IMPACTS OF ROAD CONSTRUCTION DELAY ON TRANSPORT COST AND BENEFIT

A CASE STUDY ON HAGEREMARIAM -YABELO ROAD CONSTRUCTION PROJECT

M. Sc. THESIS

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A THESIS SUBMITTED TO THE
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We, the undersigned, members of the Board of Examiners of the final open defense by **SELAMAWIT KIFTAGA NAMAGA** have read and evaluated his/her thesis entitled **"Impacts of Road Construction Delay on Transport Cost and Benefit (A Case Study on Hageremariam -Yabelo Road Construction Project)"**, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree

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DECLARATION

I hereby declare that this MSc thesis is my original work and all sources of materials used for this thesis have been duly acknowledged. I declare that this thesis is not submitted to any other institution for the award of any academic degree.

Name: **Selamawit Kiftaga**

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

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This thesis is dedicated to my beloved late father who paved my foundation for my success.

LIST OF ABBREVATIONS OR ACRONYMS

AADT: Average Annual Daily Traffic

ERA: Ethiopian Road Authority

HDM-4: Highway Development and Management Tool

IRI: International Roughness Index

MS: Mean score

MT: Motorized Transport

PCSE: Passenger Car Space Equivalent

RAC: Road agency cost

ROW: Right of way

RSDP: Road Sector Development Program

RUC: Road User Cost

TTC: Total Transport Cost

VOC: Vehicle Operating Costs

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLE IN THE APPENDIX

ABSTRACT

Completion of a project is considered as the most important factor of successes of road projects which helps to decrease problems for all concerned parties and give new chances to a county's economy. Delays in completion of road projects will result in significant loss of benefits for all road users. Accordingly, this research is carried out with the view of evaluating the impacts of road construction delays on transport costs and benefit considering Hageremariam-Yabelo Road. Questionnaire surveys were used to collect data on causes of delays and impact of delay on vehicle operating cost as well as an analysis was conducted by using the Likert Scale with mean score value. A total of 35 responded questionnaires from the client, consultants and contractors were collected. In addition, pertinent data were collected from vehicle operators on Hageremariam-Yabelo Road project. Respondents identified twenty-seven (27) causes of delays and nine (9) impacts. The most important causes of delays were: delays to furnish and deliver the site (right-of-way problem) and lack of possession of the site in various locations; variation of order (additional works not considered during the first time); and late site mobilization. The most common impacts of delays regarding vehicle operating cost were identified as; working hours per year (frequency of journey per day); tire consumption / tier-wear and average vehicle service life. This research also used the Highway Development and Management (HDM-4) tool in quantifying additional costs due to delays in respect of road agency and road user costs with the total loss of benefits. Using the Model, results were generated in the case of both alternatives (with delay and without delay) of the subject construction project. Overall, the 'with delay' alternative was compared with the 'without delay' alternative and the total transport costs increased by Birr 674.22 million. The amount of lost benefits from vehicle operating cost savings, travel time cost savings and accident cost reduction that resulted in the case of 'with delay' alternative was calculated at Birr 17.49 million. It is believed that these findings will guide to improve the performance of the construction industry of Ethiopia in the future.

Key words: road construction delay, causes of delay, impacts of delays, HDM-4, time and cost overruns, benefits.

1. INTRODUCTION

1.1 Background

In the context of Ethiopia, road is the most important infrastructure that provides access to rural and urban areas in the country. Transportation infrastructure is generally considered as an essential element for economic and social development as it provides the links required to make market functions. The development of economical vital sectors such as agriculture, industry, tourism and others are directly dependent on the existence of a functioning transport infrastructure system. Hence, in the socio economic growth of a country like Ethiopia, the on time completion of road construction plays a vital role.

Recognizing the importance of road transportation in supporting social and economic growth and in meeting poverty alleviation, the Ethiopian government has placed increased emphasis on improving the quality and size of road infrastructure. The development of the Country's road network was given top priority as a core component of the country's economic progress. In this regard, the road authority needs to be examined and tasked with securing the delivery of an efficient, reliable, safe and environmentally acceptable road network. With this consideration, major roads and a network of local feeder roads are being constructed. In order to achieve this economic growth by utilizing the budget as planned and to facilitate the construction of the road as it is needed to serve the society, road construction works have to be properly planned, designed, constructed and completed as programmed. However, due to different factors, road project construction works are not completed within the scheduled times. Delays happen in most construction projects, whether project is simple or complex.

Construction delays could be defined as the time overrun either beyond the contract date or beyond the date that the parties agreed upon delivery of a project or a service to customer (Motamedi, 2014). Delays in construction projects therefore adversely impact the economic projections of a nation. (Sunjka, 2013) Stated that construction projects impact a nation's economy. Successful completion of construction projects leads to wealth creation; socio-economic growth and improved standards of the livelihood of citizens of nations that were evaluated as developed, developing and underdeveloped based on the quantity and quality of completed construction projects in their domain. Delays are endemic to the road construction projects in Ethiopia. (Haseeb et al, 2011) in their research stated that: "The construction delay is a universal evident reality not only in Ethiopia; but most countries face this global facts". In Ethiopia, most of the road projects are delayed well beyond the expected time for completion and also had required additional budget (road agency cost) more than the ones envisaged during the commencement of respective projects (Adiam, 2016). (Abdissa, 2003), in his research examining fifteen (15) completed road projects in different region of Ethiopia, the delay encountered in most projects range from 20.66% to 500% of original contract time and Project delays are the major causes of claims for time extension and associated cost.

Furthermore the Delay of road construction impact on road user cost includes travel delay cost, vehicle operating cost and crash cost. This road user cost increase because of the additional construction. Due to delay of road construction project, road user cost saving is loss. Road construction completed on time is attributable to significant improvement in roughness and reduction in travel time and vehicle operating costs.

This paper aims to identify the possible factors that adversely influence the on-time completion of road construction and to investigate the impact of road construction delays on transport cost and benefit taking the Hageremariam-Yabelo road project as a case study.

1.2. Statement of the Problem

On time completion is considered as the most important factor of successful road projects, which help to the development of county's economy. It also helps to increase the profits and development of construction industry. Most of the time, construction projects fail to achieve their mission within the specified cost and time. In the case of Ethiopia, only few projects get completed on time and within estimated budget. This is because of construction projects are exposed to different uncertainties because of construction complexity that is the presence of various interest groups such as the project owners, end users, consultants, contractors, financiers; materials, equipment, project funding; climatic environment; the economic and political environment and legal regulation.

Delays have negative effects on project in terms of performance, time and cost. Delays affect road construction economically; such as increase agency cost and road user cost (construction material, increase payment for manpower and equipment cost, increase in travel time, high vehicle operating costs).Therefore, it is an important issue to the road construction sector in Ethiopia.

Regarding the Hageremariyam-Yabelo road construction project, the original time set for completion was May, 2014. However, the project was not completed as scheduled and time extension was provided until May, 2016. The project road was envisaged to foster economic integration between Ethiopia and Kenya by providing swift access to border areas and to increase the productivity and trade between the two countries. But, this project road was not speeded up as scheduled. So, investigation into the problem was needed to examine the causes and the impacts of the road construction delays on the road agency and road user costs to estimate the loss in envisaged benefits and additional costs involved due to time extension. Therefore, estimating the value and volume of benefits lost due to delays in road construction is important for Ethiopia to consider as learned lessons since it happens frequently. In addition, finding the means of minimizing delays will help to achieve better management of road construction which will significantly contribute to the national economy and environmental benefits to the neighboring communities. Furthermore, it will be helpful to control project delays and to establish investment programs for road construction. Therefore, this research has been prepared to assess the causes of delays of the Hageremariam-Yabelo road construction and its adverse impacts in respect of transport cost and benefit.

1.3. Objective of the Study

1.3.1. General Objective

The general objective of this research is to evaluate the impacts of road construction delay on transport cost and benefit considering the Hageremariam-Yabelo Road.

1.3.2. Specific Objectives

The specific objectives of this thesis are to:

- ❖ Assess and identify the causes for late completion of road construction projects regarding the Hageremariam-Yabeloroad project.
- ❖ Assess the impact of road construction delays on vehicle operating costs on Hagermariam-Yabelo road.
- ❖ Quantify the costs expended during the construction period (without delay and with delay).and
- ❖ Determine the lost road user benefit due to road construction delays.

1.4. Research Questions

- ❖ What were the significance causes of road construction delay in case of Hageremariam-Yabelo road?
- ❖ How much costs were increased due to the impact of the subject road construction delay?
- ❖ What and how much are the lost benefit as a result of construction delay?
- ❖ How did subject road construction delay adversely affect the economic and social development of Ethiopia in general and the study area in particular?

1.5. Scope

The scope of the study is limited to Hageremariam-Yabelo road with a total length of 94.5 kilometers. The study focus on the impact of road construction delay on transport costs and benefits on the study route and the analysis is done by using highway development and management tool (HDM-4). Finally, propose appropriate recommendations to minimize road construction delays in other ongoing and future road projects of Ethiopia.

1.6. Limitation

In this study, there is some limitations that could be encountered. One of this is unwillingness of communities' along the study road to provide the required data and information through questionnaires and interviews.

2. LITERATURE REVIEW

Construction delays can be defined as the late completion of works compared to the planned schedule or contract schedule. Delays occur in many construction projects and the significance of these delays varies considerably from project to project. Several studies have attempted to about project delays in the public construction industry. In the case of Ethiopia, economic impacts related to road construction delays have not been exhaustively studied. (Abubeker, 2015)Stated that a project is considered successful if completed within stated costs or budgets, making the project utilized by a target date, meet the technical specification, and if there is a high level of satisfaction concerning the project outcome among the project participants. (Saeed, 2009) Stated that delays to projects are adversely affecting the economies of nations throughout the world.

(Sepahi et al, 2016)Stated in their study on how many delays a year are allowed to be economically sound in execution of a project. The research used modeling for analysis (based on fundamentals of engineering economics). The output indicated that in civil project, the rate of return and net present worth are reduced according to delay period and the maximum tolerable delay period. Delays in civil projects result in increased construction time which is undesirable for all beneficiaries; they all will experience losses regarding contractors' profits because of the increase in costs due to engaging resources without generating the envisaged economic, social and environmental benefits of the project.

2.1. Definition of Construction Delays

Different researchers defined construction delays differently in their own contexts based on their research findings. According to (Al-Hejji, 2006), construction, delay could be defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project. Another definition was by (Ahmed, 2015), as delay is; to make something happen later than expected; to cause something to be performed later than planned; or to not act timely. According to (Worku, 2016), construction delays can be defined as the late completion of work compared to the planned schedule or contract schedule. Delay is the slowing down of work without stopping construction entirely and that can lead to time overrun either beyond the contract date or beyond the date that the parties have agreed upon for the delivery of the project. According to (Abubeker, 2015), construction delay could be defined as the time over run either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project. Each of this definition describes a delay to an activity of work in a schedule.

2.2. Causes of Construction Delays

There are many causes for late completion or delays of construction projects. In this regard, several studies have pointed out various factors based on the underlying conditions that the specific study is concerned; that is, for a particular project type, specific location or to a particular project size. The findings of such studies have been reviewed in this research.

(El Razek et al, 2008), conducted a survey to identify the main causes of delays in construction projects in Egypt from the point of view of contractors, consultants, and owners. They identified thirty two (32) causes of scheduled delays which were grouped into nine (9) groups to fit the Egyptian construction industry. These groups were: financing, materials, contractual relationships, changes, rules & regulations, manpower, scheduling and control, equipment, and environment-related causes. Their findings indicated that the most important causes are: delays in contractor's payment by owner, design changes by owner or agent during construction, partial payments during construction, and no utilization of professional construction/contractual management.

(Adiam, 2016), identified the major causes for late completion of road construction projects. The analysis of the data was made using the aforementioned statistical methods from the viewpoints of the clients, consultants and contractors. The analysis illustrates the findings and results of the survey for the severity, frequency and importance indices of all the variables of delay. Finally, (Adiam, 2016)concluded that the main responsibility lies on the client in following the performance of the contractor, supervision consultant and design consultant while performing their contractual obligations and take action when it is found necessary to do so. The client also has its own problem in fulfilling its contractual duties. Eventually, most cases are tried to be solved administratively rather than penalizing the liable party, which in the end affect the construction project by extending the contractual time and money.

(S.Ramya, 2015), conducted a research to identify the causes, effects and minimization of construction delays and ranked by using relative importance index. The top affecting causes of delays category-wise are: late in revising and approving design documents by clients, ineffective planning and scheduling by contractor, mistakes and discrepancies in design documents by consultant, changes in material types and late procurement of materials, equipment breakdowns, personal conflict among labors, and rise in prices of materials. When the cause's delays were ranked overall, the main causes are: ineffective planning and scheduling by contractors rise in prices of materials and late in revising and approving design documents by clients. The top effects of delay are: time overrun and cost overrun. The top means of minimization of construction delays are effective strategic planning, frequent progress meeting, accurate initial cost estimates, proper project planning and scheduling, site management and supervision.

(Abubeker, 2015), conducted a research on factors affecting time and cost overrun in road construction in Addis Ababa. According to the result of his study the factors that influence time and cost overruns have been identified and ranked in order of significance. The results of his research come up with, the most common causes of time overrun are: delay to deliver the site (right-of-way problem), financial problems of contractors, improper planning, and site management. (Abubeker, 2015) Also pointed out that the most common causes of cost overrun are: design change, fluctuation in the cost of materials, and inadequate review for drawings and contract documents. The most common causes of delays and their associated costs, according to (Abdissa, 2003), were: shortage of spare parts, untimely payment, poor planning and control, increase in scope (design changes/extras), differing soil and site conditions, limited access to the site (partially or totally) not ready for work to progress, unusual and long rainy weather condition, war and instability, poorly equipped contractors and public sector agencies, lack of motivation, and lack of experience in project management. (Abdissa, 2003) Concluded that most of the delays were concurrent delays; that is to say that delays occurred by contractor, owner and third party at the same time. The overlapping of the causes of delays makes difficult to identify which portion of delay is which party's sole responsibility. Poor record keeping of events makes the problem even worse.

(Worku, 2016), investigated the causes of construction delay in the Ethiopian Construction Industry and the following factors as the major cause of delays.

i. Difficulties in financing project by a contractor;
ii. Escalation of the materials prices;
iii. Scheduling or resource management by contractor;
iv. Delay in progress payments for completed works;
v. Lack of skilled professionals in the field of construction management in the organization; and
vi. Fluctuating labor availability season to season /seasonal labors availability.

(Ahmed et al., 2003) and (Theodore J, 2009), identified and categorized the factors that cause construction delays into four as follows:

a. **Contractor's responsibility:-**The factors that are related to contractor's responsibility are; poor qualification of the contractor's technical staff; shortage of materials on site; construction mistakes and defective work; poor skills and experience of laborers; shortage of site labor; low productivity of labor; financial problem; coordination problems with others; conflicts in sub-contractors schedule in execution of project; lack of site contractor's staff; poor site management; and delays in site mobilization.
b. **Consultant's responsibility:-**The factors that are related to consultant's responsibility are; absence of consultant's site staff, lack of experience on the part of the consultant, inadequate experience of consultant, delay in approving major changes in the scope of work, and mistakes and discrepancies in design documents.
c. **Owner's responsibility:-**The factors that are related to owner's responsibility are; delay to furnish and deliver the site, lack of working knowledge, slowness in making decisions, lack of coordination with contractors, change orders by owner during construction (replacement and addition of new work to the project and change in specifications), financial problems (delayed payments, financial difficulties, and economic problems)**,** slowness in decision making process; and poor communication and coordination.
d. **External factors:-**The factors that are related to external factors are: delay in obtaining permits from municipality; lack of materials on the market; lack of equipment and tools on the market, poor weather conditions; poor site conditions (location, ground, etc.); poor economic conditions (currency, inflation rate, etc.), changes in laws and regulations; transportation delays; external work due to public agencies' (utilities and

public services); and delay in providing services from utilities (such as water, electricity).

2.3. Types of Construction Delay

According to (Trauner et al, 2009)**,** delays may be categorized into: critical and non-critical delays; excusable and non-excusable delays; compensable and non-compensable delays; and concurrent and non-concurrent delays. Each of these is explained below:

- ❖ Critical delays correspond to delays in the critical activities of the project which will directly affect the project's final deadline. Non-critical delays are not so constricting since they occur in activities with a much looser execution deadline.
- ❖ Excusable delays earn the contractor some extra time to conclude the work because they are caused by unpredictable events that cannot be controlled. If the delay is caused by acts or omissions of the client, the contractor is entitled to a financial compensation. If the delay is none of the parties fault, there will be no financial compensation. Non-excusable delays are of the contractor's responsibility and they earn him no extra time or financial compensation. However, these delays may entitle the client to a financial compensation.

Concurrent and non-concurrent delays: if there is only one isolated delay, then we can say we are in the presence of a non-concurrent delay. In such cases, it is easy to assign responsibilities. In situations where two or more critical delays occur simultaneously, these are called concurrent delays. Most of the times, assigning responsibilities may become a tricky task since delays are caused by two or more of the parties. (Yang et al, 2007), classified delay following a logical process as shown in figure2.1 below.

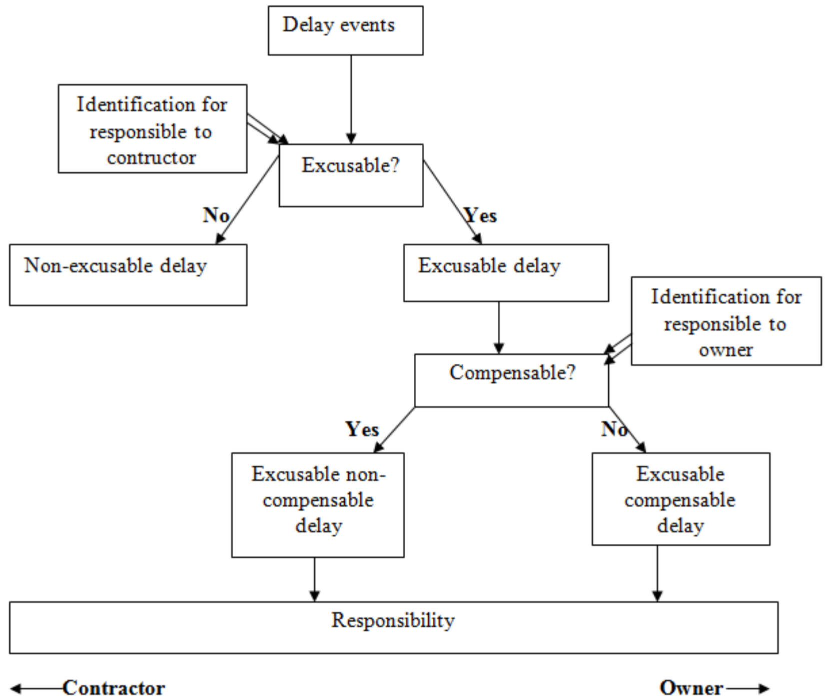


Figure 2.1: Logical process of delay classification (Yang et al, 2007)

2.4. Effects of Road Construction Delays

(Haseeb et al, 2011), studied the problems of projects and effects of delays in the construction industry of Pakistan. It was concluded that the consequences of delays were different for different parties. The general consequences are the loss of wealth, time and capacity. For owner, delay means the loss of income and unavailability of facilities and for contractor, delay means the loss of money for extra spending on equipment and materials and hiring labor and loss of time. Effects of delay in their research finding in construction projects of Pakistan are: overtime, over cost, disputes, negotiations, lawsuit, litigation; and abandonment.

(Sunjka, 2013), studied the significant causes and effects of project delays in the Niger Delta Region, Nigeria. The research was conducted by analyzing the respondents' mean scores and results of sub-hypotheses' testing. The research finding indicated that there were three most important effects of project delays in the Niger Delta Region, namely:

- **Time overrun**: Overall, respondents ranked time overrun as the first most important effect of project delays (mean score = 4.03). The t-test results indicated that, this is significant in the Niger Delta region (p-value=0 at 5% significance level).

- **Budget (Cost) overrun**: Overall, respondents ranked budget overrun as the second most important effect of construction project delays (mean score=3.90). The t-test of mean score at 5% significance level gave a “p-value” = 0. Cost overrun is the amount by which actual costs exceed the baseline or approved costs. Cost overrun is a very common phenomenon and majority of projects and construction industry are facing this problem (Abubeker, 2015).
- **Disputes and claims**: Overall, respondents ranked disputes and claims as the third most important effects of project delays (mean score = 3.53). Results of the t-test on the mean score at 5% significance gave a p-value of “0” which implies that this is one of the significant effects of project delays in the Niger Delta region. Delays in construction projects generate grievances among the stakeholders. Therefore, aggrieved parties could make claims to remedy damages that they incurred.

Overall delay-related costs on any given project are non-time-related and time-related costs. Non-time related is a one-time cost that has nothing to do with the duration of the project – thus, making that Time-related costs for either contractors or subcontractors fall into four distinct; Labor, materials, equipment, and escalation. Time-related labor costs include: project management, supervision personnel (field engineers, quality control, etc.), and home office personnel (accounting, human resources, etc.). In addition, time-related materials costs include utilities (telephones, mobile phones, and electricity), portable toilets, and traffic control signs. aTime-related equipment costs include items such as forklifts and loaders to load, unload, and handle materials; tower cranes for building projects; graders to maintain haul roads; buses to transport personnel; and pickup trucks for project managers. In the case of time-related escalation costs, it includes any expenditure that increases due to when the expenditure is made. For instance, if the installation of steel on a stadium project is delayed a year, and the price of steel doubles while the contractor is waiting to commence work, the cost increase may be recoverable as a delay-related expense. Expenditure unrecoverable should delays to the critical path occur the above was stated by (Chris Beirise, 2009).

2.5. Impacts of Road Construction

Highway rehabilitation projects impacts road users, adjacent businesses and property owners, transportation agencies, contractors and third-parties (Eduardo et al, 1995). The existence of delays represents losses to all of the parties: the loss of income to the client; increased costs to the contractor; and the non-utilization of the facilities by the population.

2.5. 1. Environmental Impacts

Environmental impacts caused by work-zones are mostly due to emissions from construction equipment, emission due to unstable traffic, work-zone waste, and noise pollution. (Salem et al, 2014) stated that: "In urban areas, traffic emissions around work-zones increases due to frequent acceleration and deceleration, reduced speed and queuing. This impact can be minimized by utilizing management techniques."

2.5.2. Social Impacts

Work-zones are hazardous for both construction workers and motorists that drive through the work-zones with unorganized barrels and equipment and various complex signs around them (Salem et al, 2014). In research, it was indicated that proper estimation of construction duration of each phase is necessary for providing accurate information to daily commuters about the work-zones near specific businesses which will allow them to plan accordingly in advance. Work-zones affect public properties including: parks, recreational facilities, fire stations, police stations, and hospitals, as well as private properties including businesses and residences (Mallela, 2011).

2.5.3. Economic Impacts

According to (Salem et al, 2014), economic impacts of work-zones are crash cost, travel delay costs, and vehicle operation costs. It was pointed out that crashes can be reduced by increasing visualization such as using signs related to speed limits and detours in proper distance from work-zone. Delay time is the additional time necessary to reduce the speed from upstream speed to the work-zone speed, as well as, the additional time needed to pass the work zone in lower posted speed. Detours also cause delay time due to the extra distance of the detour route. Vehicle operating cost increases due to speed change, stopping, queue idling and detours. These costs include fuel consumption, engine oil consumption, tire-wear, repair and maintenance, and mileage-related depreciation costs (Mallela, 2011).

(Andre, 2010) established: to present a Microsoft Excel model that allows estimating the impact of the delays on the costs of a construction project. It was concluded that there are, generally, two types of delay damages – direct and indirect. Direct delay damages include such costs as idled and extended labor and equipment costs, extended storage costs, extended bond costs, material inflation costs, etc. Indirect delay costs include loss of efficiency, extended or unabsorbed home office overhead costs and extended field office overhead costs. Provided that the contractor has maintained reasonably good cost records during the performance of the work, proving the direct delay costs should not be a monumental task. According to the author large, prolonged construction projects "can have a measureable fiscal impact on the municipal and local government tax base, business sales and personal income within the project's influence zone"

(Allouche, 2004), recognized several negative economic impacts including as follows:

Loss of income: Businesses within the influence zone of a construction site may often face decreased income or revenue due to reduced accessibility and detours that lead customers away from their location and construction nuisances. Noise and dust can also deter customers. This loss of income can ultimately force companies to go bankrupt and close.

Productivity reduction: The ability to perform work at intended levels may be lessened from the impacts of construction. Construction annoyances, including: traffic delays, dust and noise, can cause employee's productivity rate to decrease. Traffic congestion can also negatively affect people's mood which in turn can transfer directly to work, inhibiting productivity.

Reduction in tax revenue: With diminishing sales caused by decreased customer traffic, businesses naturally will pay less income tax. This is detrimental to city and state tax revenues.

Property damage: Construction activities can bring about damage to surrounding properties resulting in a number of costs to property owners. Settlement is the most damaging cost and can result in structural failure of buildings. Dust and noise not only affect customer retention and productivity but can lower property value.

2.5.4. Impacts on Road Users

Highway users include all of those who may be using any portion of the highway right-of-way and its immediate environs (e.g., vehicle operators and their passengers) (Eduardo et al, 1995) pointed out that, the two approach to reduce the impacts on road users resulting from highway rehabilitation are by implementing a range of mitigation strategies during the rehabilitation project, and, by adopting a rehabilitation alternative that may reduce the number of rehabilitation cycles (i.e., a more durable rehabilitation method). In order to conduct an economic evaluation of alternatives, researchers should estimate the adverse impacts on road user costs resulting from disruptions to traffic during highway rehabilitation.

2.5.5. The Costs Attributed to Project Delay

(Beaty et al, 2011), assessed the costs attributed to project delays. It was recognized that there were unreliable accounts of the significant financial impact that the delay of a highway project had on project costs, local businesses and commuters, and other users of the highway. But in many cases, hard data on financial impact are lacking. In their research, the Texas Department of Transportation (TxDOT) aimed to develop a simple but sound methodology for estimating the cost of delaying most types of highway projects. The project developed a simplified model that incorporates sixteen (16) user- controlled variables and produces estimates of the effect of project delay on personal and commercial travel and the cost to the general economy.

Types of costs associated with project delays in their research were:

- ❖ **Direct costs of project delay**: actual out- of- pocket costs borne by any stakeholder are affected by a delay in project delivery. Most of the direct costs accrue to TxDOT and, therefore, are passed on to the public in the form of less efficient use of taxpayer resources.
- ❖ **Indirect costs of project delay**: hidden costs that are borne by stakeholders, often a much greater amount than the direct costs of project delay and include:
    - ✓ Wasted traveler fuel and time;
    - ✓ Economic impacts in the vicinity of the project; and
    - ✓ Loss of business efficiency for those businesses that rely on the transportation system for their productivity.

(Sepahi et al, 2016), pointed out the cost increase due to delay in civil projects. According to their research; delay in execution of civil project will cause increase in the following costs: execution delay costs and lost profits; costs due to inflation (increase in material and execution costs), increase in labour force and equipment costs, cost increase due to extension of contracts and agreements, Increase in input investment interest costs, losing the competitive market; cost increase due to decrease in government incomes and social welfare; cost increase due to losses in substitution project; increase in environmental costs of the substitution project; and cost increase due to economic and political instability.

2.6. Time and Cost Overrun in the Ethiopian Roads Construction

Time and cost overruns in road construction projects in Ethiopia is one of the most significant problems in the field construction management. Research and studies in this field in Ethiopia are few compared to the problem of time and cost overruns. Taking this into consideration, this research was done on factors affecting time overrun and impact of delay, specifically on vehicle operating cost regarding the Hageremariam-Yabelo road construction projects. Despite the importance and the significance of the construction sector in Ethiopia, it is noted that the parties of project (owner, consultant, and contractor) didn't give sufficient evaluation for time and cost overruns at the end of the project.

(Turkey, 2012) in his study of the risk factors leading to cost overrun in Ethiopia's federal road construction projects and its consequences, examined the effects of cost on the delivery of construction projects in the country. The result of the desk study indicated that out of 30 upgrading and rehabilitation road construction projects investigated, 24 projects (80%) suffered cost overrun in their execution. The average rate of cost overrun in these projects was 26.95% of the contract amount. In addition, 100% of the respondents to the questionnaire recognized cost overrun as one of the major problems in Federal road construction projects. Unexpected inflation/ material price escalation, delays on completion time, scope changes, unstable cost of manufactured materials, inadequate site investigation and right-of-way problems (access to site and quarry) were identified as the major factors leading to cost overrun.

(Abubeker, 2015) in did a study on "Time and Cost Overrun in Road Construction Projects in Addis Ababa"; The result of the desk study indicated that the rate of time overrun ranges from a minimum of 25% to the maximum of 264.38% of the contract time. And cost overrun ranges from a minimum of 4.11% to the maximum of 135.06% of the contract amount for individual projects. The problem of projects delay and cost overruns can nearly be noticed in every project in Ethiopia road construction activities indicating that this problem didn't receive enough attention by both researches and responsible authorities.

2.6.1. Physical and Financial Performance of Road Sector Development Program

Over the nineteen years of the Road Sector Development Program (RSDP), physical works have been undertaken on a total of 128,470 km of roads excluding routine maintenance work and community roads. The total budget for the planned works during this period amounted to ETB 232.5 billion (USD 15.9 billion). The total amount disbursed in the same period, was ETB 266.2 billion (USD 17.4 billion). A physical and financial performance of RSDP over the past 19 years against planned was 86% and 115% respectively. Table 2.1 below shows a summary of the 19 years physical and financial performance of RSDP.

Table 2. 1: Summary of 19 years Performance of RSDP (ERA, 2017)

Program	**Physical Plan Vs. Accomplishment, km**			**Financial Plan Vs. Disbursement, in million ETB**		
	Plan	**Actual**	**% age**	**Budget**	**Disb.**	**% age**
Total RSDP I	8908	8709	98	9812.9	7284.6	74
Total RSDP II	8252	11589	140	15985.9	18112.8	113
Total RSDP III	14686	12395	84	34643.9	34957.9	101
Total RSDP IV	97,517	85,860	88	125409.1	158,333.5	126
RSDP V (First Year)	20270	9917	49	46605.1	47520.3	102
Total RSDP (19 yrs)	149,633	128,470	86	232456.9	266209	115

2.6.2. Some Sample Projects that shows time and cost overrun

2.6.2.1 Time overrun

As shown in table 2.2 below, all contracts were not completed at the original contract time. Extension of time (EOT) was requested by each contractor due to problems encountered during construction. Major reasons for request for EOT by contractors and consultants were rainfall, ROW problem, design problems and shortage of cash flow & construction materials such as cements, shortage of construction engineers. Time overrun accounts for minimum time overrun ranges from a minimum of 31% to the maximum of 177% of the contract time. Time overrun of all projects are significant. Significant time overrun in all contracts contributed to significant price escalation and delayed benefits to be materialized from the projects. Table 2.2 shows Projects time overrun.

Table 2. 2: Contract time and actual completed time of some road projects in Ethiopia

road project name	**Length (km)**	**Original Contract time (Days)**	**Revised Contract time (Days)**	**Time Overrun (Days)**	**Rate of Time Overrun (%)**
Jimma – Bonga	1,10.4	1,036	2,140	1,104	107
Bonga – Mizan	1,19.2	1,034	2,866	1,832	177
Mekenajo –Ayra	52.06	910	1,264	354	39
Ayra – Chanka	70.6	910	1,531	621	68
Chanka – DembiDolo	65.5	910	1,193	283	31
Wolkite –Arekit	60	913	1,200	287	31
Arekit – Hossaina	65.5	913	1,321	408	45
Average Rate of Overrun (%)					71

Source: Ethiopian Roads Authority (Projects' completion report, 2017)

2.6.2.2 Cost Overrun

Cost overrun of all projects was ranging from a minimum 7.97% to maximum of 148.61%. The major reasons for high cost overruns of the projects are; price escalation, variation due to increase in quantity of works, claims to delays in ROW clearance, shortage of cement and fuel, and shortage of key professionals and other reasons. Table 2.3 below presents cost overruns of certain road projects.

Table 2. 3: Contract amount and actual completed amount of some Projects

Road Project Name	Length (km)	Contract Amount (million ETB)	Actual Disbursement (million ETB)	Increasing Cost (%)
Jimma – Bonga	110.4	15.87	33.43	110.65
Bonga – Mizan	119.2	16.87	41.94	148.61
Mekenajo –Ayra	52.06	633.53	712.82	12.52
Ayra – Chanka	70.6	669.1	937.65	40.14
Chanka – DembiDolo	65.5	648.6	700.32	7.97
Wolkite –Arekit	60	717.44	1105.7	54.12
Arekit – Hossaina	65.5	621.2	827.19	33.16
Average Rate of Cost Overrun (%)				58.17

Source: Ethiopian Roads Authority (Projects' completion report)

Tables 2.2 and 2.3 clearly show that, the rate of time and cost overrun were significantly high in road construction projects. From the project's completion reports, it was found that the main reasons for time and cost overruns were: right-of-way problem, design change, variation due to increase in quantity of work and contractors' financial problem.

2.7. Highway Development and Management System (HDM-4) Overview

HDM-4 is computer software for Highway Development and Management System. It is a decision-making tool for checking the engineering and economic viability of the investments in road projects. The World Bank developed the Model for the global use.

2.7.1. Background

HDM-4 is the new windows version after its predecessor, HDM-II, with incorporation of many new features so that it can be used in any locality of the globe with any environmental and engineering situation.

HDM 4does:

- Strategic Analysis
- Program Analysis
- Project Analysis

2.7.2. Project Analysis

Project analysis allows the users to assess the physical, functional and economic feasibility of specified project alternatives by comparison against a base case (without project).

The key issues are:

- **Pavement structural performance**: Pavement is generally designed to carry the load of traffic that runs over it. If the structure of the road is not strong enough to withstand the traffic loading then the road structure will fail. HDM 4 has the analytical tool that can calculate the structural strength of the pavement for the traffic running over it.
- **Life cycle prediction of deterioration, maintenance effects and costs;**

  For the particular traffic loading, HDM 4 is able to calculate the deterioration of the road structure and the surface for each year of the analysis period. If the user provides the maintenance option then HDM 4 can apply the maintenance, calculates the cost of maintenance and the effects. For example, if the user gives the option that whenever the roughness will reach 6 IRI, an overlay has to be applied. In this case the HDM-4 will calculate the roughness increase every year due to traffic loading and whenever the roughness will reach 6 IRI, HDM 4 will apply an overlay. As an effect of this maintenance, the roughness will be decreased to an extent as will be specified in the overlay option. HDM-4 will also calculate the costs of the overlay with the help of the rate supplied by the user.
- **Road user costs and benefits**;

  The road user costs consist of Vehicle Operating Costs (VOC), Travel Time Cost (TTC) and the Accident Costs (AC). If no improvement is done (do nothing option/without project) the road user costs will be high but if any improvement is applied such as overlay (do something option), the road user costs will be reduced to a great extent. If the Road User Costs of the above two options are compared then, it will be seen that a benefit will be obtained by doing the maintenance.

- **Economic comparison of project alternatives;**

  For the maintenance of the road, the user might have various maintenance strategies. HDM 4 can calculate the economic indicators like net present value (NPV), internal rate of return (IRR) for every option of the maintenance strategies for the projected analysis period. The most beneficial maintenance option will be one that gives the maximum economic return;

The project analysis can be done for:

Maintenance of existing roads include; crack sealing, pothole patching, seal coat, single bituminous surface dressing (SBSD),double bituminous surface dressing (DBSD),carpeting, overlay, pavement strengthening, improvement of existing roads, pavement reconstruction, pavement upgrading, road widening and geometric improvements, realignment, new construction, involves entirely new construction, stage construction, planned improvements at fixed stages, say from HBB to bituminous pavement; project evaluation; and assessment of the performance of the completed project to see if objectives set out during appraisal have been met.

2.7.3. Program Analysis

Multi-year rolling program for road network through maximization of NPV/C ratio. It deals primarily with the prioritization of a defined long list of candidate road project in to one or multi-year work programmed under a defined budget constraint. The program analysis as it is termed, is the analysis for doing the yearly maintenance program or the multi-year rolling program. The program analysis tool has been incorporated in HDM-4 for easy analysis of the whole road network for identifying the candidate road section for maintenance for a particular budget period. For the constraint budget, the economic criteria for selecting the candidate road is the maximization of NPV/C.

By doing the program analysis one can get the following:

- ❖ Identify the candidate road sections for maintenance;
- ❖ Determine the alternative improvements;
- ❖ Optimization of the program in case of budget constraints; and
- ❖ Obtain the optimized list of projects for the budget period.

2.7.4. Strategic Analysis

This is analysis of the whole network for long term planning under different budget scenarios. The analysis is done on the entire road network for long term budget planning or for optimizing the maintenance strategies. In any case, the whole network is sub-divide in to several the networks according to the key attributes that influence the pavement performance. For example, we can subdivide the network according to three categories: two pavement types (paved, unpaved); three types of traffic groups (high, medium, low); and three pavement conditions (poor, fair, good). In this case the entire network will be divided into 3x3(9) sub networks. Then, a life cycle analysis for 20 years will be carried out say, run the 9 section to see which maintenance option will be appropriate for which network, what is the total budget requirement and if you don't have the enough money we can make optimization.

2.7.5. Research, Policy and Regulation Analysis

HDM may also be used for research purposes such as:

- ❖ Funding policies for competing needs; for example, feeder roads versus main roads;
- ❖ Road User charges for setting up road funds;
- ❖ Impact of axle load limits;
- ❖ Pavement design evaluation;
- ❖ Pavement maintenance and rehabilitation standards;

Figure 2.2 below illustrates the HDM 4 Software Structure - System Structure

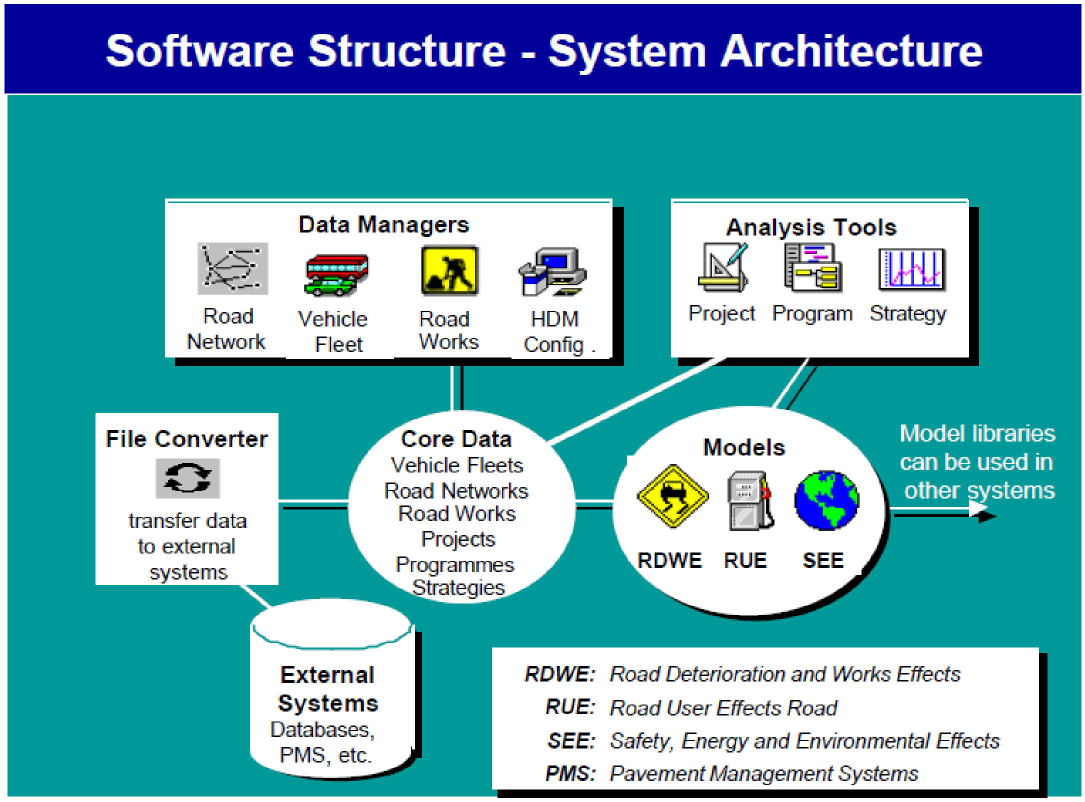


Figure 2. 2*:* HDM-4 software structure

Road maintenance & improvement

- Affects long term pavement performance
- Funding requirements depend on specified maintenance standards & unit costs.

Figure 2.3 below illustrates life cycle pavement conditions under improvement.

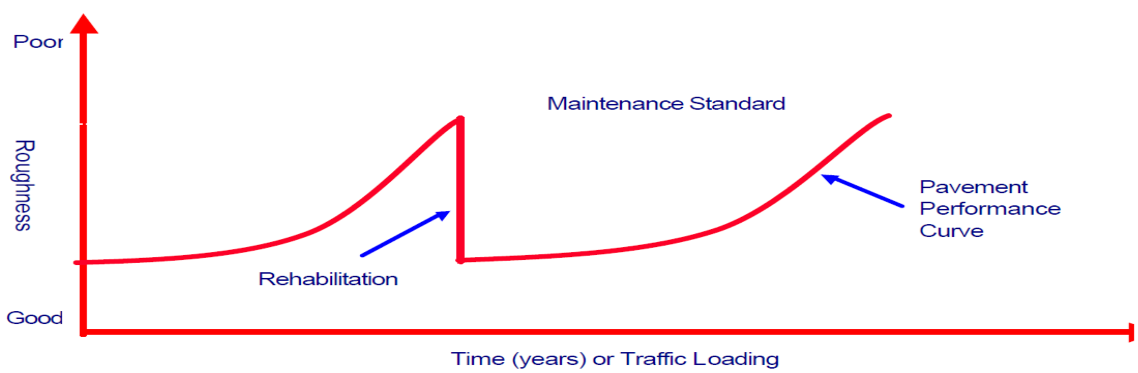


Figure 2. 3: Road Maintenance & Improvement (HDM-4)

2.8. Summary

The problem of project delays can nearly be noticed in every road construction projects. This indicates that this problem didn't receive enough attention by both researchers and responsible authorities. Even if few researches have studied on delay of road construction, these researches were focused mainly on causes of road construction delay. Since, these delays have impact on economic, social and environmental aspects. By taking the above into consideration, this study will mainly focus on the impacts of construction delays on transport cost and benefit in the case of the Hageremariam-Yabelo road project.

2.9. Background of the Case Study of the Project Road

The project road was double surface dressed which was built several years ago and currently serves moderate level of traffic which is expected to rise in the near future when the country commences the use of the Kenyan port of Mombasa once the Isiolo - Moyale road is upgraded to bitumen standard.

The rehabilitation of the project road constitutes mainly the improvement of the horizontal and vertical alignments, the construction of new pavement layers, and placing of asphalt concrete, upgrading of the road furniture and the rehabilitation or widening of the drainage structures. The work also includes the construction of new culverts and the rehabilitation of the existing bridge and erosion control.

The project is funded through the African Development Fund (ADF) which was initially signed on 29th of March, 2011 and work commenced on 11th may, 2011.The project road was envisaged to foster economic integration between Ethiopia and Kenya by providing swift access to border areas and to increase the productivity and trade between the two countries. The road is a component of the Cairo (Egypt) – Cape Town (South Africa) continental network envisaged to directly connect about ten African countries, including Ethiopia. However, the project construction was not speeded up as scheduled because of the hurdles of capacity limitations of contractors and issues related to boundary demarcations with property owners. Figure 2.4 below shows the project location map as provided by Google earth.

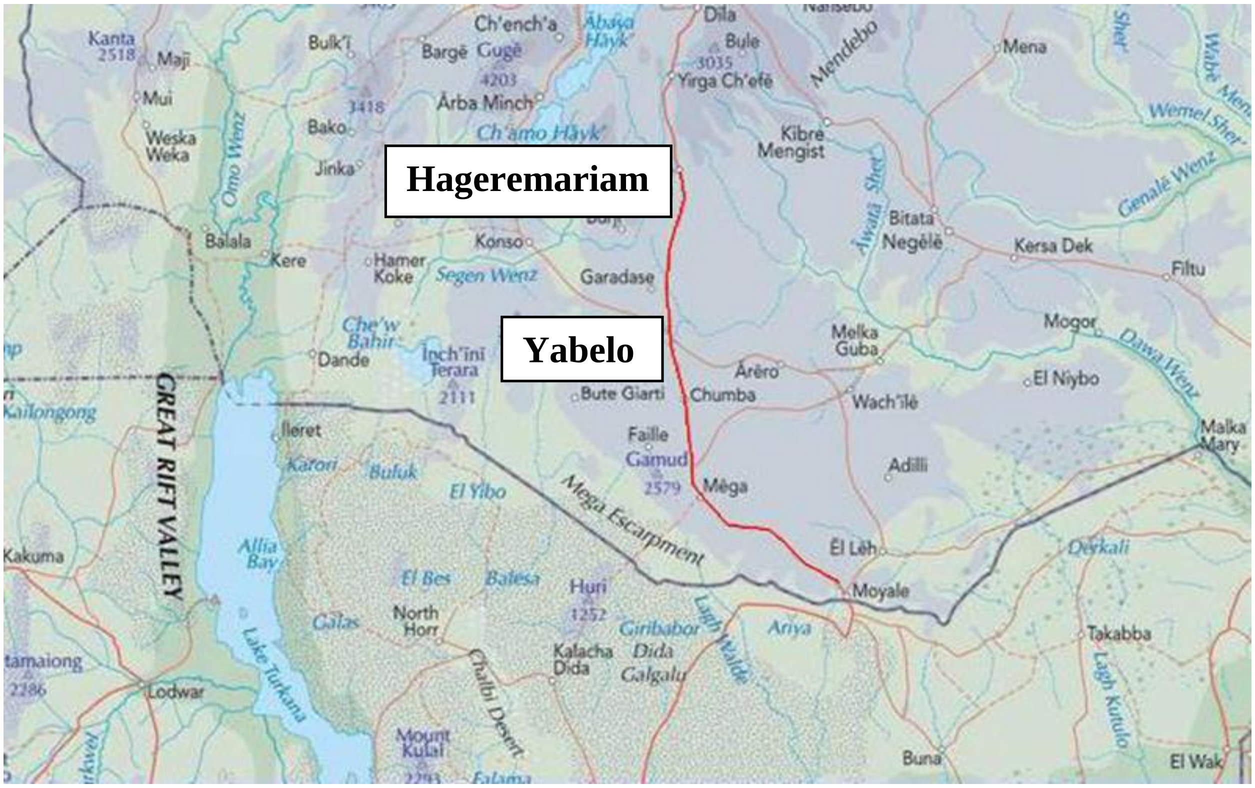


Figure 2.4: Project location map

3. MATERIALS AND METHODOLOGY

3.1. General

This chapter addresses the research approach adopted for capturing the data needed to achieve the aim and objectives of the research. The project road is part of the Addis Ababa - Hawassa - Moyale national trunk road. The average elevation of the area is 1,718 meters above sea level. The average annual temperature is in the range of 14 ^{0}C – 20^{0} C. The mean annual rainfall is 786 mm around Hageremariam and 575 mm around Yabelo.
A study design is a means of providing a plan of framework for data collecting and analysis. The nature of the research topic, its aims, objectives and the resource available largely determine its design. The study data that used are quantitative in nature. Several literatures related to the aims and objectives of this research were reviewed to provide sufficient explanation about the impact of delay and delay-related issues. This further classified the research design into descriptive explanatory case study.
The methodology adopted in carrying out this research were Likert scale and computer software program, Highway Development and Management tool (HDM-4). Likert scale is used for questionnaires analysis to assess the cause and impact of construction delay of subjected road and (HDM-4) is used for determination of additional cost and lost benefit due to delay of road construction.

The study population necessarily for this specific case study was the construction parties that participate on the construction of Hageremariam-Yabelo and vehicle operators along the road segment. The sampling technique that was for selection of samples from population of the road user was simple random sampling techniques.

The samples size were based on population of each samples selected. The number of the construction parties were selected based on the stakeholders involved in Hageremariam-Yabelo project. The road construction project was limited to only one each consultant, contractor and client. The questionnaires were rather simply distributed to five engineers on the client side, to 15 consultants and similarly to 15 contractors. All the responded were returned. The samples were drawn by randomly selected of road users (vehicle operators).Statistical equations were used in order to calculate the sample size of vehicle operator.

(Cochran, 1963) Developed the equation 3.1for population that is large in order to yield a representative sample for proportions.

$$no = \frac{Z^2 pq}{e^2} \tag{3.1}$$

Where:

n_o: is the sample size;

Z^2: is the abscissa of the normal curve that cuts off an area α at the tails (1 - α equals the desired confidence level, e.g., 95%);

e: is the desired level of precision;

p: is the estimated proportion of an attribute that is present in the population; and

q:is 1-p.

Since z=1.96 for 95% level of confidence

p=0.5

q=1-p=0.5

e=0.05

$$no = \frac{(1.96)^2 * 0.5 * 0.5}{(0.05)^2} = 384.16$$

If the population is small, then the sample size can be reduced slightly. The sample size (n_o) can be adjusted using equation 3.2 and the total vehicle operators (the population) ofHageremariam-Yabelo are sixty (60).In total, 52 questionnaires were distributed and 40 were returned.

$$n = \frac{no}{1 + \frac{(no-1)}{N}} \tag{3.2}$$

Where

n:is the sample size; and

N: is the population size;

According to transport minister of Yabelo, the total vehicle operators along the Hageremariam-yabelo road corridor are sixty (60).

$$n = \frac{384.16}{1 + \frac{(384.16 - 1)}{60}} = 52$$

The study used both primary and secondary data's sources for analysis. The primary data is the original information collected for a specific purpose. A questionnaire was used as a primary information collecting tool. Duplicated questionnaires were distributed to road construction parties (client, contractor and consultant) and road users (vehicle operators) that were involved with Hageremariam –Yabelo road project to grasp their perceptions regarding the causes and impacts on Hageremariam-Yabelo road construction delay respectively. The Likert scale analyses were carried out using primary data.

The secondary data were mainly obtained from the Ethiopian Roads Authority. Furthermore, secondary data were collected from pertinent reports and documents. Other relevant data were also collected from government and private offices such as: traffic police, insurance companies; recorded documents; literatures and population, gross domestic product (GDP) growth rates and per capital income from development plans and government documents. Those data were accounted for input data in the HDM-4 software.

3.2. Data Analysis;

3.2.1. Questioner Analysis

Questioner Analysis were analyzed using the Likert psychometric scale with five levels of agreement, punctuated from one (1) to five (5). This scale allows for the calculation of the mean score (statistics method). The mean score (MS) for each factors of the cause and impact of time overrun were computed using the formula that state in equation 3.3.

$$MSi = \frac{\sum (f)(s)}{N} \tag{3.3}$$

Where;

s: represents score given to each cause of delay by the respondents;

f:represents the frequency of responses to each score for each cause of delay and

N: represents total number of responses in the respective cause of delay.

There are different aspects that contribute road construction delays as causes and impacts. Such causes and impacts were selected based on different literatures, project completion reports and interview results.

- ❖ The significant factors that cause road construction delays are client, contractors, consultant, equipment and external related factors. In totally twenty seven (27) factors were selected that were envisaged to influence delay.
- ❖ Similarly nine (9) factors to significantly affect the vehicle operating costs were selected.

Therefore, the degree of significant between different causes and impacts that were selected above were ranked using Mean Score and were used to discuss the significance of causes and impacts on Hageremariam- Yabelo road construction project delay.

The Spearman (rho) rank correlation coefficient is used for measuring the differences in ranking between two groups of respondents scoring for various factors (clients versus consultants, clients versus contractors, and consultants versus contractors).

The Spearman (rho) rank correlation coefficient for any two groups of ranking is given by the following formula.

$$rho = 1 - \frac{6\sum d^2}{N\left(N^2 - 1\right)} \qquad (3.4)$$

Where;

rho: Spearman coefficient;

di: the difference between ranks; and

N: number of subjects or pairs of ranks

The procedures for hypothesis testing are:

- ❖ Define the null hypothesis (H_0) and the alternative hypothesis (H_A);
- ❖ Choose the significance level;
- ❖ Calculate the value of the test statistic, rho (ρcal);
- ❖ Compare the calculated value with a table of the critical values of the test statistic;
- ❖ If the calculated value of the test statistic is less than the critical value from the table, accept the null hypothesis (H_0). If the absolute (calculated) value of the test statistic is greater than or equal to the critical value from the table (Appendix C), reject the null hypothesis (H_0) and accept the alternative hypothesis (H_A).

The questionnaire was designed in respect of both open-ended and close-ended questions. A copy of the final version of the questionnaire is indicated in the Appendix A. The questionnaire contains scale requiring ticked-box responses and open-ended questions. If the respondents have any other further comment or views in respect of each question and additional to the closed questions, there will provide space for their answer. The questions were organized in the form of a priority scaling (1 = not significant, 2 = slightly significant, 3 =moderately significant, 4 = very significant, and 5 = extremely significant).

In this research, ordinal scales were used. Ordinal scale is a ranking or a rating data that normally uses integers in ascending or descending order. The numbers assigned to the agreement or degree of influence (1, 2, 3, 4, 5) neither indicate that the interval between scales are equal nor the absolute quantities. They are merely numerical labels. The following value in table 3.1 was established based on Likert scales.

Table 3. 1: Likert scales that represent degree of significance

Degree of significant	Extremely significant	Very significant	Moderately significant	Slightly significant	Not significant
Scale	5	4	3	2	1

3.2.2. Analysis of Highway Development and Management Tool (HDM-4)

3.2.2.1. Data Input for HDM-4

The data were provided by Southern District Office of the ERA, Traffic Police Office of Borena and Guji zone and the private dealer’s offices. The data’s were classified under following four categories:

- ❖ Road network data;
- ❖ Vehicle Fleet Data;
- ❖ Traffic accident data; and
- ❖ Road works data.

3.2.2.1.1. Road Network Data

The road network data were obtained from the Southern District Office of the ERA and the data included; road inventory data and road geometry, structural evaluation (structural capacity);

functional evaluation (pavement condition and riding quality) and evaluation of pavement material.

Detailed analysis was performed on two road sections of the subject road, rural and town section. Each section was defined based on the number of carriageway after improvement. In this study, both sections have a carriageway width of 6m, no shoulders and auxiliary lanes, medium traffic flow and the surface class is treated with bituminous material. The geometry of each road section includes rise + fall, superelevation, average horizontal curvature, acceleration noise, posted speed limit, speed limit enforcement, and altitude. Rise plus fall is defined as the sum of the absolute values of total vertical rise and total vertical fall of the original ground along the road alignments over the road section in either direction divided by the total section length. This is shown in figure 3.2 and can be calculated using equation 3.5.

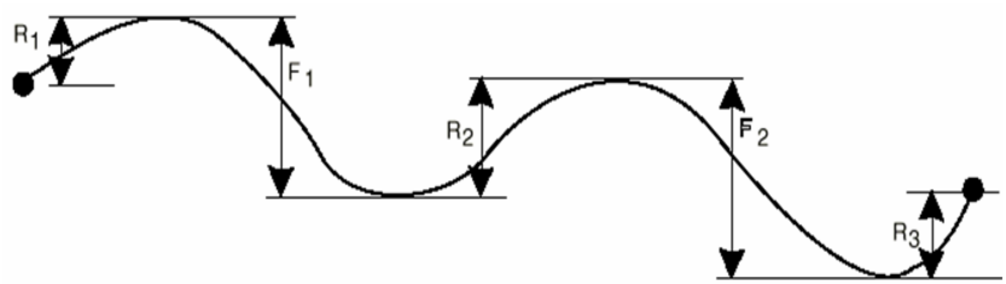


Figure 3. 1: Rise + fall

Source: HDM-4, part D application guide line.

$$Riseplusfdll(\frac{m}{km}) = \frac{R_1 + R_2 + ... + R_n + F_1 + F_2 ...... + F_n}{Length} \tag{3.5}$$

Another geometric characteristic that is used to describe the road section is superelevation and acceleration noise. Acceleration noise provides an indication of the smoothness of traffic flow. Superelevation of a curve section is the vertical distance between the heights of the inner and outer edges of the road divided by the road width.

$$Superelevation(\%) = \frac{100X}{Y} \qquad (3.6)$$

Figure 3. 2: super elevation

Source: HDM-4, part D application guide line.

The horizontal curvature is defined as the weighted average of the curvatures of the curvy sections of the road. This is shown in figure 3.4 and equation 3.7 is used to calculate the curvature.

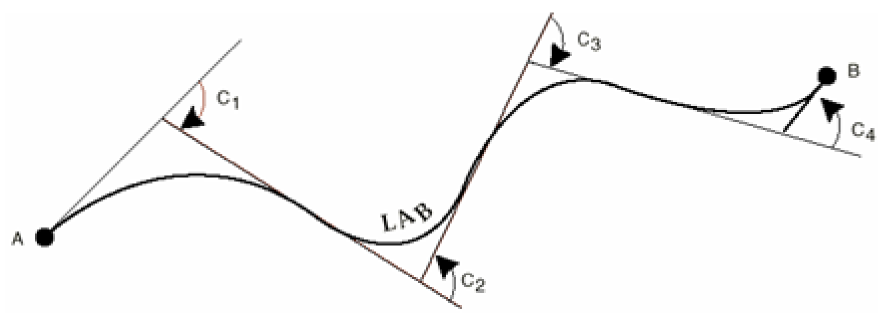


Figure 3. 3: Horizontal Curvature

Source: HDM-4, part D application guide line.

$$Horizontal\,curvature(\frac{\deg}{km}) = \frac{C_1 + C_2 + ... + C_n}{Length} \qquad (3.7)$$

The geometry of the Hageremeriam – Yabelo road is mostly bendy and gently undulating. The default values of geometric parameter are used from HDM-4 Manual, Volume-2.

The altitude is also included within the geometric characteristics. The altitude of Hageremeriam-Yabelo is 1718m.The posted speed limit is specified, 80 kmph for rural section and 60 kmph for town section. Depending on the mean annual rainfall and effective temperature of the area, the climatic zone is classified as sub-humid/tropical.

HDM-4 considers the number of hours of the year (traffic flow period) for which different hourly flows are applicable. The first flow period or the peak period accounts for 87.6 hour of a year with an hourly volume of 0.09. The table 3.2 specifies the percentage of annual traffic dedicated to the particular period categorized by road classification. The roads are classified as inter-urban, commuter and seasonal. Inter-urban roads provide direct routes between the cities. Hageremaria-Yabelo road project is between two towns and within town since road is under inter-urban and commuter road classification. The default flow periods are used for this studies traffic flow. Table 3.2 below shows the traffic description as provided by HDM 4.

Table 3. 2: Hourly traffic flow distribution data

Period	Description	Hrs.per year	Hourly volume (pcse/ln/hr)	percentage of Annual Traffic on each Period		
				Seasonal Road	commuter Road	Inter-Urban Road
1	Peak	87.6	0.09	4.25	3.05	2.17
2	Next to Peak	350.4	0.08	13.24	11.33	7.59
3	Medium flow	613.2	0.07	16.6	16.55	11.64
4	Next to Low	2978.4	0.05	40.32	56.26	40.24
5	Overnight	4730.4	0.03	25.59	12.81	38.36

Source: HDM-4 user guide volume-3

The speed flow characteristics include the ultimate capacity of the road which is the maximum number of vehicles that can pass a point in one hour. Since ultimate capacity (Qult) for two lanes is 1400 passenger car space equivalent per lane per hour (pcse/ln/hr) these values represent Hageremaria-Yabelo speed flow. The free flow capacity (Qo) occurs when traffic interactions are insignificant. Nominal capacity (Qnom) arises when the vehicle speeds begin to decrease at the same rate with the increase in traffic. Jam speed at capacity (Sult) is the vehicle speeds observed during ultimate capacity [World Bank, 2010]. For Hageremaria-Yabelo conditions, 140 (0.1*1400) PCSE/lane/hour is the capacity. When traffic is free flowing, 1260 (0.9*1400) PCSE/lane/hour (is the nominal capacity when the speeds begin to decrease with the increase in traffic) and 25 kilometer/hour is considered the speed that occurs during ultimate capacity. The speed at nominal capacity (Snom) is calculated as 0.85 × minimum free speed. S1, S2, and S3 are the free flow speeds of different vehicle types (Archondo-Callao, 2017).

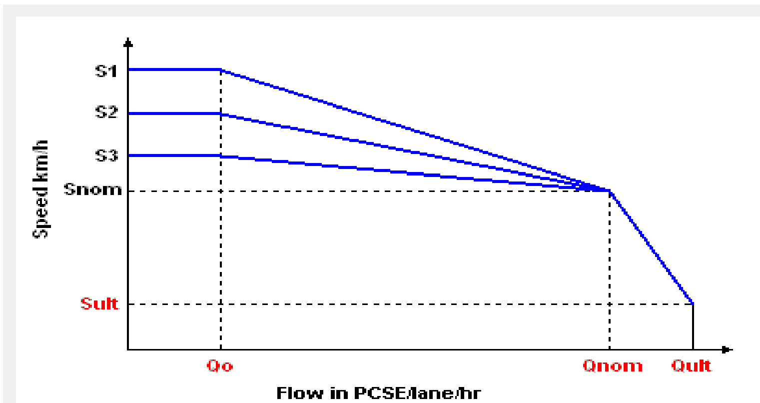


Figure 3. 4: speed flow characteristic

All the road network data that used for this study are listed in table 3.3 below.

Table 3. 3: Road network section aggregate data

Road Networks		
Speed flow pattern	Two lane narrow	
Capacity characteristics		
Ultimate capacity (Qult)	1400	
Free flow capacity (Qo)	140	
Nominal capacity (Qnom)	1260	
Jam speed at capacity(Sult)	25km/hr.	
Definition		
Section	**Rural section**	**Town section**
Length(km)	91	3.5
Traffic flow pattern	inter-urban	Commuter
Speed limit (km/hr.)	80	60
Carriageway width(m)	6	
Shoulder width(m)	0	
Flow direction	Two-way	
Surface class	Bituminous	
Road class	Trunk or primary	
Climate zone	Sub-humid/ tropical	
Geometry		
Rise+Fall(m/km)	15	
Number of rise +falls(No/km)	2	
Super elevation (%)	3	
Average horizontal curvature(deg/km)	75	
Acceleration noise (m/s2)	0.1	
Speed reduction factor	1	
Speed limit enforcement	1	
Altitude(m)	1718	
Pavement		
Surfacing		
most recent surfacing thickness(mm)	50	
previous/old surfacing thickness(mm)	100	
previous work		
last reconstruction or new construction	2000	
last rehabilitation (overlay)	2005	
last resurfacing	2010	
last preventive treatment	2010	

Study road condition

In order to measure the problem condition of a pavement, different testing techniques were used by ERA. These tests help to identify distresses, degree of cracking as well as the roughness of the surface to determine the IRI rating for each section of roadway. Table 3.4 below presents the rating range for each evaluation criteria according to the ERA PMS manual.

Table 3. 4: Road distress evaluation criteria according to the ERA PMS manual

Distress	**Data range describing each problem category – paved roads**				
	Severe	Warning	Moderate	Isolated	None
Condition Index (CI) %	0-35%	35-50%	50-70%	70-85%	85%
NARROW Cracks (%)	>15%	10-14%	5-9%	1-4%	0%
WIDE Cracks (%)	>15%	10-14%	5-9%	1-4%	0%
Ravelling (%)	>15%	10-14%	5-9%	1-4%	0%
Potholes (No / km)	>15	10-14	5-9	1-4	0
Roughness (IRI)	>6.5 IRI	4.5-6.5 IRI	3-4.5 IRI	2-3 IRI	< 2 IRI
Rut Depth (mm)	> 25 mm	15 – 25 mm	5 – 15 mm	2 – 5 mm	< 2 mm
Mean Texture Depth (mm)	< 0.3 mm	0.3-0.7 mm	0.7 – 1.0 mm	1 – 1.5 mm	1.5 mm
Edge Break (m2 / km)	>300m2	100-300 m2	10-100 m2	0-10 m2	0 m2
Side Drainage Condition (1-5)	4	3	2	1	0

Source: (Ethiopian Road Autority, 2010)

Data collected from the South District ERA Authority through interviews and road condition surveys result was conducted by the ERA. It was considered relevant for this thesis. The previous road condition data for study road at 2010 are listed in table 3.5.

Table 3. 5: the study road previous distress value.

Hagermariam-Yabelo road condition at 2010	
Distress	**Value**
Condition Index (CI %)	2.00
Narrow Crack (%)	18.00
Wide Crack (%)	48.00
Raveling (%)	90.00
Pothole (No/km)	438.00
Roughness(IRI)	6.10
Rut Depth (mm)	13.13
Mean Texture Depth (mm)	1.45
Edge Break (m2/km)	63.12

Source: (Ethiopian Road Autority, 2010)

3.2.2.1.2. Vehicle Fleet Data

The vehicle fleet data included the collection of basic vehicle, physical and utilization characteristics. The vehicle classification incorporates: passenger cars, land rover, small bus, large bus, small truck, medium truck, heavy truck and truck trailer. These vehicles were classified by the ERA and were selected in this study. The physical characteristics include passenger car space equivalent which accounts for the relative space taken up by the vehicle, the number of wheels per vehicle and the number of axles per vehicle. The default values in HDM-4 were used. The utilization characteristics include annual kilometer driven, annual working hours, service life of the vehicle, percent of the time a vehicle is driven for private use, average number of passenger per vehicle, and percent of the time passengers use the vehicle for work-related trips. The utilization characteristics are used the default values since these values represented Hageremariam-Yabelo vehicle fleet conditions.

Financial unit costs for each vehicle fleet include prices of new vehicle, tire, fuel and lubricants. In addition working hour, crew wages, overhead costs and interest rate were inputted. The annual interest rate provided by the Commercial Bank of Ethiopian is 11%.The financial unit costs was converted into economic costs multiplying by 0.85, indicating that 15% of the costs are transfer payments mainly taxes. The financial unit cost of each vehicle type is given in table 3.6.

Table 3. 6: Resource unit cost of each type of vehicle

vehicle Type		**Price (2016/17) Birr**							
		Engine size	One new vehicle (Birr)	one tyre (birr)	One liter fuel (Birr)	Fuel type	one liter lubricant (Birr)	One working hour in work shop (Birr)	One working hour for crew (Birr)
Car	Toyota Corolla(sudan)*	1300	1,378,000	2200	15.11	petrol	90.16	60.36	40.12
Large car	Misubishi(Pajaro) *	4200	4,594,000	4800	17.5	diesel	80.23	52.31	39.79
small bus	Misubishi**	Dawo	1,874,000	8500	17.5	diesel	80.23	40.33	29.9
Large bus	Iveco	150 E18	2,650,000	15800	17.5	diesel	80.23	54.49	48.35
Pick-up	Toyota (D/CAB)	3000	2,387,000	3500	15.11	petrol	90.16	52.31	43.2
Small truck	mitsubishi (70quintals)	8.25-20140PR	1,860,000	8100	17.5	diesel	80.23	29.55	28.13
Medium truck	Iveco (246quintals)	AT380T38H	3,150,000	15800	17.5	diesel	80.23	54.16	42.59
Large truck	Scania (400 quintal)	360HP Turbo	3,400,000	16000	17.5	diesel	80.23	48.55	51.62
Truck and Trailer	M. Truck +trailer(170+235q)	360HP Turbo	4,281,727	17700	17.5	diesel	80.23	33.52	49.02

Source: Ethiopia Trade Commission, 2016/2017

The time value includes passenger working time and passenger non-working time cost. Passenger working time (Birr per hour) includes the delay cost that occurs when performing work activities while passenger non-working time include delay costs that occur when performing non-work activities like visiting families. The time values for all motor vehicle passengers were estimated using per capital income (gross domestic product of Ethiopia during a year divided by the population size of Ethiopia). The time value for one hour per passenger is calculated by dividing the average annual wage of the passenger by annual working hours. Thus, the annual average wage per person in Ethiopia is Birr 23,196.42birr/year and the annual working hours is 2,532hr/year. According to Proposed SASEC Road Connectivity Investment Program, the estimated wages (Birr/hour) were multiplied by 0.33 in the case of working time and by 0.30 in the case of non-working time.

Freight time cost is reduced cargo delay which can be considered as potential source of benefits. Freight in transit is capital and reduction in travel time can therefore be translated into saving in inventory costs. Thus, the saving in time can be valued by the price of capital that is rate of interest. However, it is difficult to value the cost of freight time delays especially in Ethiopia. Therefore, it was ignored in this study. The general vehicle data for analysis by the HDM-4 are summarized in table 3.6 below. Other vehicle type data are included in Appendix B.

Table 3. 7: vehicle fleet data for representative vehicles.

vehicle Fleets			
passenger car			
basic characteristics			
Physical		Tires	
passenger car space Equivalence factor(PCSE)	1	tire type	radial-ply
number of wheels per vehicle	4	base number of recaps per tire carcass	1.3
number of axles per vehicle	2	retread cost as a percentage of tire cost	15%
Utilization			
annual km driven	23000	percentage of vehicle use on private trips	100%
working hours	550	Average number of passenger per vehicle	1 persons

vehicle Fleets			
passenger car			
Average vehicle service	10	percentage of passengers trips which are work related	75%
Loading			
ESALF	0	operating weight	1.2 tons
Economic unit costs			
vehicle resources			
new vehicle	117130	Maintenance labor (birr/hr.)	51.306
Replacement tire (birr/tire)	1870	Crew wages (birr/hr.)	34.102
fuel(birr/liter)	12.844	Annual overhead	27560
lubricating oil (birr/liter)	76.636	Annual interest (%)	15%
Time value			
passenger working time (birr)	2.570	Cargo (birr/hr.)	0
Passenger non-working time (birr/hr.)	2.336		

3.2.2.1.3. Traffic Data

i. Traffic volume and composition

Traffic volume is a critical input data in HDM-4 analyses. On interurban roads, transport costs are dominated by vehicle operating costs which are proportional to the traffic volume. In addition, vehicle volumes influence the rate of pavement deterioration. From ERA 2010 traffic count results, the average AADT of three cycle count (February 1-7, July 1-7 and November 1-7) was 737 vehicles per day and the composition of each vehicle type are presented in table 3.8 below.

Table3. 8: Vehicle composition on Hageremariam - Yabelo road

Motorized vehicle composition (2010)										
Vehicle type	Car		Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck Trailer	Total
Composition (%)	1.54	13.6	22.4	12.35	24.15	12.03	8.82	5.11	100.00

Source: (Ethiopian Road Autority, 2010)

ii. Traffic growth r ates

Estabilishment of traffic growth rate for analysis is a very important task. This is because, it will not only influence the road user effect (RUE) but also will influence capacity improvements and other intervetion alternatives.The traffic growth rate is usually established using historical traffic trendes, national or regional economic trend such as growth in GDP, vehicle ownership trends, or combination. In this study, GDP and population growth rates were used to establish traffic growth rates; specifically by taking the average of the last 10 years. Table 3.9 below shows the established traffic growth rates.

Table 3. 9: population, GDP and corresponding growth rates (2010-2020)

Year	**Population growth**	**GDP growth**	**Average Growth rate**
2010	2.7	10.6	6.65
2011	2.7	11.4	7.05
2012	2.7	8.7	5.7
2013	2.7	9.9	6.3
2014	2.7	10.3	6.5
2015	2.6	10.2	6.4
2016	2.6	6.5	4.55
2017	2.5	7.5	5.00
2018	2.5	7.5	5.00
2019	2.5	7.55	5.03
2020	2.05	11	6.525

Source: Commercial Bank of Ethiopia and World Population, 2017

The utilized traffic growth rates for the periods: from 2021-2026, 2026-2031 and beyond 2031 were 7.0%, 7.3% and again 7% respectively.

iii. Generated traffic

The estimation of generated traffic is related to the reduction in transport costs resulting from the road improvements. According to the World Bank Technical paper, there are big differences within and between countries in the price of transport. These disparities suggest that in many parts of the world there may be interventions that could lower costs. The per kilometer cost is always likely to be higher for rural transport than for national, regional or urban transport because of lower demand, shorter distances, smaller vehicles, and poorer roads.

$$\%\ \text{Generate traffic} = \%\ \text{of travel time cost reduction} * \text{Elasticsity} \tag{3.8}$$

Generally, traffic generation is estimated in terms of percent of existing/normal traffic. This percentage is usually determined by taking the product of the likely transport costs reduction and the additional transport demand /cost reduction elasticity. According to Ghana manual of project evaluation criteria, it can be mentioned that a 50% and 40% travel cost reduction for freight and passenger transportation by assuming a 0.3 and 0.6 elasticity for freight and passenger transportation respectively. As a result, 15% and 25% generated traffic has been accounted for freight and passengers transportation.

iv. Estimation of other benefits

Improved accessibility within the influence area of the study road will have a favorable impact on many socio-economic sectors such as health and education.

Impact on health: - Improved road access to the study zone will ease both the access to medical personnel to this zone and that of the population living in this zone to the health care services available in the nearest towns. Theoretically it is possible to estimate the benefits accruing from the resulting improvement of the health condition of the population in terms of lives saved, number of days of hospitalization avoided, number of days of sickness non availability avoided. Since supporting data such as health condition statistics in the zone and costs of health care services are not easy to collect, it will be very difficult to quantify the savings accruing from the improvement of the health condition of the concerned population. However, any favorable impact on health condition should be identified in order to supplement the list of non-quantified benefits accruing from this project road.

- ❖ **Impact on education**: - Improved road access to the study zone will facilitate the mobility of educational personnel within the project area and students to schools. It is of course difficult to quantify the benefits generated as the result of improved level of education within the influence zone of the study road. However, any favorable impact on educational access should be identified in order to supplement the list of non-quantified benefits accruing from the project road.

v. Road accidents data

In HDM-4, road safety effects are analyzed according to the following accident severity/types;

- ❖ **Fatal: -**an accident is considered as fatal if the death occurs within a fixed period following to accident. In Ethiopia, 30 days following the accident.
- ❖ **Injury: -**an accident resulted in injury but not fatality.
- ❖ **Property only Damage: -**this is an accident that resulted in property damage, but neither in injury nor in fatality. Accident data were acquired from the West Gujie and Borna Zones police office records are listed in table 3.10.

Table 3. 10 : Total accident data on the study road

Accident type	**Hageremariam**	**Dugdadawa**	**Yabelo**	**Total**
Fatality	11	3	8	22
Injury	0	0	0	0
Serious injury	5	4	7	16
Light injury	6	5	8	19
PDO	2	1	1	4
Total No of accident	23	13	23	59
Estimated cost for PD(ETB)	3,647,640	3,639,060	1,707,100	8,993,800

Source: woreda traffic police accident record book.

The primary data required for accident analysis in this study were; traffic volume, length of the road sections, accident rates and unit cost of accidents. Unit cost of accidents can be expressed by accident type (fatal, injury, property damage) or a general cost. Accidents data were accounted for the study by collecting the necessary costs from insurance companies. Accordingly, fatality, injury and property damage costs were collected, that are: 42,000, 70,000 and 200,000 ETB respectively.

Accident rate:

Accident rates were determined using data from the West Gujiand Borna zone Police office records. Accident rates in 'number per 100 million vehicle kilometers' were determined using equation 3.9 for each category of accidents (fatal; injury; and property damages).The term accident rate is defined as the average number of reported accidents per year, measured over a period of time (for 5 calendar years)and divided by the exposure(HDM-4 application guideline).

$$ACCRATE = \frac{ACCYR}{EXPOSURE} \tag{3.9}$$

Where;

ACCRATE: accident rate;

ACCYR: number of accident per year and

EXPOSURE: annual exposure to accidents.

The annual exposure of road section in terms of one hundred million vehicles was estimated using the equation 3.10 below.

$$Exposure = \frac{365 \times AADT \times L}{10^8} \tag{3.10}$$

Exposure= $(365*737*94.5)/10^8$

=0.25

Respective accident rate and corresponding unit costs used on the 94.5 km road are presented in table 3.11.

Table 3. 11: Accident input data

	Accident type		
	Fatal	**Injury**	**Property damage**
No of accidents	22	35	4
Length (km)	94.5		
AADT (veh/day)	737		
Accident rate	86.55	137.69	15.74
Unit cost (ETB)	42,000	70,000	200,000

Source: Traffic police accident record book and Insurance company accident cost

3.2.2.1.4 Road works Data

Road works refer to the targets or levels of condition and response that a road administration aims to achieve. Road agencies set up different standards that can be applied in practical situation in order to meet specific objectives which are related to functional characteristics of the road network system. Thus, the work effect is used to estimate road agency resource needs for road preservation and development. These needs are expressed in terms of the physical quantities and the monetary costs of works to be undertaken. Road agency costs are used together with road user costs, social and environmental costs to determine the economic viability of different road investment options and strategies. The road work standard that applied on Hageremariam-Yabelo road are:

- Maintenance and
- Improvement

A. **Maintenance work for base case**:

The maintenance activity at base case implemented every year for the road to give service without any improvement work. Routine maintenance standards of Hageremariam-Yabelo road comprises four work activities; Patching, Crack Sealing, Edge-Repair and drainage (repairing erosion damage with selected fill, culvert cleaning, ditch cleaning and grass cutting) each of which is condition responsive but drainage is schedule. Table 3.12 presents the detail of work item.

Table 3.12: Detail of routine maintenance for base case.

General					
Work item					
Short code of for work item		H-Y RM			
Type of operation		Patching	Crack sealing	Edge-repair	Drainage
Code		PACH	CRS	EDGRE	DRA
Intervention type		Responsive			Scheduled
Interventions					
Responsive criteria		Severely damage area>=5%	Wide structural crack>=15%	Edge break>=10m2/km	
		Pothole>=25no/km			
Time Interval		1 year			1 year
Last year		2099			2099
AADT	Max	1,00,000			
	Min	0			
Maximum roughness		16	12.5	16	
Maximum quantity		5000			
Cost	Economic	134.31	42.38	161.73	42,500
	Finical	158.01	49.86	190.28	50,000
Effect the percentage of distress repair (100%)		Sever Damage	Transverse	Edge-repair	
			Thermal cracking		
			Wide structural crack		

B. Maintenance work after improvement

Each alternative includes a routine maintenance standard providing condition schedule pavement works effective from the year following completion of the widening works. This maintenance standard includes the following work items: Patching, Crack sealing and Drainage work. The intervention type is scheduled which is apply every one year.

C. Improvement works

Hageremariam-Yabelo road rehabilitation project aim to provide addition capacity and comprises the following improvement standard;

For Rural section

- ❖ Widening of carriageway for 3 and 5 year duration

- ❖ Re-surfacing the existing carriageway

For Town section

- ❖ Lane addition for 3 and 5 year duration
- ❖ Horizontal and vertical realignment along widening for 3 and 5 year duration
- ❖ Re-surfacing the existing carriageway

i. Widening improvement and Realignment

In rehabilitation of Hageremariam-Yabelo road project for widening, horizontal and vertical realignment are required but no need realignment for existing carriageway. It means the realignment work is performed only on the lane addition (town section). Cut and Fill earthworks as necessary to accommodate the new 7.0 m wide carriageway and 1.50m wide shoulders on either side (for rural section).The road section have incorporate dual carriageway for the town that had expanded since new developments are being constructed along the international Trunk road linking Ethiopia with Kenya. The road section having dual carriageway are;

- ❖ Hageremariam-yabelo from 0+00 to1+200(1200m)
- ❖ Finchawa from 27+525 to 28+525(1000)
- ❖ Surupa from60+425 to 60+825(400m)
- ❖ Harobake from 79+575 to 79+975 (400m)
- ❖ Yabelo from94+00 to 94+50 (500m)

ii. **Re-surfacing the existing carriageway**

Rehabilitation of Hageremariam-Yabelo 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 defect that have occurred mainly due to poor construction quality and bituminous material being too rich or brittle, resurface the existing pavement by 50mm asphalt concrete.

Estimated unit cost for improvement and maintenance of the road

In respect of agency costs, infrastructure costs for improvement and maintenance costs of the Hageremariam-Yabelo road were estimated based on information from relevant sources such as on engineer’s estimate, prevalent market rates, data from recently awarded projects, quotations from vendors

The study road project delay of two year since the construction cost increase. So, in case of with delay alternative the unit cost of construction is included inflation rate. According to International Monetary Fund, World Economic Outlook Database, Inflation Rate in Ethiopia averaged 16.23 percent from 2006 until 2018.So, this road project construction cost consider 16.23% inflation rate. (International Monetary Fund, April 2015)**.**

ERA Cost Estimates

Routine Maintenance -- Paved = Birr 200,000 per km

Unpaved = Birr 150,000 per km

Improvement = Between Birr 7, 000,000 up to Birr 15,000,000 per km.

The following unit costs were estimated:

- ❖ Partial widening in rural section having construction period 3 year (without delay)= Birr 12,750,000 per km;
- ❖ Partial widening in rural section having construction period 5 year (with delay)= Birr 17,403,750 per km;
- ❖ For lane addition in town section having construction period 3 year (without delay)=Birr 17,450,000 per km;
- ❖ For lane addition in town section having construction period 5 year (with delay) 23,205,000 per km.

Details of the improvement standard are given under table 3.13 as example and the rests improvement; partial widening of rural section for 5 year duration, lane addition of town section for 3 duration, realignment along widening for 3 year duration, lane addition of town section for 5 duration, realignment along widening for 5 year duration are present in Appendix B.

Table 3. 13: Detail of improvement standard for rural section 3 year duration

<table>
<tr><th colspan="4">road improvement for rural section</th></tr>
<tr><th colspan="4">General</th></tr>
<tr><td>Name</td><td colspan="3">H-Y partial widening with 3yr duration</td></tr>
<tr><td>Short code</td><td colspan="3">H-Y pw</td></tr>
<tr><td>Existing Surface Class</td><td colspan="3">Bituminous</td></tr>
<tr><td>Improvement type</td><td colspan="3">Partial Widening</td></tr>
<tr><td>Duration of work</td><td colspan="3">3 year</td></tr>
<tr><td>Intervention type</td><td colspan="3">Scheduled</td></tr>
<tr><th colspan="4">Design</th></tr>
<tr><td>Speed-Flow type</td><td colspan="3">two lane standard</td></tr>
<tr><td>Road Class</td><td colspan="3">Primary or trunk</td></tr>
<tr><td>New pavement type</td><td colspan="3">Asphalt Mix on Granular</td></tr>
<tr><td>Increasing carriageway (m)</td><td colspan="3">1</td></tr>
<tr><th colspan="4">Intervention</th></tr>
<tr><td>Start</td><td colspan="3">2011</td></tr>
<tr><td>Last application year</td><td colspan="3">2099</td></tr>
<tr><th colspan="4">Cost</th></tr>
<tr><td rowspan="2">unit cost (per km)</td><td colspan="2">financial</td><td>Economical</td></tr>
<tr><td colspan="2">15,000,000</td><td>12,750,000</td></tr>
<tr><td rowspan="2">% of cost (Each year of the work period)</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>20</td><td>50</td><td>30</td></tr>
<tr><td>salvage value</td><td colspan="3">10%</td></tr>
<tr><td>preparatory unit cost (ETB)</td><td colspan="2">financial</td><td>Economical</td></tr>
<tr><td>re-surfacing existing carriageway(m2)</td><td colspan="2">114.11</td><td>97</td></tr>
<tr><td>Patching(m2)</td><td colspan="2">158.01</td><td>134.309</td></tr>
<tr><td>crack sealing(m2)</td><td colspan="2">49.86</td><td>42.381</td></tr>
<tr><td>Edge-repair (m2)</td><td colspan="2">190.26</td><td>161.738</td></tr>
<tr><th colspan="4">Pavement</th></tr>
<tr><td>surface material</td><td colspan="3">Asphaltic concert</td></tr>
<tr><td>surface structure number</td><td colspan="3">5</td></tr>
<tr><td>surface thickness(mm)</td><td colspan="3">50</td></tr>
<tr><td>Relative compaction (%)</td><td colspan="3">97</td></tr>
<tr><th colspan="4">Geometry</th></tr>
<tr><td>adral(m/s2)</td><td colspan="3">0.1</td></tr>
<tr><td>speed limit(km/hr.</td><td colspan="3">80</td></tr>
</table>

<table>
<tr><th colspan="3">road improvement for rural section</th></tr>
<tr><td>speed limit enforcement</td><td colspan="2">1</td></tr>
<tr><td rowspan="3">speed reduction factor</td><td>XNMT</td><td>1</td></tr>
<tr><td>XMT</td><td>1</td></tr>
<tr><td>Road side friction</td><td>1</td></tr>
<tr><th colspan="3">Effect</th></tr>
<tr><td>Traffic flow pattern</td><td colspan="2">inter-urban</td></tr>
<tr><td>Roughness (m/km)</td><td colspan="2">2.2</td></tr>
<tr><td>mean rut depth (mm)</td><td colspan="2">0</td></tr>
<tr><td>skid resistance (SCRIM at 50km/h)</td><td colspan="2">0.55</td></tr>
<tr><td>surface Texture depth(mm)</td><td colspan="2">0.7</td></tr>
</table>

3.2.2.1.5. Project Alternatives

Normally, the road is constructed to reduce costs and increase benefits derived from reduced user costs and improvements to social-economic services. The economic appraisal of road projects is essentially a comparison of transportation cost components calculated for at least two alternatives referred to as 'Do Minimum' or 'Without Project" and 'Do Something' or 'With Project Alternative'. This case study presents the economic analysis of the rehabilitated Hageremariam-Yabelo road with delay and without delay. The objective is therefore to examine and demonstrate the impact of construction delay on total transport cost and benefits. By utilizing the HDM-4 software, the input data were analyzed under two alternatives; Base Case and Project Case alternatives that correspond to without delay and with delay of the rehabilitation. An opportunity cost of 10.23 % was used as the discount rate to convert all costs and benefits to present values.

Detailed analyses were performed on the two road sections; one is the town section with 3.5km and other one is the rural road section with a total length of 91km.

The case study considers three project alternatives as defined:

Alternative 0: base case

Alternative 1: rehabilitation without delay, constructed between 2011-2014

Alternative 2: rehabilitation with delay, constructed between 2011-2016

3.6.2.2. Project Analysis

HDM-4 Tool is computer software developed by the World Bank. HDM-4 is a decision making tool for verifying the engineering and economic viability of investments in road projects. As mentioned in literature part, the major functions of HDM 4 are: Strategy Analysis, Program Analysis and Project Analysis. The analysis of the data in this case project was performed under the function of the project analysis.

Project analysis deals with a single road project analysis, may be by dividing into different sections if differences between sections exist in terms of economic activity, altitude, traffic and alignment. Project analysis allows aggregating of several road works or more than one road sections under one agreement. Project title, road network and vehicle fleet information are required to create a project. To begin a project analysis, work standards, general traffic composition and growth rates, extra benefits, and costs must be specified.

In the case of this study, project analysis was conducted in respect of road agency costs and road user cost and benefit. Agency costs include the capital costs of road construction and the total costs that are acquired depending on the standards of maintenance and improvement applied to road networks. So, the HDM-4 Software was utilized to analyze the data and generate pertinent parameters to understand the additional costs and the loss benefits considering the two alternative of improvement with delay and without delay of the road construction project. If the project were completed on time, the benefits would have emanated earlier; however, the project was delayed by two years and the generation of benefits was delayed accordingly.

For each improvement alternative, the following were compared with and without delay of the project:

- Road agency costs
- Road user costs and
- Road user costs saving

An analysis period 23 and 25 years with construction period of 3 years in the case of without delay and 5 years in the case of delay were used respectively. A discount rate of 10.23% was considered which is commonly used on ERA projects.

Project analysis that used to conduct the impact of road construction delay on total transport cost and benefit; the benefit are only the vehicle operating cost saving, travel time cost saving and accident reduction cost saving. Since, those benefits are easily quantified in the monitory term which is the quantified benefit but other non-quantified benefit is not expressed on the monitory term for this specific study work.

Analysis conducted firstly by defines the section, vehicle fleet and road work standard that used to perform project analysis for this study road. Such analysis activity are described below step by step.

A. Define Road Network

Define the road network that contains the road classes will be evaluated. In the road network below, two (2) possible road classes were defined in terms of surface type, traffic load and condition .Figure 3.5 below shows the road network definition template under HDM 4.

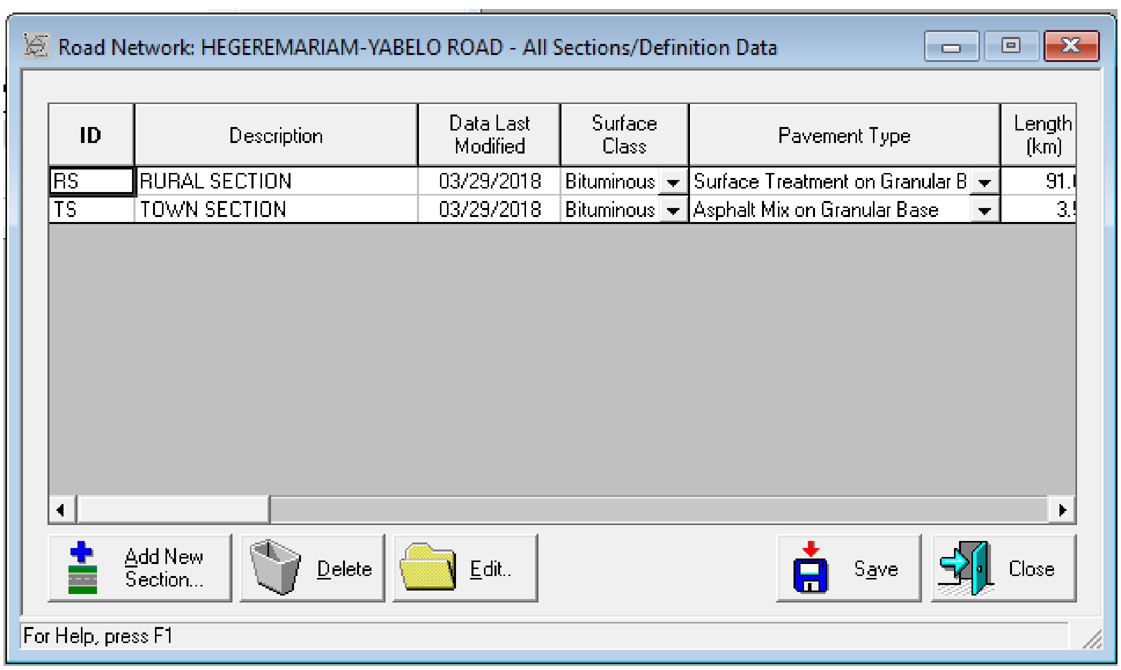
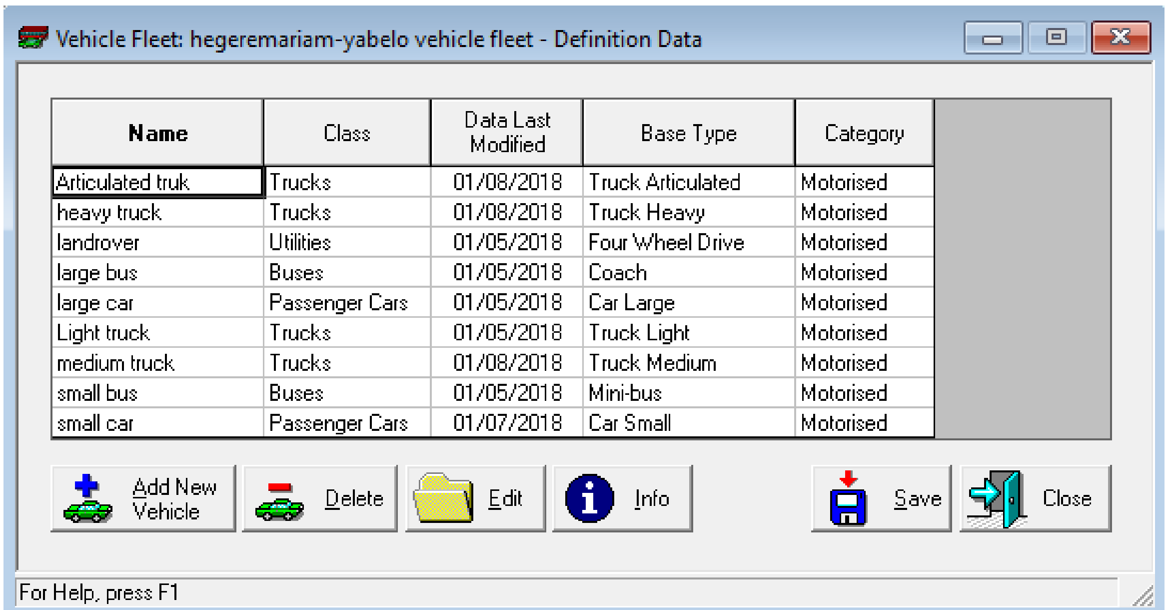


Figure 3. 5: Road network definition data

B. Define Vehicle Fleet

Roads are provided to enable their use by vehicles and the representation of the vehicles is a key data requirement for HDM-4. The vehicle fleet folder provides facilities for the storage and retrieval of vehicle fleet details used for calculating vehicle speeds, operating costs, travel time cost and other vehicle effects. For this study road the vehicle fleet consist of motorized vehicle classified under eight (8) vehicle types. Typically, the same vehicle fleet is defined for all roads sections. Figure 3.6, 3.7, 3.8, 3.9, and 3.10 show the HDM-4 input template in respect of Hageremariam - Yabelo road vehicle definition Data; vehicle attributes/definition screen; vehicle attributes/basic characteristics screen; vehicles attributes/economic unit cost screen; and vehicle attributes/ financial unit cost screen respectively.



Name	Class	Data Last Modified	Base Type	Category
Articulated truk	Trucks	01/08/2018	Truck Articulated	Motorised
heavy truck	Trucks	01/08/2018	Truck Heavy	Motorised
landrover	Utilities	01/05/2018	Four Wheel Drive	Motorised
large bus	Buses	01/05/2018	Coach	Motorised
large car	Passenger Cars	01/05/2018	Car Large	Motorised
Light truck	Trucks	01/05/2018	Truck Light	Motorised
medium truck	Trucks	01/08/2018	Truck Medium	Motorised
small bus	Buses	01/05/2018	Mini-bus	Motorised
small car	Passenger Cars	01/07/2018	Car Small	Motorised

Figure 3. 6 :Hageremaiam-Yabelo Vehicle fleet definition data

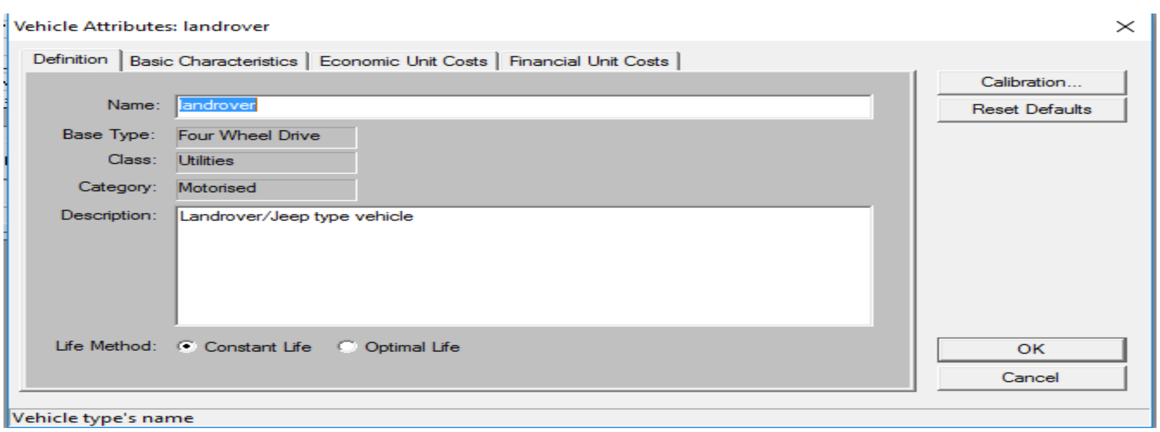


Figure 3. 7: Vehicle attributes/Definition screen

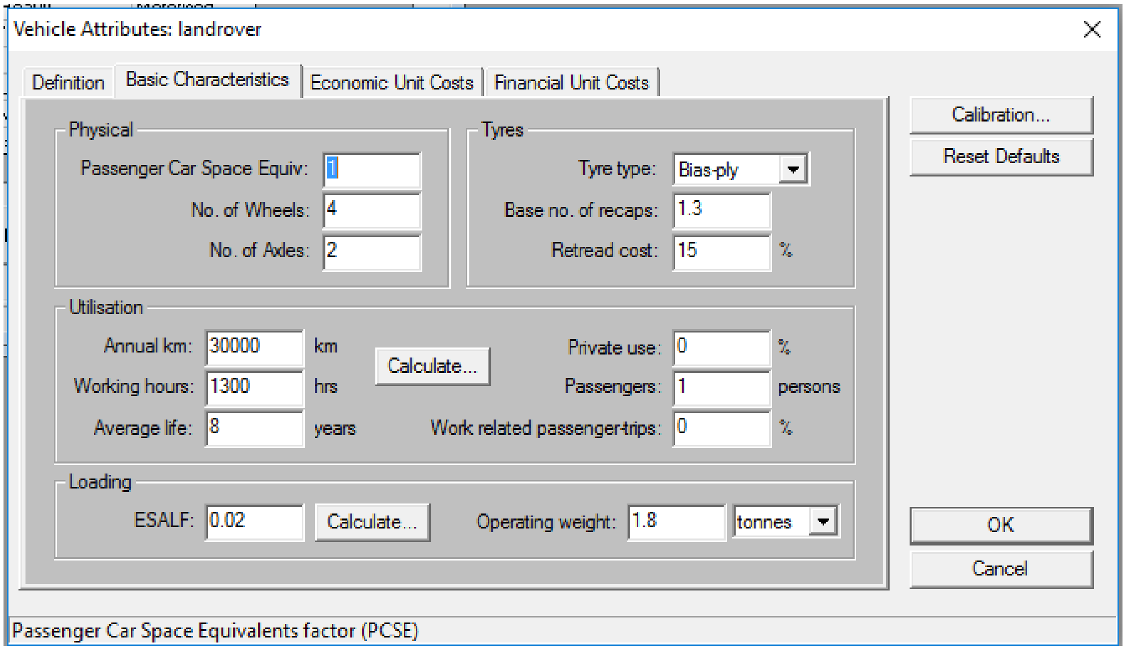


Figure 3. 8: Vehicle attributes/Basic characteristics screen

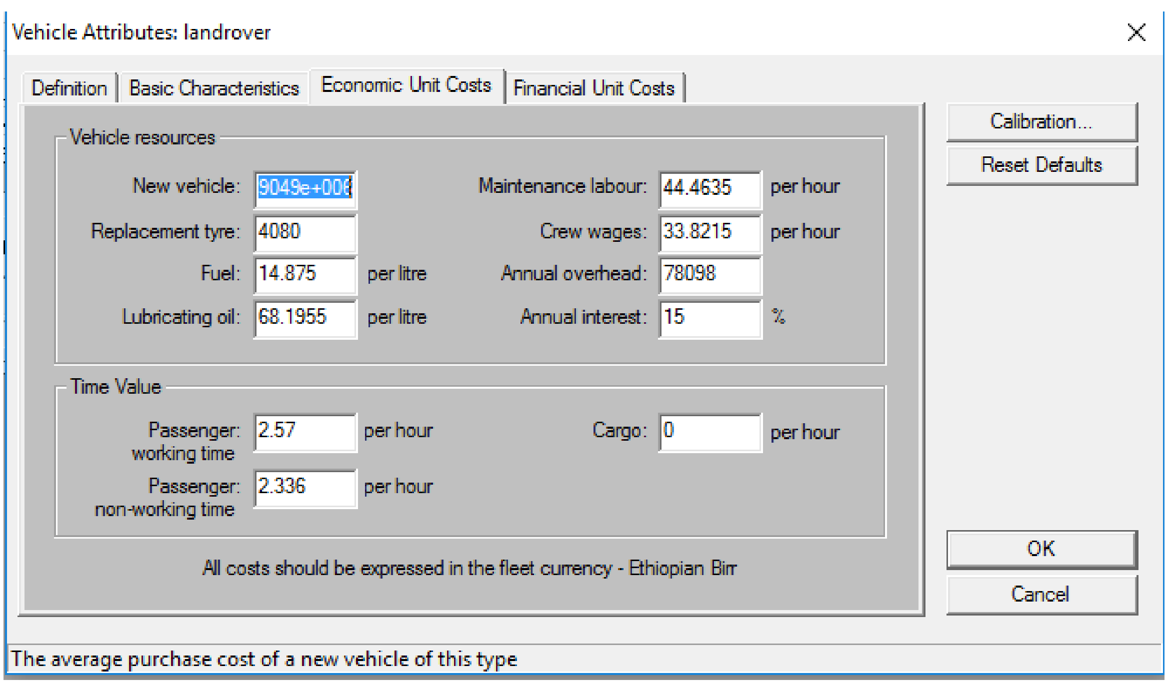


Figure 3. 9: Vehicle attributes/Economic unit cost screen

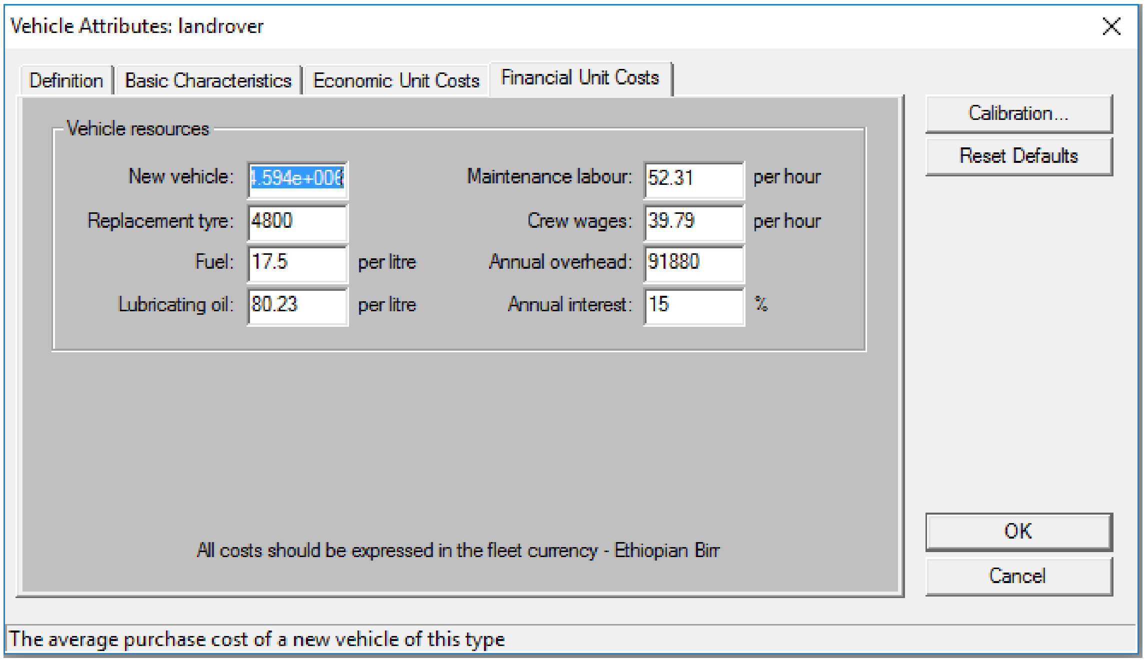


Figure 3. 10: Vehicle attributes/ finical unit cost screen

C. Road Works Analysis

Under the road works analysis alternatives, maintenance and improvement work were assigned. This case study presents the economic analysis of alternative rehabilitation standard for 94.5-km road. In defining the maintenance standards to be used in the evaluation; first, define different maintenance standards, and then define the possible capital road works that could be executed, scheduling these different types of road work in different calendar years. The assigned work items: patching, crack sealing, edge-repair and drainage. In the case of improvement standard, three standards were defined as an alternative in the analysis of this project. Table 3.14 presents' details of road works standard for project alternatives and subsequently figure 3.11 shows the HDM 4 work standard screen.

Table 3. 14: Detailed works standards for Hageremariam - Yabelo road project.

<table>
<tr><th colspan="2">Project alternative</th><th>Section</th><th>Road work standard</th><th>Effective from</th><th>Maintenance works/ improvement type</th></tr>
<tr><td rowspan="4">Without Project</td><td rowspan="4">Base case</td><td>Rural section</td><td rowspan="4">(M) Maintenance</td><td rowspan="4">2011</td><td>Patching (PATCH)</td></tr>
<tr><td rowspan="3">Town section</td><td>Crack sealing (CRSE)</td></tr>
<tr><td>Edge repairing (EDGB)</td></tr>
<tr><td>Drainage repairing(DRR)</td></tr>
<tr><td rowspan="16">With project</td><td rowspan="8">With delay</td><td rowspan="5">Rural/Town section</td><td rowspan="5">(M) Maintenance</td><td rowspan="5">2016</td><td>Patching (PATCH)</td></tr>
<tr><td>Crack sealing (CRSE)</td></tr>
<tr><td>Edge repairing (EDGB)</td></tr>
<tr><td>Drainage repairing(DRR)</td></tr>
<tr><td>50mm overlay</td></tr>
<tr><td>Rural section</td><td rowspan="3">(I) Improvement</td><td rowspan="3">2011</td><td>Partial widening</td></tr>
<tr><td rowspan="2">Town section</td><td>Lane addition</td></tr>
<tr><td>Realignment</td></tr>
<tr><td rowspan="8">Without delay</td><td rowspan="5">Rural/Town section</td><td rowspan="5">(M) Maintenance</td><td rowspan="5">2014</td><td>Patching (PATCH)</td></tr>
<tr><td>Crack sealing (CRSE)</td></tr>
<tr><td>Edge repairing (EDGB)</td></tr>
<tr><td>Drainage repairing(DRR)</td></tr>
<tr><td>50mm overlay</td></tr>
<tr><td>Rural section</td><td rowspan="3">(I) Improvement</td><td rowspan="3">2011</td><td>Partial widening</td></tr>
<tr><td rowspan="2">Town section</td><td>Lane addition</td></tr>
<tr><td>Realignment</td></tr>
</table>

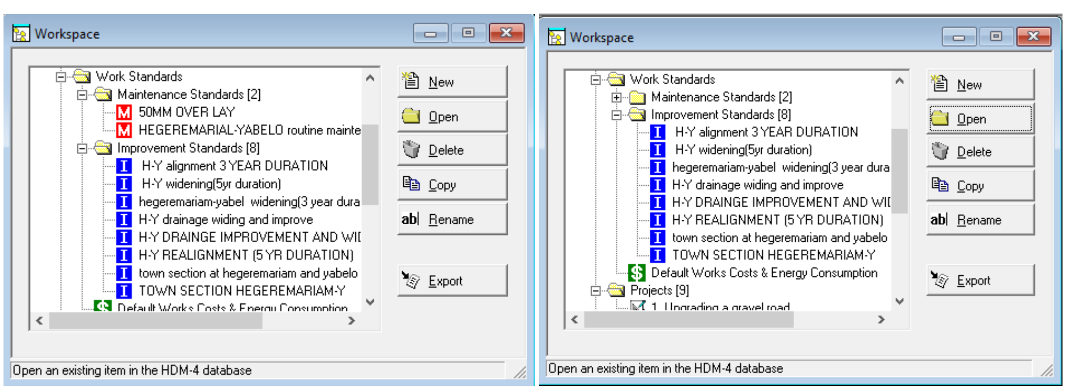


Figure 3. 11: work standard screen

D. Define project detail

On this window General, select section, select vehicle and define normal traffic tab page is displayed

- **General:** This screen confirms the project description, analysis type, analysis period and the pre-defined road network and vehicle fleet. This case study is presented as a project analysis. The road under study was analyzed by section. The analysis period comprises of starting in 2011, duration of 23 and 25 and 10.23% of discount rate. Figure 3.12 below shows project definition of Hageremariam-Yabelo road under HDM-4 screen.

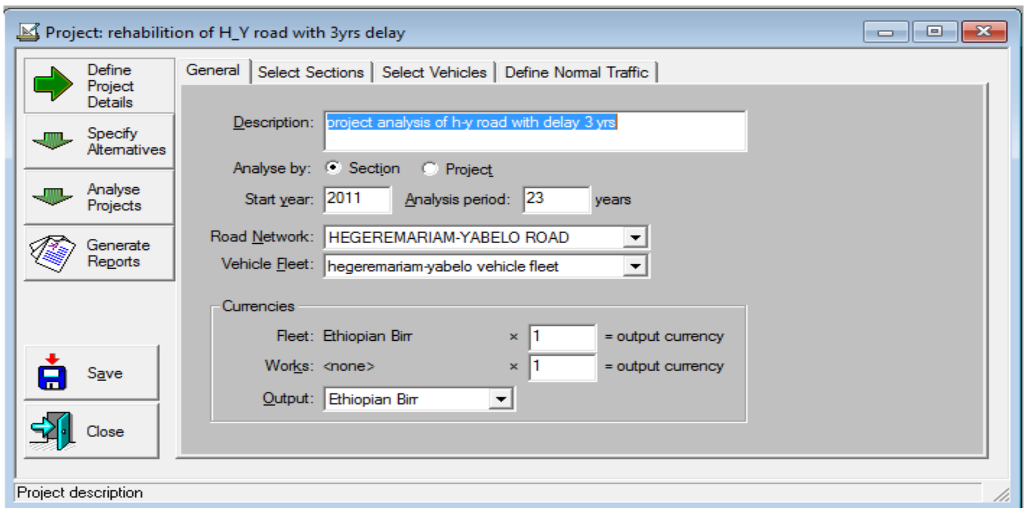


Figure 3. 12: Project definition

Select section: The select section tap page display those sections of Hagerimariam-Yabelo road network that will be included in analysis. Figure 3.13 shows the two selected sections under the HDM 4 screen.

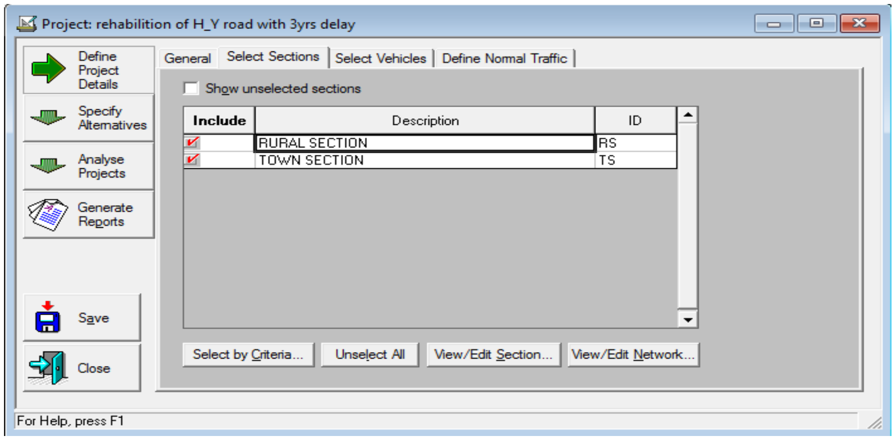


Figure 3. 13: select section

❖ **Section/definition:** list basic characteristic such as speed flow type and traffic flow pattern, carriageway length and width. Figure 3.14 shows section/definition under the HDM-4 screen.

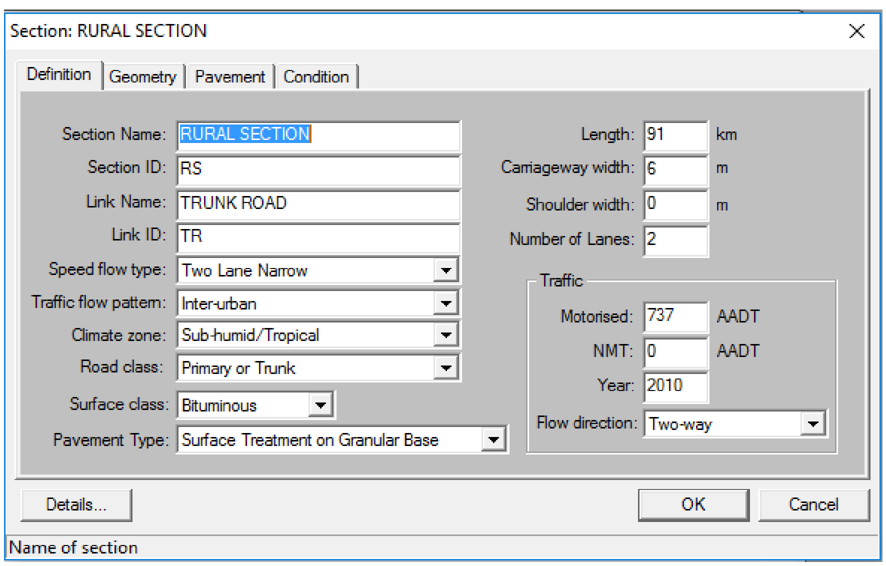


Figure 3. 14: section/definition

❖ **Section/geometry:** This is the existing geometry including those for horizontal and vertical alignment. The data represent the geometric condition of the study road which is bending and gently undulating. Figure 3.15 shows section/geometry under HDM-4 screen.

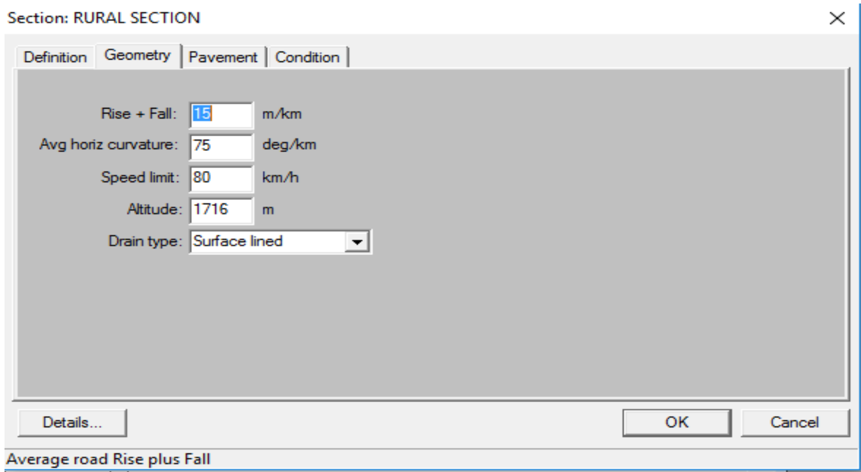


Figure 3. 15: Section/Geometry

❖ **Section/pavement:** This isthe existing pavement construction consisting ofdoule bituminous surface dress with total thckness of 50mm. This pavement type is automatically updated immediately after maintenance and improvement works. Figure 3.16 shows section pavement of Hegeremariam-yabelo road under HDM-4.

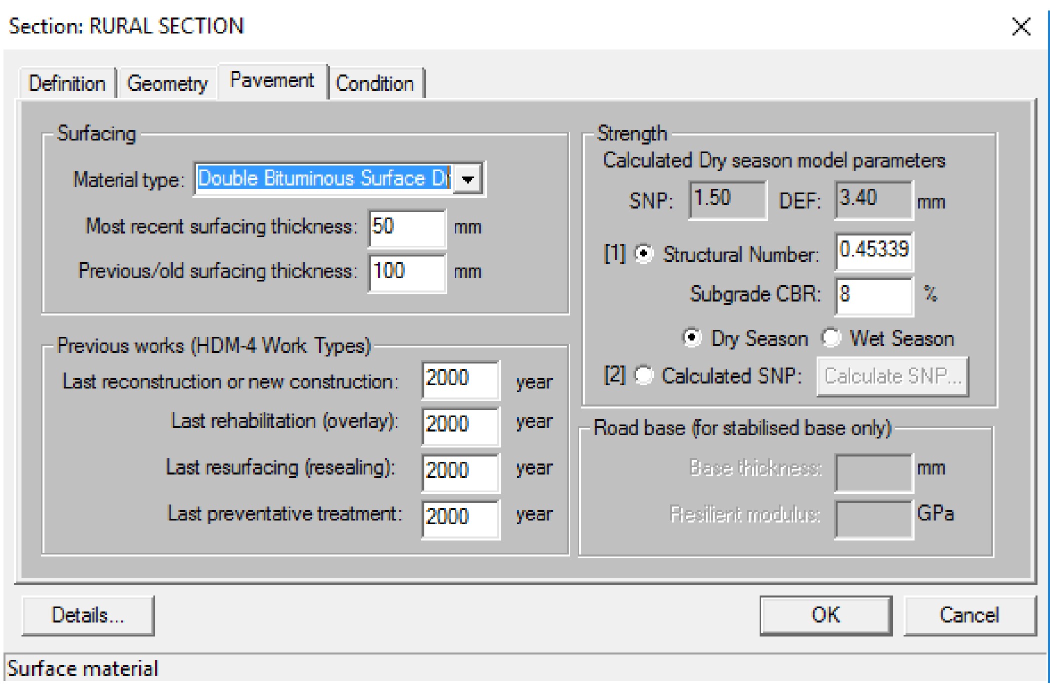


Figure 3. 16:section/pavement

Section/condition: This is the condition of the road in 2010 which is reviewed under the following tap page. For project analysis, road condition data should bepresented as part of detail condition survey. Figure 3.17 shows section condition of Hageremariam-Yabelo road under HDM-4 screen.

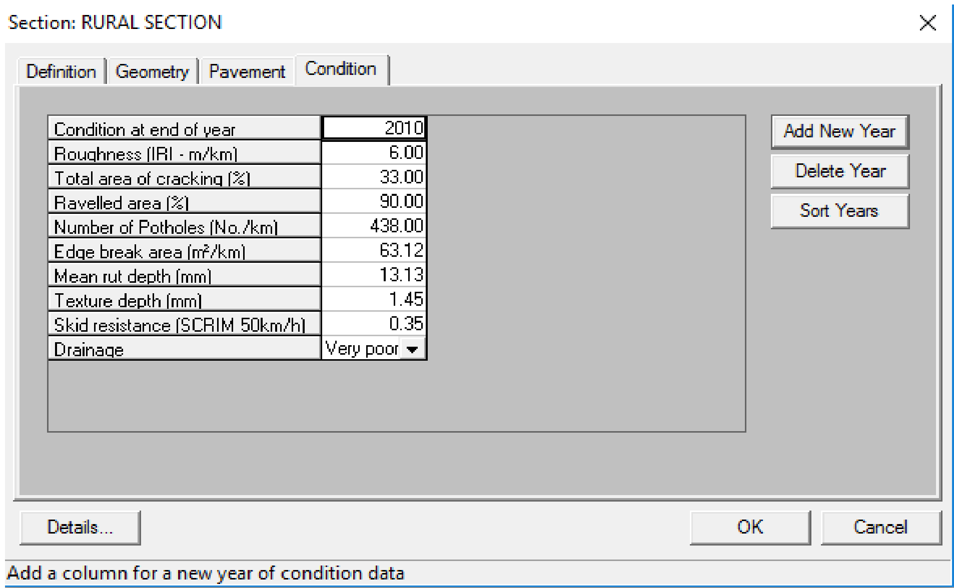


Figure 3. 17:Section/condition

❖ **Select vehicles**:In this case, the vehicles were selected from the Hageremariam-Yabelo pre-define vehicles fleet.

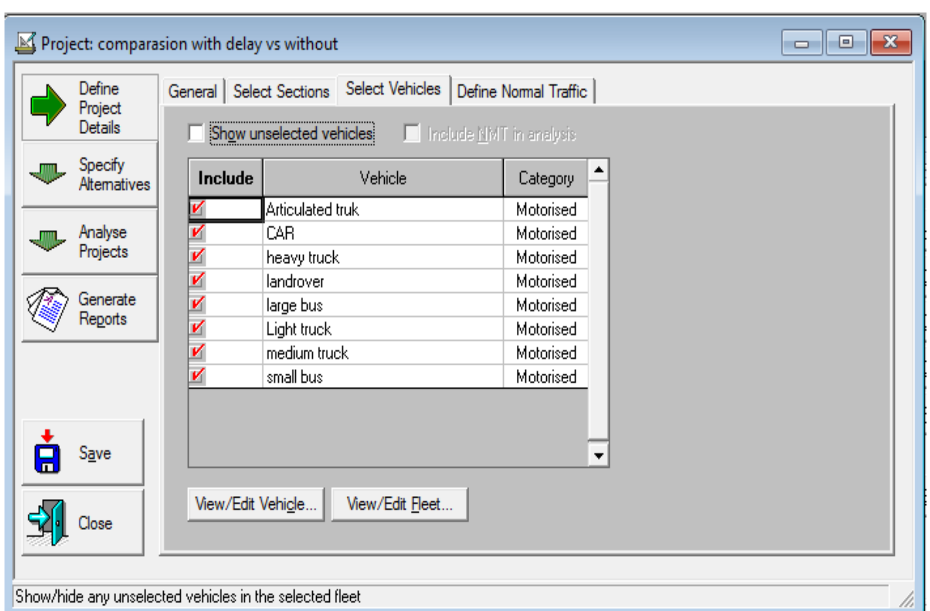


Figure 3. 18: selected vehicle fleet

- **Define normal traffic**: This page confirms the volume of traffic using selected road section at initial year. The initial traffic composition and growth rates were defined. Figure 3.19 shows normal traffic under HDM-4 screen.

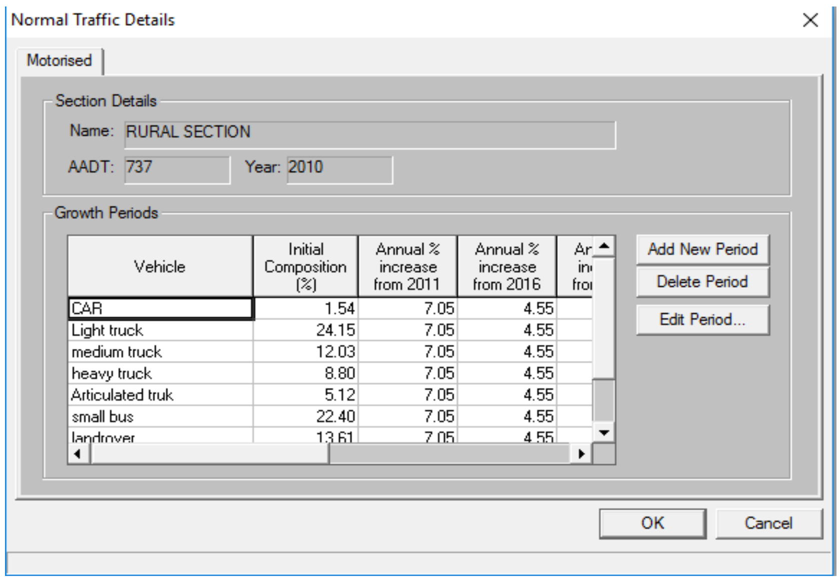


Figure 3. 19: Normal traffic detail

- **Alternatives:** This case study considered the effect of rehibilation construction delay. Two alternative were considered as follows:

Alternative 1 ; Without delay; effective from 2011 with construction duration of 3 years.

Alternative 2; With delay; effective from 2011with construction duration of 5 year.

The two project alternatives considered in this case study were defined to discern the impact of road construction delay and each alternative is without construction delay and with construction delay. The reasons of using these alternatives is to compare the total cost and benefits (vehicle operating cost, travel time and accident cost saving) under the conditions of delay and without delay of the construction to understand the impacts of the delays. The assigned maintenance and improvement standards are same under both alternatives.

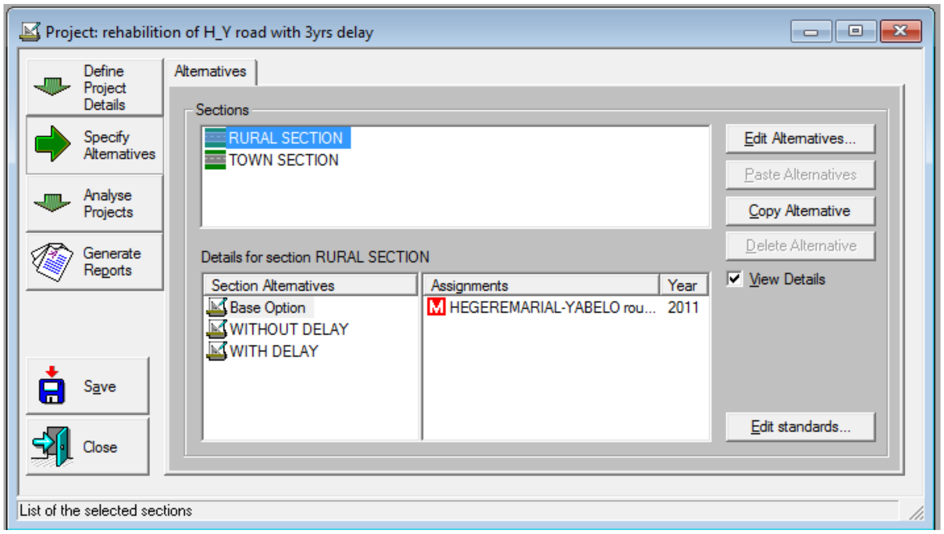


Figure 3. 20: specify Alternative

- **Analysis the Project**: the project analysis including specifying the comparisons to be undertaken, the discount rate,choices about which vehicle life model to use, what road safety analysis to be undertaken and whether or not to perform emissions analysis and energy balance analysis. In this case study the dicount rate of 10.23% ,the vehicle life model is constant model and include road safety analysis with having unit cost of each component. Figure 3.21 shows setuprun of Hageremariam-Yabelo road under HDM-4 screen.

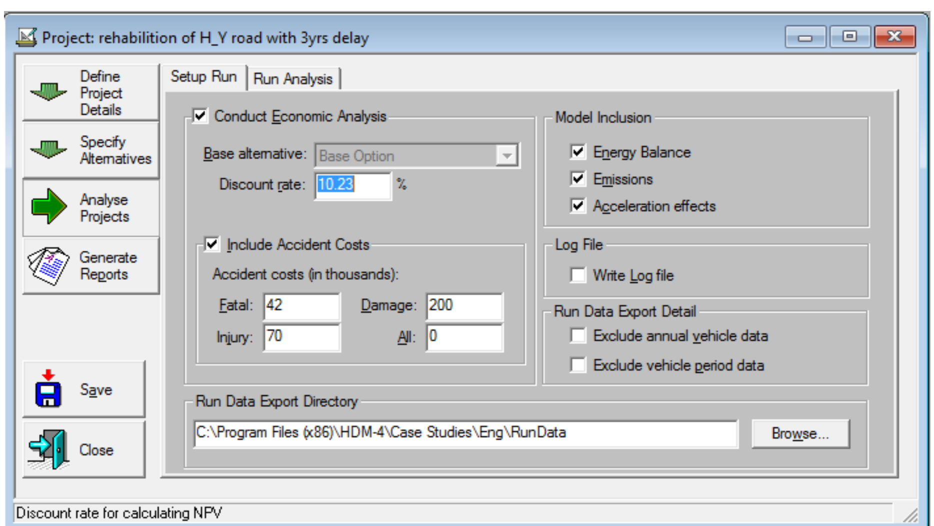


Figure 3. 21: Analysis Project

In the run set-up, specify the technical models to be used. These include

Economic analysis: If economic analysis is to be performed, the base case, project alternative, discount rate, road accident analysis, energy balance analysis, vehicle emissions and acceleration effects parameter should be specified to successfully complete the study.

Base case project alternative: This is the case against which all other project alternatives are compared. In the case of this study, base case project alternative, discount rate and accident cost were defined.

The set up run confirms that the base case alternative for economic analysis is the first alternative and that the discount rate is 10.23%. For this case study, accident cost and acceleration effects were all included in the analysis.

- ❖ **Run analysis**: Following set-up, selecting the start button under analysis project/Run analysis runs the project analysis. During the status is displayed in terms of the stage of analysis reached and the percentage completion. Figure 3.22 presents run analysis under HDM-4 page.

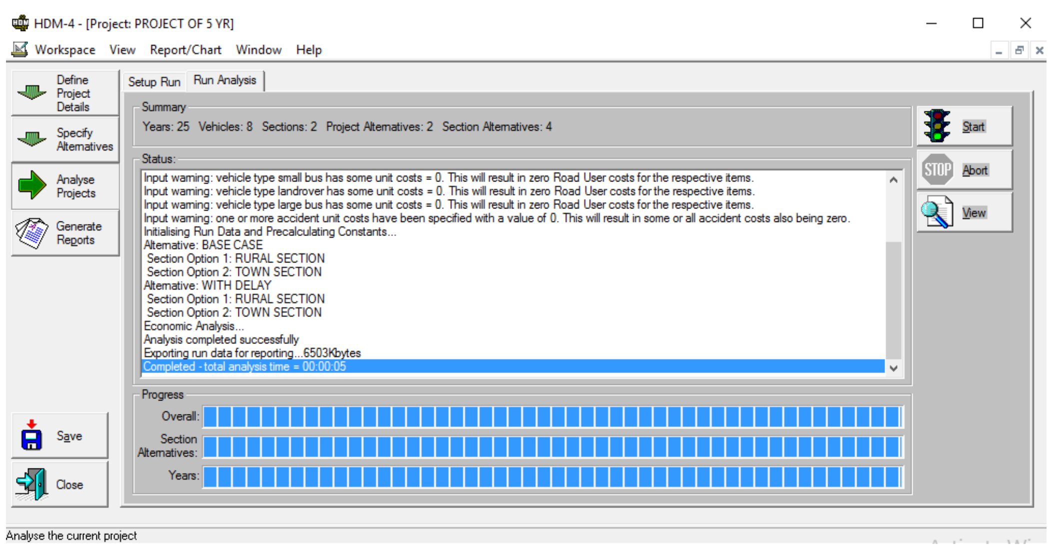


Figure 3. 22: Run the analysis tap page

❖ **Generate report:** the output report from the HDM-4 analysis is produced under generate report/select report. The output result that present on the generate report sheet are; traffic, deterioration/work effects, road user effect, environmental effects, and cost stream. From this report sheet select the important result data that used to conclude the impact of construction delay on road user cost and benefit. The out result used in this study is: road user effect, cost stream and environmental effect.

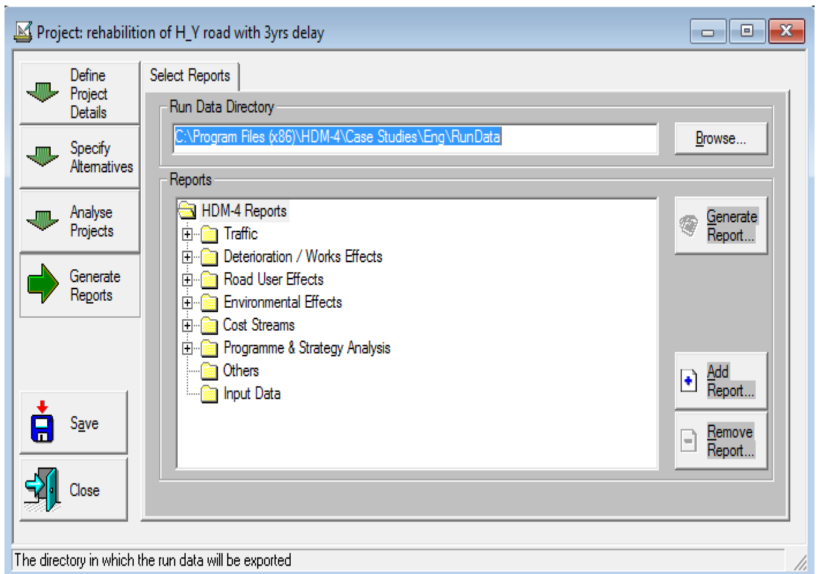


Figure 3. 23: Generate reports

4. RESULT AND DISCUSSION

4.1 Introduction

This chapter describes the results and discussions of questionnaire and HDM-4 analysis concerning causes and impacts of time overruns regarding the Hageremariam-Yabelo road construction project.

4.2. Results of Questionnaire for Causes and Impacts of Delay

4.2.1. Causes of Delay on Construction Projects

This part consists of results and discussions of factors that influence delay. These factors include; consultants, client, contractors, equipment and external related factors. Analysis of the data has been made by using the Mean Score method from the view points of the client, consultants and contractors.

4.2.1.1. Contractor View

The contractors ranked “Delay to deliver the site (ROW)” and “lack of possession of site in various locations” as first with a mean score of 4.20 as shown in table 4.1. This indicates how ROW problem affect the project time. If there is a right-of-way problem in a construction project, it will lead to a significant delay in a project. In this project, delayed ROW provision, which was one of cause of delay, in Hageremariam town was happened during construction period.

The third important factor, ranked by contractor was “Variation of order/changing scope of work” with a mean score of 4.13. This is a strong indication for a cause of delay. In this project, it was observed that the project have additional works such as widening town section in Hageremariam-Yabelo into dual carriageway, flood protection work and developing ground water at six sites. These are the most important works on Hageremaryam-Yabelo road project. However, it was not considered during the design of the rehabilitation time due to lack of site visiting before designing. This time gap results delay.

The above three issues are the most significant factor that resulted road construction delay. The other factors which are less significant causes relatively to the other are listed in Table 4.1 below.

Table 4. 1 : Factors cause time overruns from point view of contractors, consultants and client

FACTOR FOR LATE COMPLETION	client		consultant		Contractor		Weighted average	
	MS	Rank	MS	Rank	MS	Rank	MS	Rank
Variation of order/changing scope of work	4.00	1	4.00	1	4.13	3	4.04	1
Delay to furnish and deliver the site (ROW)	3.75	2	3.67	2	4.20	1	3.87	2
lack of possession of site in various locations	3.75	2	3.67	2	4.20	1	3.87	2
Delay in site mobilization	3.75	2	3.60	4	4.00	4	3.78	4
Unforeseen circumstances	3.50	5	3.50	5	3.60	5	3.53	5
Poor Assessment of original contract duration	3.50	5	2.53	7	2.53	12	2.86	6
Sit management	2.75	20	2.67	6	2.87	6	2.76	7
Slow decision-making by owners.	3.50	5	1.67	16	2.87	6	2.68	8
Preparation and approval of drawings	3.00	11	2.47	8	2.33	13	2.60	9
Poor qualification of consultant / engineer's staff assigned to the project	3.50	5	2.07	9	2.20	15	2.59	10
Improper planning	3.00	11	2.07	9	2.60	11	2.56	11
Sub-contractor problem	2.75	20	1.87	13	2.87	6	2.49	12
Contract management.	3.00	11	1.93	12	2.33	13	2.42	13
Financial problems	3.00	11	1.53	21	2.73	9	2.42	13
Mistakes during construction	2.75	20	1.60	18	2.67	10	2.34	15
Delays in installation of the batching plant	3.25	9	1.87	13	1.87	18	2.33	16
Finance and payments of completed work	3.25	9	1.53	21	1.73	22	2.17	17
Poor communication and coordination of other party	2.50	24	2.00	11	1.93	17	2.14	18
Delay in performing inspection and testing by the consultant	2.50	24	1.67	17	2.20	15	2.12	19
Equipment breakdown/failure	3.00	11	1.60	18	1.60	23	2.07	20
Labor supply	2.75	20	1.60	18	1.80	20	2.05	21
Labor productivity	2.50	24	1.80	15	1.80	20	2.03	22
Absence of consultant's site staff	2.50	24	1.73	16	1.87	18	2.03	22
Major disputes and negotiations.	3.00	11	1.40	22	1.40	24	1.93	24
Severe weather conditions on the work site	3.00	11	1.33	23	1.27	25	1.87	25
Low productivity and efficiency of equipment	3.00	11	1.27	24	1.27	25	1.84	26
Unavailability of utilities in site (such as, water, electricity, telephone, etc.)	3.00	11	1.27	24	1.20	27	1.82	27

4.2.1.2. Consultant View

The consultant ranked “variation of order (additional scope)” with a mean score of 4.00 as the first factor that causes delay that shows in table 4.1.This indicates the high importance of thorough site visit before rehabilitation design work for the progress of project. The second factors that rank by consultant was "Delay to deliver ROW on time" and “lack of possession of site in various locations” with a mean score of 3.67. This directly delays site hand over. Domestic contractors tolerate delayed hand over of construction sites but foreign contractors do not tolerate delayed hand over of construction sites by employers. Foreign contractors claim compensation because of idle hours of man power and equipment’s due to the delay. These are due to cultural differences between domestic contractors and foreign contractors; as a result, domestic contractors suffered mostly from delayed projects.

The consultants ranked “Delay in site mobilization "in the fourth position with mean score of 3.60, which indicates the high importance of work organization. Therefore, it must be performed before beginning of the construction works in order to complete the project on time. Site organization delay creates disagreements between the parties of the project. As a consequence, the project activities are affected and causes delay of the project.

The other important factors ranked with their mean score are illustrated in table 4.1above.

4.2.1.3. Client View

Client ranked "Variation of order/changing scope of work" as the first factor that caused the delay with a mean score of 4.00. Additional (unexpected) work that was not considered during the planning of the rehabilitation was a major reason for time delay.

The second important factors were “Delay to furnish and deliver the site (ROW), lack of possession of site in various locations and late site mobilization” with a mean score of 3.75. Late hand over of construction sites, sometimes may happen and substantially increase the cost of construction projects. ROW and lack of possession of site area major reason for time overrun according to the contractor firstly while to the consultant and the client ranked secondly. This result shows the importance of planning to deliver the project on time. When the activities' executions are without priorities of tasks, it certainly causes the delay of the project. Variation of order is the main significance factor for causing delay that is ranked firstly in client and consultant side as well as Contractor ranks thirdly. The first and second factor on client view strongly supported by all parties with a close ranking. Therefore, it shows that those factors are the most significant cause for delay of the project.

The fifth important factor was "Unexpected circumstances" with a mean score of 3.5. This result is in full conformity with the consultants, client and contractors; but in the case of contractors, the value of the MS is higher which is 3.60. This is a strong indication that unforeseen circumstances highly affected the progress of the project. Unforeseen circumstances in this project include factors such as procedures for customs clearance, mobilization, abnormal rainy season (weather condition) and fuel shortage in the country.

4.2.2. Tests for Agreements on Causes of Delay Among in the Construction Parties

Here, responses by the participants were tested for correlation using Spearman Rank Correlation Coefficients. To see if there are ranking differences between two groups of respondent; Client versus Contractor; Contractor versus Consultant; and Client versus Consultant on the cause of delay.

The purpose of a hypothesis test is to avoid deceit by chance occurrences. The tests also help to evaluate whether agreement of opinions exist among respondents. The following were the established hypotheses.

- **Null Hypothesis (H_O): -**No agreement in the ranking of causes of time overrun between two groups of respondents.
- **Alternative Hypothesis (H_A): -**There is agreement in the ranking of causes of time overrun between two groups of respondents.

The spearman correlation coefficient (ρ) was calculated by using equation 3.5 and presented as shown in table 4.2 below. In order to decide whether to accept or reject the null hypothesis, the level of significance at 95% ($P = 0.05$) was used. This allows understanding whether there was "agreement" or "disagreement" between responses.

If the calculated value of ρ is greater than the critical value, H_o is rejected, that means there is evidence of statistical significance in agreement between the groups. If the calculated value of ρ is less than the critical value, H_o is accepted**,** i.e. there is no evidence of statistical significant of agreement between the two groups.

Table 4.2: Summary of correlation test on the ranking of causes of delay

Respondents	$Rho(\rho cal) = 1 - \frac{6\sum d^2}{N(N^2-1)}$	Critical value **ρ**	Significance for p<0.05
Client vs contractor	0.8175	0.3242	Significantly reject
Contractor vs consultant	0.8175	0.3242	Significantly reject
Client vs consultant	0.4832	0.3242	Significantly reject

In this case, with a significance level of 95% (P = 0.05), the calculated value of ρ for all the three parties were greater than the critical values of ρ. So, the null hypothesis is rejected. From table 4.2 above, it can be concluded that there is strong correlation between the attitudes of the respondents in all the three groups. Hence, the null hypothesis should be rejected and the alternative hypothesis should be accepted. This means that most of the respondents have the same perception about the causes of delay.

4.2.3. Assessment of Impact of Delay on Vehicle Operating Costs

During the field work of interviewing the vehicle operators, the impact of delay on vehicle operating cost was assessed. Accordingly, the most significant impact that affects the vehicle operating costs were selected by using ranking of the MS result of the total impact. Table 4.3 below presents the summary of the results of the impact assessment.

Table 4.3: Summary of the impact assessment results.

Impact of delay on vehicle operating costs	$MS = \frac{\sum F \times S}{N}$	**Rank**
Working hour per day(frequency of the journey per day)	5	1
Cost of new tire /tier-wear repair	4.8	2
Average service life of the vehicle	4.2	3
Maintenance labour cost(per hour)	4	4
Cost of fuel used by vehicle per liter	2.4	5
Cost of lubricant oil (per liter)	2	6
Traffic accidents	1.8	7
Total crew wages (per hour)	1.4	8
Annual overhead costs(per year) administration, insurance, parking/garage and crew training, uniform and other)	1	9

Table 4.3 above displayed the following:

- ❖ The working hour per day (frequency of the journey per day) ranked first with MS value of 5.00. This indicated that frequency of the journey per day is the most significant impact on vehicle operating performances. This impact is highly related to the roughness of the road during the construction works. Most of the vehicle operators said that at the time of construction the frequency of the number of trips per vehicle per day was one. However; after finishing the construction, the trips doubled. This shows that vehicle operating costs were adversely impacted because of delay of the project work.
- ❖ The second impact which is cost of new tire /tire-wear repair ranking with means score value of 4.8. When at the time of construction similar to the first impact new tire/ tire wear consumption are increased because the road was not suitable, which is highly rough surface, result reduced the age of the tire. This impact highly affected on vehicle operating cost second to 1st impact strongly supported by the vehicle operators.
- ❖ The third impact of delay was average service life of the vehicle with mean score value of 4.2. This impact indicate that most of vehicle part influenced due to the bad condition

of the road at the time of elongation of construction work which result to reduce the service life of the vehicle.

Generally, the other impact that ranked by mean score on the table are also highly affected the vehicle operating cost with slightly less impact than the first three impacts.

When asking the vehicle operators “if you have additional comments regarding the late completion impact” they raises as additional impact due to delay of the construction are health, social and environmental problems. This generally indicates that delay have an economy, social, health and environmental impacts.

4.3. HDM-4 Result and Discussion

4.3.1 The Costs Expended during Construction Period (by Comparing with Delay and without Delay)

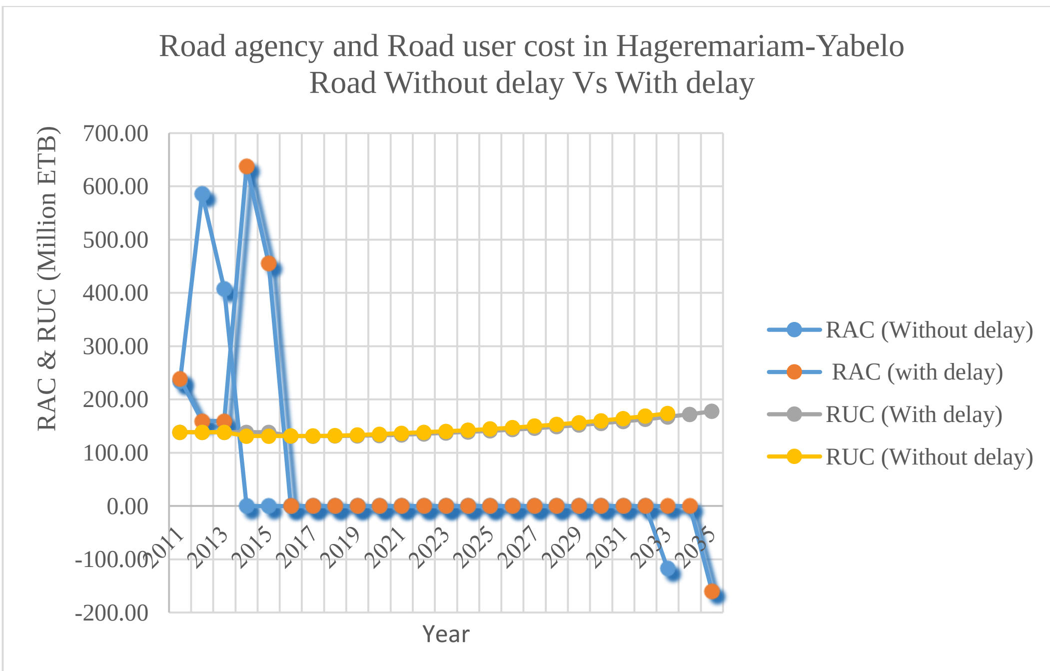


Figure 4. 1: Road agency and road user cost with delay Vs without delay

The figure above show that the construction cost with delay is increased as result of two year delay of the construction completion time. So that, the road agency cost (RAC) and road user cost (RUC) of with delay has higher than without delay within 2014-2015.The two year extension period from 2014-2015 with delay with respect to without delay of the RAC increase from zero to 638.37 million ETB for 2014 and from zero to 455.6 million ETB for 2015 whereas RUC increase from 131.25 to 138.58 million ETB for 2014 and 131.25 to 138.58 million ETB for 2015.

Furthermore, if the project is ended as schedule at the end of 2013 with having total RAC of 1,233.31 million ETB and the total RUC of 415.74 million ETB. When the construction are delay by two year, additional RAC and RUC are generated and the project were completed at the end of 2015 with a total road agency cost of 1,631.53 million ETB and the total road user cost of691.74 million ETB. Generally, the total additional cost due to this delay from both RAC and RUC are 398.22 million ETB and 276 million ETB respectively. Due to this delay of construction, this road project loss cost not necessary to apply on the work which mean indirectly reduced the benefit of the road that expected to gain during this overrun time period.

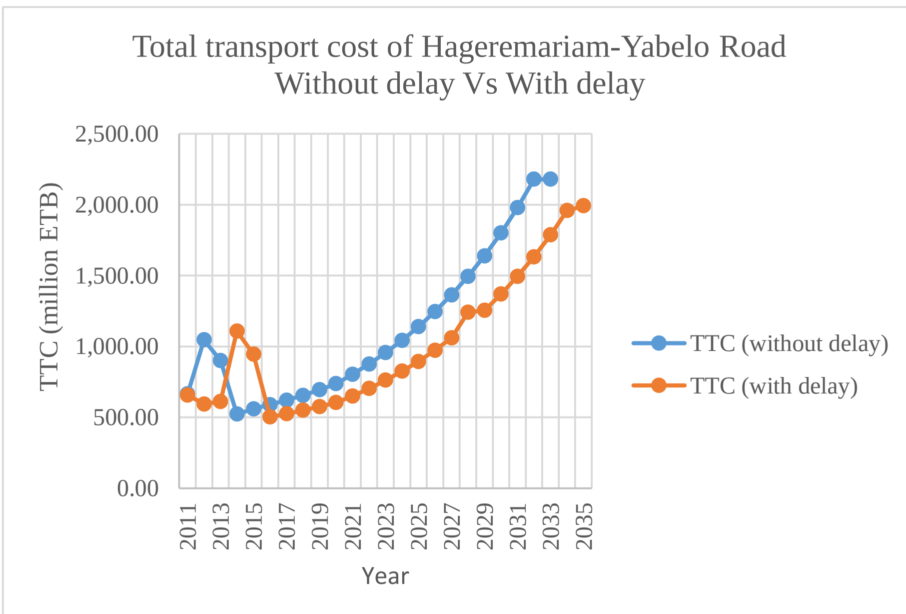


Figure 4. 2: Total transport cost with delay Vs without delay

The RAC and RUC are summarized by the total transport cost that needed in the total life of the project. For this specific road project the total transport cost that losses on the two year construction delay are one quantification tool of the impact of the construction delay on Hageremariam-Yabelo road construction project. The above graph show that the total transport cost increased with amount of 674.22 million ETB due to two year delay road project.

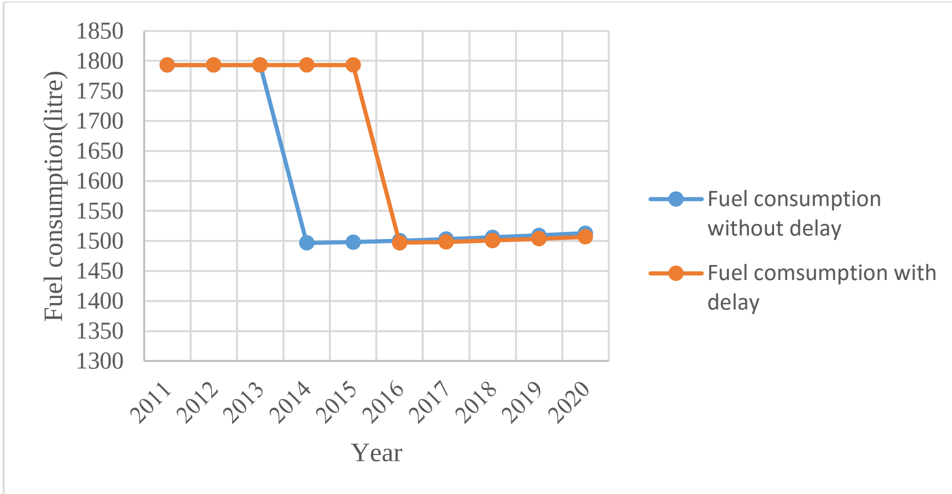


Figure 4. 3: Fuel consumption with delay Vs without delay

Fuel consumption is also highly affected by road construction delay if the road is not completed with schedule. The amount of the fuel that used by all vehicle type are increased because the consumption of the fuel during construction and after completion of the construction are different. Since, the HDM-4 fuel consumption quantification result show that during 2014-2015 with delay respect to without delay fuel consumption amount increased from 1498.23 liter to 1793.18 liter. As result of this the total additional fuel consumption due to two years delay was 294.95 liters.

4.3.2. Determine the Lost Road User Benefit due to Road Construction Delays

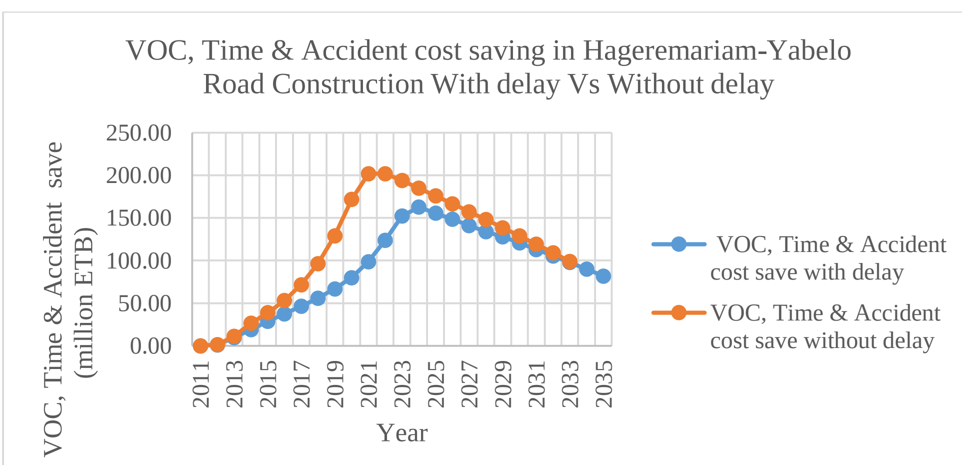


Figure 4. 4: Total sum of VOC, travel time cost and accident cost saving with Vs. without delay

There are different benefits that are gained from this specific project. Those benefits are economic, social and environmental benefits. However; HDM-4 software quantified only benefits that result from vehicle operating, travel time and accident reduction cost saving and some environmental emission also included. But the social, health and other environmental impact are difficult to quantify by this software program.

The minimum benefit that quantified from this project work are vehicle operating cost, travel time and accident cost saving that are totally increased from 2012-2024 with amount of 1.38 million ETB to 202.05 million ETB and 1.38 million ETB to 162.79 million ETB without delay and with delay respectively. Generally from this quantification result the loss benefits are 39.26 million ETB. So this result show that road construction delay is highly affected the benefit of the road project. Even though if the benefit is decreased after 2024 to end of year still without delay of the construction project benefit are increased. Furthermore, within two years delay period (2014 and 2015) the benefits loss was 17.49 million ETB.

The quantified benefit results that show on the graph with in delay of the construction total benefit are lower than without delay. This means so many benefits are losses that expected from the road project due to construction delay.

The two project alternative with delay and without delay of the net benefit (subtract the total cost from total benefit) result are shown on the figure 4.5 below. This figure show that the net benefit are slightly increased from 2014 to end of year.

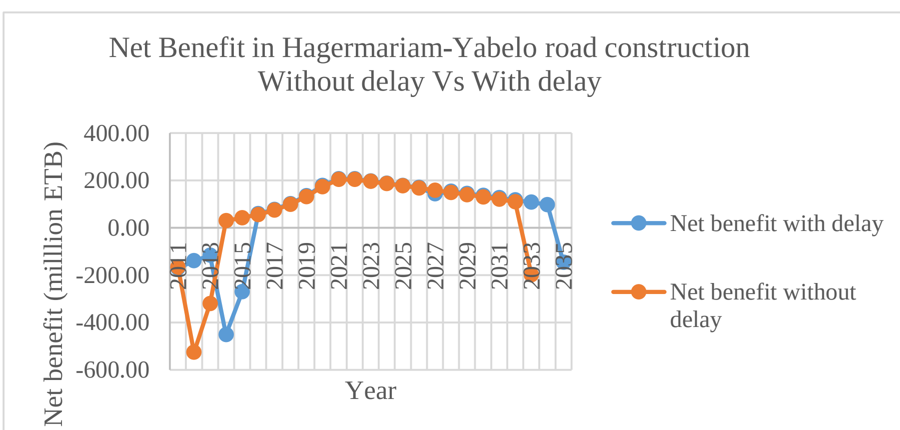


Figure 4. 5: Net benefit without delay Vs with delay of the project

Since, the benefit with delay during construction period from 2011-2013 are greater than without delay because the total transport cost with delay are lower compared to without delay. The net benefit loss as a result of two year construction delay period (2014-2015) is650.56 million ETB. That is the net benefit of without and with delay in period 2015-2015 is 71.15 and -721.71million ETB respectively.

The HDM-4 also quantify emission of gases in addition to cost and benefit the result show that the amount of emission increased during delay time expressed separately for each gas. such gases were emitted in this environment are Hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO2), Nitrous oxide (NO), Sulphur dioxide (SO_2), particles (par) and lead (Pb).The detail amounts of these gasses without delay project and with delay in over total life of the project are listed in Appendix D. During the two years delay period, the emission results in respect of with and without delay, the differences and aggregates are shown in the adjacent table 4.4. The result show that the road construction delay had an environmental impact.

Table 4.4: Amount of emission in gram with delay Vs Without delay

Emission gasses	Amount of emission in gram						
	With delay		Without delay		Difference		Total
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014-2015**
Hydrocarbon (HC)	8.69	9.3	6.68	7.53	2.01	1.77	3.78
Carbon monoxide (CO)	55.73	59.64	38.09	40.81	17.64	18.83	36.47
Nitrous oxide (NO)	22.48	24.06	17.74	19	4.74	5.06	9.8
Sulphur dioxide (SO2)	0.64	0.7	0.51	0.55	0.13	0.15	0.28
Carbon dioxide (CO)	1591.42	1703.33	1328.58	1423.41	262.84	279.92	542.76
Particulates (Par)	0.29	0.31	0.24	0.26	0.05	0.05	0.1
Lead (Pb)	92.34	98.83	80.81	86.55	11.53	12.28	23.81
Total							617

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusions

Based on the results of the analysis of questionnaire and HDM-4 software program the following conclusions are drawn;

- The first specific objective was to assess and identify the causes for late completion of road construction projects specifically on the Hageremariam-Yabelo road project;

  In this case, twenty-seven (27) causes of time overrun were identified by the respondents. The most common causes of time overrun were identified as the following three:

  - ✓ delay in delivering the site (right-of-way problem) and lack of possession of site in various locations;
  - ✓ variation of order (performed additional work); and
  - ✓ Delay in Site mobilization.

By comparing the results obtained at this thesis with the results and analysis of pertinent literatures, it was found that there are real similarities of the important factors that influence time.

- Vehicle operating cost that affect by delay are; working hour per year, consumption of tire, fuel, lubricant, average service life, total crew wage, maintenance labour cost, annual overhead and traffic accident. As result of the mean score value ranking; the working hour per year (frequency of trip per day) has first position while tire consumption and service life get second and third position respectively. In addition to vehicle operating cost; health, social and environmental problems are additional impact due to delay of the construction.
- The third specific objective was to quantify the project costs expended during the construction period (without delay and with delay). The HDM-4 software was utilized in this case. The road user costs (RUCs) and the road agency costs (RACs) were generated. The results showed that with the delay alternatives in two years delay period, both RUC and RAC were higher than without delay with Birr 276 million and Birr 398.22 million respectively. This indicated that due to two years of additional construction time, the overall RUC and RAC increased since the construction costs and total vehicle operating costs

significantly increased. The costs expended due to delay amounted to Birr 674.22 million in relation to without delay which was a significant impact.

- ❖ The last specific objective was determination of lost benefits to road user due to road construction delays. In this regard, the HDM -4 analysis results were expressed in terms of travel time and road accidents and these amounted to Birr 17.49 million.
- ❖ Generally, road construction delay affects the economic development of Ethiopia depending on this particular study and ERA project completion reports.

5.2. Recommendation

Based on the result of analysis, the following recommendations are forwarded:

- ❖ The client should give attention to the ROW problem. This means that before the construction commences, the client has to fulfill all the necessary requirements for delivering the site. Failure to deliver the sites will cause delay and then impacts on cost.
- ❖ The client should minimize the change orders as much as possible as they can to avoid any time and cost overruns. Additionally, the client should be assign their own person that makes sure detail design work appropriately performed or not.
- ❖ The client should determine the required construction period to avoid delays and its impact. The client should have qualified technical staff to properly manage the different stages of any project and to follow the performance of percentages, and also able to compare the actual performance with the initially planned.
- ❖ Contractors should establish a proper planning system by considering the detail site condition, social activities in different aspects of the project to avoid that may lead to re-design work that culminate delay and adverse impact.
- ❖ Contractors should setup stores for required construction materials especially for scarce ones that are in limited quantity in the markets to avoid overruns the RAC.
- ❖ Contractors should assigned site managers/supervisors, administrators and technical staff as soon as the project is awarded to achieve completion within specified time with the required quality and estimated cost.
- ❖ Consultants should perform continuous coordination and direct communication with contractors and clients. This will eliminate design discrepancies and errors as well as omissions in design and also provide an opportunity to thoroughly review the contract.

This would help in eliminating change orders or variations due to discrepancy in contract documents.

- Consultants are advised to adopt efficient information distribution systems to guard against communication gaps; respond as quickly as possible to the contractor and client questions and requests for clarification to avoid associated delays and confusions which consequentially will lead to delay.
- Government should give capacity building for professionals and firms on the construction sector to develop and enhance the performances of the professionals. In addition, government has to initiate intellectuals through financial allocation to do researches regarding causes of time overrun and impact.

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APPENDIX

Appendix A: A Questionnaire

IMPACTS OF ROAD CONSTRUCTION DELAY ON TRANSPORT COST AND BENEFIT

(A CASE STUDY ON HEGEREMARIAM -YABELO ROAD CONSTRUCTION PROJECT)

Introduction

This questionnaire is prepared to obtain data from pertinent key informants. The data are required for the academic research entitled "IMPACTS OF ROAD CONSTRUCTION DELAY ON TRANSPORT COST AND BENEFIT": A Case Study on Hageremariam - Yabelo Road construction project" which is required as a partial fulfillment of a M.Sc. Thesis in road and transport. The main objective of the research is to evaluate the impacts of road construction delay on transport cost and benefit considering the Hageremariam-Yabelo Road and forward recommendations based on the findings.

The questionnaire consists of factors of time overruns and impact of delay on vehicle operating cost in Road construction projects in Hageremariam - Yabelo. At the end there is a space that left for general comments regarding the research topic.

Your response, in this regard, is highly valuable and considered contributory to the outcome of the research. All feedbacks will be kept strictly confidential, and utilized for this academic research only.

Thank you,

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Hawassa University Institute of Technology, School of Civil Engineering
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INTERVIEW SCHEDULE FOR EMPLOYER, CONSULTANT AND CONTRACTOR

Declaration: The information provided will be treated with confidentially and will be used for academic purpose only

FACTORS OF LATE COMPLETION ON HAGEREMARIAM-YABELO ROAD CONSTRUCTION PROJECT

Please indicate the significance of each factor by ticking the appropriate boxes. Add any remarks relating to each factor on the last column e.g. as to the reasons, the critical factors or the solutions.

E.S. = extremely significant (5); V.S. = Very significant (4);

M.S. = moderately significant (3); S.S. = slightly significant (2);

N.S. = Not significant (1):

Table A. 1: Factor of late completion of Hageremariam-Yabelo road

No	**FACTOR FOR LATE COMPLETION**	E.S	V.S	M.S	S.S	N.S	Additional comment(if any)
1	**FACTOR RELATED TO CONSUTANT**						
A	Absence of consultant’s site staff						
B	Contract management.						
C	Preparation and approval of drawings						
D	Delay in performing inspection and testing by the consultant						
E	Poor qualification of consultant / engineer’s staff assigned to the project						

No.	FACTOR FOR LATE COMPLETION	E.S	V.S	M.S	S.S	N.S	Additional comment (if any)
2	**RELATED TO CLIENT**						
A	Delay to furnish and deliver the site (ROW)						
B	Poor communication and coordination of other party						
C	Finance and payments of completed work						
D	Slow decision-making by owners.						
E	Poor Assessment of original contract duration						
F	Variation of order/changing scope of work						
G	lack of possession of site in various locations						
3	**RELATED TO CONTRACTOR**						
A	Delay in site mobilization						
B	Financial problems						
C	Sub-contractor problem						
D	Sit management						
E	Improper planning						
F	Mistakes during construction						
G	Labor supply						
H	Labor productivity						
4	**EQUIPMENT RELATED FACTOR**						
A	Equipment breakdown/failure						
B	Delays in installation of the batching plant						

No.	FACTOR FOR LATE COMPLETION	E.S	V.S	M.S	S.S	N.S	Additional comment (if any)
C	Low productivity and efficiency of equipment						
5	**EXTERNAL RELATED CAUSE**						
A	Severe weather conditions on the work site						
B	Unavailability of utilities in site (such as, water, electricity, telephone, etc.)						
C	Major disputes and negotiations.						
D	Unforeseen circumstances						

If you have comments regarding the late completion factors, you are kindly requested to write here:…………………………………………………………………………………………
………………………………………………………………………………………

INTERVIEW SCHEDULE FOR VEHICLE OPERATING COSTS

Declaration: The information provided will be treated with confidentially and will be used for academic purpose only

IMPACT OF LATE COMPLETION OF HAGEREMARIAM-YABELO ROAD CONSTRUCTION PROJECT

Please indicate the significance of each impact by ticking the appropriate boxes. Add any remarks relating to each factor on the last column e.g. as to the reasons, the critical factors or the solutions.

E.S. = extremely significant (5); V.S. = Very significant (4);
M.S. = moderately significant (3); S.S. = slightly significant (2);
N.S. = Not significant (1):

Table A. 2: Impact of late completion on vehicle operating costs of Hageremariam-Yabelo road

No	**Impact of delay on vehicle operating costs**	ES	VS	M.S	S.S	N.S	Additional comment(if any)
1	Cost of new tire /tier-wear repair						
2	Maintenance labour cost(per hour)						
3	Cost of fuel used by vehicle per liter						
4	Cost of lubricant oil (per liter)						
5	Total crew wages (per hour)						
6	Annual overhead costs(per year) administration, insurance, parking/garage and crew training, uniform, etc)						
7	Average service life of the vehicle						
8	traffic accidents						
9	Working hour per year(time for to finish the journey)						

If you have comments regarding the late completion impact, you are kindly requested to write her……………………………………………………………………………………………………
……………………………………………………………………………………………………

Appendix B: Vehicle fleet data

Table B. 1: Vehicle fleet data for 4WD

vehicle Fleets			
(4WD/Landover)			
basic characteristics			
Physical		tires	
passenger car space Equivalences factor(PCSE)	1	tire type	radial-ply
number of wheels per vehicle	4	base number of recaps per tire carcass	1.3
number of axles per vehicle	2	retread cost as a percentage of tire cost	15%
Utilization			
annual km driven	30000	percentage of vehicle use on private trips	100%
working hours	1300	Average number of passenger per vehicle	3
Average vehicle service	8	percentage of passengers trips which are work related	75%
Loading			
ESALF	0	operating weight	1.8
Economic unit costs			
vehicle resources			
new vehicle	3904900	Maintenance labor (birr/hr.)	52.31
Replacement tire (birr/tire)	4080	Crewwages (birr/hr.)	33.8215
fuel(birr/liter)	14.875	Annual overhead	78098
lubricating oil (birr/liter)	68.1955	Annual interest (%)	15%
Time value			
passenger working time (birr)	2.57	Cargo (birr/hr.)	0
Passenger non-working time (birr/hr.)	2.336		

Table B. 2: Vehicle fleet data for small bus

vehicle Fleets			
small bus			
basic characteristics			
Physical		Tires	
passenger car space Equivalences factor(PCSE)	1.2	tire type	radial-ply
number of wheels per vehicle	4	base number of recaps per tire carcass	1.3
number of axles per vehicle	2	retread cost as a percentage of tire cost	15%
Utilization			
Annual km driven	30000	percentage of vehicle use on private trips	0%
working hours	750	Average number of passenger per vehicle	12
Average vehicle service	8	percentage of passengers trips which are work related	75%
Loading			
ESALF	0	operating weight	2.5
Economic unit costs			
vehicle resources			
new vehicle	1592900	Maintenance labor (birr/hr.)	34.2805
Replacement tire (birr/tire)	7225	Crew wages(birr/hr.)	25.415
fuel(birr/liter)	14.875	Annual overhead	31858
lubricating oil (birr/liter)	68.1955	Annual interest (%)	15%
Time value			
passenger working time (birr)	2.57	Cargo (birr/hr.)	0
Passenger non-working time (birr/hr.)	2.336		

Table B. 3: Vehicle fleet data for large bus

vehicle Fleets			
large bus			
basic characteristics			
Physical		Tires	
passenger car space Equivalences factor(PCSE)	1.7	tire type	radial-ply
number of wheels per vehicle	10	base number of recaps per tire carcass	1.3
number of axles per vehicle	3	retread cost as a percentage of tire cost	15%
Utilization			
annual km driven	70000	percentage of vehicle use on private trips	0%
working hours	1750	Average number of passenger per vehicle	50
Average vehicle service	12	percentage of passengers trips which are work related	
Loading			
ESALF	0.8	operating weight	15
Economic unit costs			
vehicle resources			
new vehicle	2252500	Maintenance labor (birr/hr.)	46.3165
Replacement tire (birr/tire)	13430	Crew wages (birr/hr.)	41.0975
fuel(birr/liter)	14.875	Annual overhead	45050
lubricating oil (birr/liter)	68.1955	Annual interest (%)	15%
Time value			
passenger working time (birr)	2.57		
Passenger non-working time (birr/hr.)	2.336	Cargo (birr/hr.)	0

Table B. 4: Vehicle fleet data for small truck

vehicle Fleets			
small truck			
basic characteristics			
Physical		tires	
Passenger Car Space Equivalences factor(PCSE)	1.3	tire type	radial-ply
number of wheels per vehicle	4	base number of recaps per tire carcass	1.3
number of axles per vehicle	2	retread cost as a percentage of tire cost	15%
Utilization			
annual km driven	30000	percentage of vehicle use on private trips	0%
working hours	1300	Average number of passenger per vehicle	0
Average vehicle service	8	percentage of passengers trips which are work related	
Loading			
ESALF	0	operating weight	2
Economic unit costs			
vehicle resources			
new vehicle	1581000	Maintenance labor (birr/hr.)	25.1175
Replacement tire (birr/tire)	6885	Crew wages (birr/hr.)	23.9105
fuel(birr/liter)	14.875	Annual overhead	31620
lubricating oil (birr/liter)	68.1955	Annual interest (%)	15%
Time value			
passenger working time (birr)		Cargo (birr/hr.)	0
Passenger non-working time (birr/hr.)			

Table B. 5: Vehicle fleet data for medium truck

vehicle Fleets			
medium truck			
basic characteristics			
Physical		tires	
Passenger Car Space Equivalences factor(PCSE)	1.4	tire type	radial-ply
number of wheels per vehicle	6	base number of recaps per tire carcass	1.3
number of axles per vehicle	2	retread cost as a percentage of tire cost	15%
Utilization			
annnual km driven	40000	percentage of vehicle use on private trips	0%
working hours	1200	Average number of passenger per vehicle	0 person
Average vehicle service	12	percentage of passengers trips which are work related	100%
Loading			
ESALF	0.7	operating weight	7.5
Economic unit costs			
vehicle resources			
new vehicle	2677500	Maintenance labor (birr/hr.)	46.036
Replacement tire (birr/tire)	13430	Crewwages (birr/hr.)	36.2015
fuel(birr/liter)	14.875	Annual overhead	53550
lubricating oil (birr/liter)	68.1955	Annual interest (%)	15%
Time value			
passenger working time (birr)		Cargo (birr/hr.)	0
Passenger non-working time (birr/hr.)			

Table B. 6: Vehicle fleet data for large truck

vehicle Fleets			
large truck			
basic characteristics			
Physical		Tires	
passenger car space Equivalences factor(PCSE)	1.6	tire type	radial-ply
number of wheels per vehicle	10	base number of recaps per tire carcass	1.3
number of axles per vehicle	3	retread cost as a percentage of tire cost	15%
Utilization			
annual km driven	86000	percentage of vehicle use on private trips	0%
working hours	2050	Average number of passenger per vehicle	0 person
Average vehicle service	14	percentage of passengers trips which are work related	100%
Loading			
ESALF	1.25	operating weight	13
Economic unit costs			
vehicle resources			
new vehicle	2890000	Maintenance labor (birr/hr.)	41.2675
Replacement tire (birr/tire)	13600	Crew wages (birr/hr.)	43.877
fuel(birr/liter)	14.875	Annual overhead	57800
lubricating oil (birr/liter)	68.1955	Annual interest (%)	15%
Time value			
passenger working time (birr)			
Passenger non-working time (birr/hr.)		Cargo (birr/hr.)	0

Table B. 7: Vehicle fleet data for truck and trailer

vehicle Fleets			
truck and trailer			
basic characteristics			
Physical		Tires	
passenger car space Equivalences factor(PCSE)	1.8	tire type	radial-ply
number of wheels per vehicle	18	base number of recaps per tire carcass	1.3
number of axles per vehicle	5	retread cost as a percentage of tire cost	15%
Utilization			
annual km driven	86000	percentage of vehicle use on private trips	0%
working hours	2050	Average number of passenger per vehicle	0 person
Average vehicle service	14	percentage of passengers trips which are work related	100%
Loading			
ESALF	0	operating weight	28
Economic unit costs			
vehicle resources			
new vehicle	3639468	Maintenance labor (birr/hr.)	28.492
Replacement tire (birr/tire)	15045	Crew wages (birr/hr.)	41.667
fuel(birr/liter)	14.875	Annual overhead	72789.359
lubricating oil (birr/liter)	68.1955	Annual interest (%)	15%
Time value			
passenger working time (birr)		Cargo (birr/hr.)	0
Passenger non-working time (birr/hr.)			

Road work data

Table B. 8: Road improvement for rural section partial widening for five year duration

with delay					
road improvement for rural section					
General					
Name	H-Y partial widening with 5yr duration				
Short code	H-Y pw(5yr)				
Existing Surface Class	Bituminous				
Improvement type	Partial Widening				
Duration of work	5 year				
Intervention type	Scheduled				
Design					
Speed-Flow type	two lane standard				
Road Class	Primary or trunk				
New pavement type	Asphalt Mix on Granular				
increasing carriageway (m)	1				
Intervention					
Start	2011				
Last application year	2099				
Cost					
unit cost (per km)	Financial		economical		
	20,475,000		17,403,800		
% of cost (Each year of the work period)	1	2	3	4	5
	15	10	10	40	25
salvage value	10%				
preparatory unit cost (ETB)	Financial		economical		
re-surfacing existing carriageway(m2)	114.11		97		
Patching(m2)	158.01		134.309		

with delay		
road improvement for rural section		
crack sealing(m2)	49.86	42.381
Edge-repair(m2)	190.26	161.738
Pavement		
surface material	Asphaltic concert	
surface structure number	5	
surface thickness(mm)	50	
relative compaction	97	
Geometry		
adral(m/s2)	0.1	
speed limit(km/hr.	80	
speed limit enforcement	1	
speed reduction factor	XNMT	1
	XMT	1
	Road side friction	1
Effect		
Traffic flow pattern	inter-urban	
roughness (m/km)	2.2	
mean rut depth (mm)	0	
skid resistance (SCRIM at 50km/h)	0.55	
surface Texture depth(mm)	0.7	

Table B. 9: Road improvement for town section lane addition for three year duration

Road improvement for town section				
General				
Name	lane addition for town section with 3yr duration			
Short code	LAts			
Existing Surface Class	Bituminous			
Improvement type	Lane addition			
Duration of work	3 year			
Intervention type	Scheduled			
Design				
Speed-Flow type	Four lane standard			
Road Class	Primary or trunk			
New pavement type	Asphalt Mix on Granular			
increasing carriageway (m)	8			
additional number of lane	2			
Intervention				
Start	2011			
Last application year	2099			
Road improvement for town section				
Cost				
unit cost (per km)	Financial		economical	
	20,000,000		17,000,000	
% of cost (Each year of the work period)	1	2	3	
	20	50	30	
salvage value	10%			
preparatory unit cost (ETB)	Financial		economical	
re-surfacing existing carriageway(m2)	114.11		97	
Patching(m2)	158.01		134.309	

Road improvement for town section		
crack sealing(m2)	49.86	42.381
Edge-repair(m2)	190.26	161.738
Pavement		
surface material	Asphaltic concrete	
surface structure number	5	
surface thickness(mm)	50	
relative compaction	97	
Geometry		
adral(m/s2)	0.1	
speed limit(km/hr.	60	
speed limit enforcement	1	
speed reduction factor	XNMT	1
	XMT	1
	Road side friction	1
Effect		
Traffic flow pattern	Commuter	
roughness (m/km)	2.2	
mean rut depth (mm)	0	
skid resistance (SCRIM at 50km/h)	0.55	
surface Texture depth(mm)	0.7	

Table B. 10: Road improvement for town section lane addition for five year duration

Road improvement for town section				
General				
Name	Realignment for town section with 3yr duration			
Short code	Rats			
Existing Surface Class	Bituminous			
Improvement type	Improvement			
Duration of work	3 year			
Intervention type	Scheduled			
Design				
Speed-Flow type	Four lane standard			
Road Class	Primary or trunk			
New pavement type	Asphalt Mix on Granular			
Intervention				
Start	2011			
Last application year	2099			
Cost				
unit cost (per km)	Financial		Economical	
	20,000,000		17,000,000	
% of cost (Each year of the work period)	1	2	3	
	20	50	30	
salvage value	10%			
preparatory unit cost (ETB)	Financial		Economical	
re-surfacing existing carriageway(m2)	114.11		97	
Patching(m2)	158.01		134.309	
crack sealing(m2)	49.86		42.381	
Edge-repair(m2)	190.26		161.738	
Pavement				

Road improvement for town section		
surface material	Asphaltic concrete	
surface structure number	5	
surface thickness(mm)	50	
relative compaction	97	
Geometry		
adral(m/s2)	0.1	
speed limit(km/hr.	60	
speed limit enforcement	1	
speed reduction factor	XNMT	1
	XMT	1
	Road side friction	1
Effect		
Traffic flow pattern	Commuter	
roughness (m/km)	2.2	
mean rut depth (mm)	0	
skid resistance (SCRIM at 50km/h)	0.55	
surface Texture depth(mm)	0.7	

Table B. 11: Road improvement for town realignment section for three year duration

Road improvement for town section	
General	
Name	lane addition for town section with 5yr duration
Short code	LAts
Existing Surface Class	Bituminous
Improvement type	Lane addition
Duration of work	5 year
Intervention type	Scheduled

<table>
<tr><th colspan="5">Road improvement for town section</th></tr>
<tr><th colspan="5">Design</th></tr>
<tr><td>Speed-Flow type</td><td colspan="4">Four lane standard</td></tr>
<tr><td>Road Class</td><td colspan="4">Primary or trunk</td></tr>
<tr><td>New pavement type</td><td colspan="4">Asphalt Mix on Granular</td></tr>
<tr><td>increasing carriageway (m)</td><td colspan="4">8</td></tr>
<tr><td>additional number of lane</td><td colspan="4">2</td></tr>
<tr><th colspan="5">Intervention</th></tr>
<tr><td>Start</td><td colspan="4">2011</td></tr>
<tr><td>Last application year</td><td colspan="4">2099</td></tr>
<tr><th colspan="5">Cost</th></tr>
<tr><td rowspan="2">unit cost (per km)</td><td colspan="2">Financial</td><td colspan="2">economical</td></tr>
<tr><td colspan="2">27,000,000</td><td colspan="2">23,205,000</td></tr>
<tr><td rowspan="2">% of cost (Each year of the work period)</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>15</td><td>10</td><td>10</td><td>40</td></tr>
<tr><td>salvage value</td><td colspan="4">10%</td></tr>
<tr><td>preparatory unit cost (ETB)</td><td colspan="2">Financial</td><td colspan="2">economical</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Patching(m2)</td><td colspan="2">158.01</td><td colspan="2">134.309</td></tr>
<tr><td>crack sealing(m2)</td><td colspan="2">49.86</td><td colspan="2">42.381</td></tr>
<tr><td>Edge-repair(m2)</td><td colspan="2">190.26</td><td colspan="2">161.738</td></tr>
<tr><th colspan="5">Pavement</th></tr>
<tr><td>surface material</td><td colspan="4">Asphaltic concrete</td></tr>
<tr><td>surface structure number</td><td colspan="4">5</td></tr>
<tr><td>surface thickness(mm)</td><td colspan="4">50</td></tr>
<tr><td>relative compaction</td><td colspan="4">97</td></tr>
<tr><th colspan="5">Geometry</th></tr>
<tr><td>adral(m/s2)</td><td colspan="4">0.1</td></tr>
<tr><td>speed limit(km/hr.</td><td colspan="4">50</td></tr>
<tr><td>speed limit enforcement</td><td colspan="4">1</td></tr>
</table>

Road improvement for town section		
Geometry		
speed reduction factor	XNMT	1
	XMT	1
	Road side friction	1
Effect		
Traffic flow pattern	Commuter	
roughness (m/km)	2.2	
mean rut depth (mm)	0	
skid resistannce (SCRIM at 50km/h)	0.55	
surface Texture depth(mm)	0.7	

Table B. 12: Road improvement for town section realignment for five year duration

Road improvement for town section	
General	
Name	Realignment for town section with 5yr duration
Short code	RAts
Existing Surface Class	Bituminous
Improvement type	Improvement
Duration of work	5 year
Intervantion type	Scheduled
Design	
Speed-Flow type	Four lane standard
Road Class	Primary or trunk
New pavement type	Asphalt Mix on Granular
Intervention	
Start	2011
Last application year	2099

Road improvement for town section				
Cost				
unit cost (per km)	financial		economical	
	20,475,000		17,403,800	
% of cost (Each year of the work period)	1	2	3	4
	20	50	30	40
salvage value	10%			
preparatory unit cost (ETB)	financial		economical	
Patching(m2)	158.01		134.309	
crack sealing(m2)	49.86		42.381	
Edge-repair(m2)	190.26		161.738	
Pavement				
surface material	Asphaltic concrete			
surface structure number	5			
surface thickness(mm)	50			
relative compaction	97			
Geometry				
adral(m/s2)	0.1			
speed limit(km/hr.	60			
speed limit enforcement	1			
speed reduction factor	XNMT		1	
	XMT		1	
	Road side friction		1	
Effect				
Traffic flow pattern	commuter			
roughness (m/km)	2.2			
mean rut depth (mm)	0			
skid resistance (SCRIM at 50km/h)	0.55			
surface Texture depth(mm)	0.7			

Appendix C: Spearman's Rank Table

Table B. 13: Spearman's rank

Sample Size(n)	p=0.05	p=0.025	p=0.01
4	1.0000	_	_
5	0.9000	1.0000	1.0000
6	0.2860	0.8857	0.9429
7	0.7143	0.7857	0.8929
8	0.6429	0.7381	0.8333
9	0.6000	0.7000	0.7833
10	0.5636	0.6485	0.7455
11	0.5336	0.6182	0.7455
12	0.5035	0.8574	0.7091
13	0.5035	0.5604	0.6783
14	0.4825	0.5385	0.6484
15	0.4464	0.5214	0.6264
16	0.4294	0.5029	0.6036
17	0.4142	0.4877	0.5824
18	0.4041	0.4716	0.5662
19	0.3912	0.4596	0.5501
20	0.3805	0.4466	0.5218
21	0.3701	0.4364	0.5091
22	0.3608	0.4252	0.4975
23	0.3528	0.4160	0.4862
24	0.3443	0.4070	0.4757
25	0.3369	0.3977	0.4662
26	0.3306	0.3901	0.4571
27	0.3242	0.3828	0.4487
28	0.3180	0.3755	0.4401
29	0.3118	0.3685	0.4325
30	0.3063	0.3624	0.4251
40	0.2640	0.3128	0.3681
50	0.2353	0.2791	0.3293
60	0.2144	0.2545	0.3005
70	0.1982	0.2354	0.2782
80	0.1852	0.2201	0.2602
90	0.1745	0.2074	0.2453
100	0.1745	0.1967	0.2327

Appendix D: HDM-4 Outputs

Amount Emissions gasses in gram without delay project and with delay in over total life of the project

Table B. 14: Amount of gasses emissions without delay project

Without delay							
	Amount Emissions gasses in gram						
Year	Hydrocarbon (HC)	Carbon monoxide (CO)	Nitrous oxide (NO)	Sulphur dioxide (SO2)	Carbon dioxide (CO2)	Particulates (Par)	Lead (Pb)
2011	7.09	45.45	18.34	0.53	1,298.22	0.24	75.33
2012	7.59	48.66	19.64	0.56	1,389.74	0.25	80.64
2013	8.13	52.09	21.02	0.60	1,487.72	0.27	86.33
2014	6.68	38.09	17.74	0.51	1,328.58	0.24	80.81
2015	7.15	40.81	19.00	0.55	1,423.41	0.26	86.55
2016	7.53	43.01	20.02	0.58	1,499.91	0.27	91.15
2017	7.94	45.31	21.10	0.61	1,580.48	0.29	95.98
2018	8.35	47.74	22.23	0.65	1,665.22	0.30	101.04
2019	8.80	50.30	23.42	0.68	1,754.33	0.32	106.35
2020	9.27	52.98	24.67	0.72	1,848.00	0.33	111.92
2021	10.01	57.25	26.66	0.77	1,997.24	0.37	120.84
2022	10.81	61.85	28.81	0.83	2,157.81	0.40	130.40
2023	11.66	66.80	31.12	0.91	2,330.67	0.43	140.68
2024	12.57	72.12	33.61	0.98	2,516.84	0.46	151.71
2025	13.57	77.84	36.28	1.06	2,717.43	0.49	163.57
2026	14.63	84.03	39.18	1.15	2,934.52	0.53	176.37
2027	15.79	90.69	42.30	1.24	3,168.72	0.57	190.12
2028	17.02	97.85	45.67	1.33	3,421.54	0.63	204.94
2029	18.35	105.55	49.34	1.45	3,696.17	0.67	220.91
2030	19.77	113.84	53.32	1.56	3,996.59	0.73	238.17
2031	21.30	122.68	57.64	1.70	4,321.30	0.78	256.73
2032	22.94	132.10	62.32	1.83	4,673.87	0.86	276.83
2033	24.71	142.09	67.43	2.00	5,057.60	0.92	298.59

Table B. 15: Amount of gasses emissions with delay project

With delay							
	Amount Emission gases in gram						
Year	Hydrocarbon (HC)	Carbon monoxide (CO)	Nitrous oxide (NO)	Sulphur dioxide (SO2)	Carbon dioxide (CO2)	Particulates (Par)	Lead (Pb)
2011	7.09	45.45	18.34	0.53	1,297.97	0.24	75.32
2012	7.59	48.64	19.63	0.56	1,389.22	0.25	80.61
2013	8.12	52.07	21.01	0.60	1,486.89	0.27	86.28
2014	8.69	55.73	22.48	0.64	1,591.42	0.29	92.34
2015	9.30	59.64	24.06	0.70	1,703.30	0.31	98.83
2016	7.45	42.64	19.77	0.57	1,479.39	0.27	89.80
2017	7.79	44.62	20.69	0.60	1,548.14	0.28	93.94
2018	8.16	46.71	21.67	0.63	1,621.03	0.29	98.30
2019	8.54	48.93	22.69	0.65	1,697.88	0.31	102.87
2020	8.94	51.25	23.78	0.69	1,778.77	0.32	107.68
2021	9.58	54.96	25.50	0.74	1,907.59	0.34	115.37
2022	10.28	58.95	27.35	0.80	2,046.22	0.37	123.62
2023	11.01	63.25	29.35	0.85	2,195.46	0.40	132.47
2024	11.82	67.87	31.49	0.91	2,356.20	0.43	142.00
2025	12.67	72.84	33.82	0.99	2,529.38	0.46	152.21
2026	13.63	78.42	36.41	1.06	2,723.70	0.50	163.66
2027	14.67	84.44	39.23	1.14	2,933.96	0.53	175.99
2028	15.78	90.94	42.26	1.24	3,161.45	0.57	189.30
2029	16.98	97.95	45.55	1.33	3,407.73	0.62	203.65
2030	18.28	105.50	49.12	1.44	3,675.23	0.67	219.15
2031	19.63	113.35	52.88	1.55	3,958.62	0.72	235.31
2032	21.07	121.77	56.98	1.68	4,266.64	0.78	252.75
2033	22.61	130.73	61.41	1.81	4,600.19	0.83	271.60
2034	24.28	140.25	66.23	1.96	4,962.19	0.91	292.01
2035	26.08	150.28	71.50	2.12	5,356.14	0.98	314.14