger and drivers gained benefit period of analysis. It plays the influence of the demonstrate economic effects and the quality in transport economic of the highway maintenance.

5.2. RECCOMENDATION

Depending on the finding of this study, the following recommendations are given:-

- The adequate thickness provided and decreases the intensity of traffic in road transport along ambo to gedo road segment to minimize highway maintenance and pavement failure
- The study area in road segments insufficient shoulder repair, traffic signs, ditch work, speed limits sign and retaining structure, so reconstruction road by using foamed bitumen are primary recommended points
- Absence of road authorities to give more emphasis on highway maintenance using foamed bitumen, period of maintenance using foamed bitumen and quality of maintenance using foamed bitumen, so road authorities need to give more emphasis on highway maintenance periodically and quality of maintenance using foamed bitumen.
- Absence of foamed bitumen in road maintenance working and adequate equipment and there are problems for ERA to executive maintaining regularly and periodically saved on the study area, so need foamed bitumen in road maintenance work.

- The road authorities have not been able to document the consequences of what will happen to the roads when there is a lack of maintenance
- Need improvement in the overall management of road maintenance activities and Competence-based education and training of human resources in the road maintenance sector
- The authorities should operate an action against the road failures by taking proper maintenance procedures using foamed bitumen, decent materials and skilled workers and supervisors to establish an effective maintenance
- Generally, the primary recommended points to highway maintenance using foamed bitumen, use foamed bitumen when road construction before maintenance, because as the use of foamed bitumen has increased improving the quality of marginal aggregates, improving mix strength and durability, energy saving and improved workability of road. And the life cycle of road construction using foamed bitumen is long rather than without foamed bitumen, so the primary recommend is used foamed bitumen when road construction.

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APPENDEXES

Appendix 1.AADT analysis

Monday December 18/2020							
Time	Direction	Car	Small bus	Medium truck	Heavy truck	Total	
2:00-2:15 AM	Ambo to Gedo	1	3	1	2	7	17
	Gedo to Ambo	2	5	2	1	10	
2:15-2:30AM	Ambo to Gedo	2	4	2	3	11	25
	Gedo to Ambo	3	7	3	1	14	
2:30-2:45AM	Ambo to Gedo	2	5	4	4	15	24
	Gedo to Ambo	1	6	1	1	9	

2:45-3:00AM	Ambo to Gedo	3	10	4	2	19	36
	Gedo to Ambo	1	11	3	2	17	
Subtotal		15	51	20	16	102	
Daily vol.of vehs	102*12=1224						
Tuesday December 19/2020							
Time	Direction	Car	Small bus	Medium truck	Heavy truck	total	
4:00-4:15AM	Ambo to Gedo	2	4	1	2	9	22
	Gedo to Ambo	2	8	2	1	13	
4:00-4:30AM	Ambo to Gedo	1	5	3	2	11	24
	Gedo to Ambo	2	7	2	2	13	
4:30-4:45AM	Ambo to Gedo	3	9	-	1	13	31
	Gedo to Ambo	2	12	2	2	18	
4:45-5:00AM	Ambo to Gedo	1	9	1	3	14	29
	Gedo to Ambo	1	10	3	1	15	
Subtotal		14	64	14	13	106	
Daily vol.of vehs	106*12=1272						
Wednesday December 20/2020							
Time	Direction	Car	Small bus	Medium truck	Heavy truck	total	
3:00-3:15AM	Ambo to Gedo	1	5	3	2	11	21
	Gedo to Ambo	2	6	-	2	10	
3:15-3:30AM	Ambo to Gedo	1	5	2	-	8	14
	Gedo to Ambo	1	3	1	1	6	
3:30-3:45AM	Ambo to Gedo	1	10	1	3	15	29
	Gedo to Ambo	3	7	2	2	14	
3:45-4:00AM	Ambo to Gedo	2	8	2	2	14	24
	Gedo to Ambo	1	7	1	1	10	

Subtotal		12	51	12	13	88	
Daily vol.of vehs	88*12=1056						
Thursday December 21 /2020							
Time	Direction	Car	Small bus	Medium truck	Heavy truck	Total	
2:00-2:15AM	Ambo to Gedo	2	6	-	5	13	18
	Gedo to Ambo	1	3	1	-	5	
2:15-2:30AM	Ambo to Gedo	3	8	-	1	12	26
	Gedo to Ambo	2	9	2	1	14	
2:30-2:45AM	Ambo to Gedo	4	10	3	1	20	27
	Gedo to Ambo	2	2	1	1	7	
2:45-3:00AM	Ambo to Gedo	1	11	4	3	19	31
	Gedo to Ambo	2	5	2	3	12	
Subtotal		17	54	13	17	102	
Daily vol.of vehs	102*12=1224						

Friday December 22/2020							
Time	Direction	Car	Small bus	Medium truck	Heavy truck	total	
5:00-5:15AM	Ambo to Gedo	-	10	-	4	14	26
	Gedo to Ambo	1	7	2	2	12	
5:15-5:30AM	Ambo to Gedo	1	4	2	2	9	19
	Gedo to Ambo	2	6	1	1	10	
5:30-5:45AM	Ambo to Gedo	-	4	-	3	7	19
	Gedo to Ambo	1	6	2	3	12	
5:45-6:00AM	Ambo to Gedo	-	9	1	2	12	21

	Gedo to Ambo	2	5	1	1	9	
Subtotal		7	51	9	18	85	
Daily vol.of vehs	85*12=1020						
Saturday December 23/2020							
Time	Direction	Car	Small bus	Medium truck	Heavy truck	total	
3:00-3:15AM	Ambo to Gedo	2	13	2	4	21	39
	Gedo to Ambo	1	11	1	4	18	
3:15-30AM	Ambo to Gedo	1	6	1	-	8	24
	Gedo to Ambo	-	9	3	3	16	
3:30-3:45AM	Ambo to Gedo	2	7	2	2	13	26
	Gedo to Ambo	-	10	-	2	13	
3:45-4:00AM	Ambo to Gedo	1	8	1	2	13	27
	Gedo to Ambo	1	10	-	1	14	
Suntotal		8	74	10	18	116	
Daily vol.of vehs	116*12=1392						

Sunday December 24/2020							
Time	Direction	Car	Small bus	Medium truck	Heavy truck	total	
6:00-6:15AM	Ambo to Gedo	-	10	1	2	14	25
	Gedo to Ambo	-	9	2	2	13	
6:15-6:30AM	Ambo to Gedo	1	5	1	2	9	16
	Gedo to Ambo	-	3	1	1	7	
6:30-6:45AM	Ambo to Gedo	-	10	2	2	14	28
	Gedo to Ambo	1	9	1	1	14	
6:45-7:00AM	Ambo to Gedo	-	7	2	3	13	25

	Gedo to Ambo	1	5	2	4	12	
Subtotal		3	58	12	17	96	
Daily vol.of vehs	96*12=1152						
Total weekly volume of vehicles	$\sum Daily\ volume\ of\ vehicles$=1224+1272+1056+1224+1020+1392+1152=8340vehs						
Total yearly volume of vehicles	Total weekly volume of vehicles*365/7=8340*365/7=434871vehs						
AADT	Total yearly volume of vehicles/365=434871/365=1191vehs/day						

Appendix 2. PASER pavement evaluation criteria [(P.Barrette, 2011)]

Surface rating	Visible Distress	General condition/treatment measures
10 Excellent.	None	New construction.
9 Excellent	None	Recent overlay. Like new
8VeryGood	No longitudinal cracks except reflection of paving joints. Occasional transverse cracks, widely spaced (40'orgreater).All cracks sealed or tight (openlessthat1/4").	Recent sealcoat or new cold mix. Little or no maintenance required.
6 Good	Slight raveling (loss of fines) and traffic wear. Longitudinal cracks (open1/4"-1/2") spaced10'or more apart, little or slight crack raveling. No patching or very few patches in excellent condition.	Shows signs of aging. Sound structural condition. Could extend life with sealcoat.

4 Fair	Severe surface raveling. Multiple longitudinal and transverse cracking with slight raveling. Longitudinal cracking in wheel path. Block cracking (over50% of surface). Patching in fair condition. Slight rutting or distortions (1" to 2" deep). Occasional potholes.	Significant aging and first signs of need for strengthening. Would benefit from a structural overlay (2" or more).
3 Poor	Closely spaced longitudinal and transverse cracks often showing raveling and crack erosion. Severe block cracking. Some alligator cracking (less than 25% of surface). Patches in fair to poor condition. Moderate rutting or distortion (1" to 2" deep).Occasional potholes.	Needs patching and repair prior to major over lay. Milling and removal of deterioration extends the life of overlay.
2 Very Poor	Alligator cracking (over 25 % of surface). Severe distortions (over 2" deep). Extensive patching in poor condition. Potholes.	Severe deterioration. Needs reconstruction with extensive base repair. Pulverization of old pavement is effective.
1 Failed	Severe distress with extensive loss of surface integrity.	Failed. Needs total reconstruction

Appendix 3.Benefit cost ratio using foamed bitumen

Annual benefit (TTS+VOS+TFS)	Net present worth of benefit	Annual cost (maintenance cost)	Net present worth of costs	Benefit cost ratio(B/C)
24,104,600+ 32,036,399.82+ 41,186,600=97,327,599.82	$(NPW_b=(A_b(1+i)^n-1)/(i(1+i)^n))$ i=10.23%,n=10		$(NPWc=(Ac(1+i)^n-1)/(i(1+i)^n))$ i=10.23%,n=10	

	10	30,262,826.69	10	
	9,51,393,933.9		2,95,824,304.1	3.216

Appendix 4.benefit cost ratio without foamed bitumen

Annual benefit (TTS+VOS+TFS)	Net present worth of benefit	Annual cost (maintenance cost)	Net present worth of costs	Benefit cost ratio(B/C)
61,527,199.2	($NPW_b=(A_b(1+i)^n-1)/(i(1+i)^n)$) i=10.23%,n=10	22,670,000	($NPWc=(Ac(1+i)^n-1)/(i(1+i)^n)$) i=10.23%,n=10	
	10		10	
	374,351,288.17		137,931,578.4	2.71

Appendix 5.Parameter consideration of passenger

Average monthly income of passenger	Average daily income	Average income per hour	Average income per minute	Average passenger working per hour

$(\frac{800+1500}{2})*8+$ $\left(\frac{1500+4000}{2}\right)*15+$ $(\frac{4000+6000}{2})*13+$ $(\frac{6000+10000}{2})*$ 6=3891.6birr/month	$\frac{3891.6}{30}$ $=\frac{129.72birr}{day}$ $\sim 130birr$ $/day$	$\frac{130}{8.22}$=15.82birr/hour	$\frac{15.82}{60}$=0.26cent /min	$\frac{2+4}{2})*12+$ $\left(\frac{4+6}{2}\right)*9+$ $\left(\frac{8+12}{2}\right)*15+$ $\left(\frac{12+16}{2}\right)*$ 6 =7hr:48min

Appendix 6**.** Road defects of severe area photos in the study road segment

Cracking showing the potholes (Goro Sole in front of Construction Company)

Fatigue cracking showing the beginning of a pothole (GUDER-GORO SOLE)

Transverse crack (GUDER)


Pothole on a residential road after heavy rains(BABICH -GEDO)

Pothole as a result of fatigue cracking(BABICH -GEDO)

Patching (GORO SOLE)

Appendix 7.Questionnarries

For driver.

1. Gender (indicate with "√" when appropriate)

Female ☐ Male ☐

2. How often do you make the trip in this direction per day?(Indicate with "√" when appropriate)

One ☐ Two ☐ Three ☐ Others ☐

3. it's comfortable to travel on this road? (Indicate with "√" when appropriate)

yes ☐ no ☐

4. How often time did you use once changed tire?

………………………………………………………………………………………………….

5. How to compare ambo to gedo road with other road, when travel on this road?

………………………………………………………………………………………………….

6. How did you use time once changed motor tire?

…………………………………………………………………………………………………

7. How many liter of Benzene use daily? ……………………………………………

8. How much time did you spend traveling Ambo to Gedo? …………………………

9. The existing condition of road?

Location	Very good	Good	Poor	Very poor	fair
Ambo to Guder					
Guder to Goro sole					
Goro sole to Babich					
Babic h to Gedo					

10. In overall what is your Remark on the road?

……………………………………………………………………………………………

For passenger

1. Gender: Female ☐ Male ☐

2. What is your work status?

Merchant ☐ Student ☐ Government employed ☐

Private work ☐ other ☐

3. What is the advantage of trips?

For work ☐ For Business ☐ related other ☐

5. How much time did you spend in work daily?

2-4hr ☐ 4-6hr ☐ 8-12hr ☐ 12-16hr ☐ Other ☐

6. Which category represents your personal income?

800-1500 ☐ 1500-4000 ☐ 4000-6000 ☐ 6000-10,000 ☐ others ☐

7. it's comfortable to travel on this road? Yes ☐ no ☐

8. What is the amount of fare for travel?

……………………………………………………………………………………………

9. In overall what is your Remark on the road?

……………………………………………………………………………………………

……………………………………………………………………………………………

For engineer

1. Gender

Male ☐ female ☐

2. What is your responsibility in your organization? (Indicate with "√" when appropriate)

Project manager ☐ Site engineer ☐ Client ☐

Office engineer ☐ Site manager ☐ consultant ☐

Architect ☐ owner ☐ Forman ☐ Supervisor ☐

3. The Ambo to Gedo road is effectively to the passengers and drivers?

Yes ☐ no ☐

4. If your answer is yes, the road are effectively to passengers and drivers what the advantage of road maintenance?...

3. What are the advantage of maintaining the road effectively to the passengers and drivers? ....

4. What are the reasons for road maintenance on the road?

....

5. What are the major signs that are seen due to inadequate road maintenance?

……………………………………………………………………………………………

6. What are the most problems that occurred in highway maintenance?

……………………………………………………………………………………………

7. How many quantities of water uses of foamed bitumen produced for highway maintenance?

……………………………………………………………………………………………

8. What are the uses of foamed bitumen for highway maintenance?

……………………………………………………………………………………………

9. In overall what is your Remark on the road? ....