



**ADDIS ABABA UNIVERISTY INSTITUTE OF
TECHNOLOGY**

**SCHOOL OF CIVIL & ENVIRONMETAL
ENGINEERING**

**“Assessment of the reliability of the traffic forecast and its
impact on pavement design and service life”**

(A Case Study Three Ethiopian Road)

Thesis submitted to the school of graduate studies of Addis Ababa
Institute of Technology as Partial fulfillment of the requirement
for the degree of masters’ science in civil engineering
(Road and Transport Engineering)

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ABSTRACT

Unrealistic or incomplete estimates of traffic characteristics during design process will affect determination of pavement type, performance of the pavement structures for the design life as well as construction and maintenance cost. Thus, accurate estimation of traffic loading is needed for a better design of pavement structures, easy of construction and maintenance as well as cost effective.

Three road projects here selected for this study, the one Shashemene-Dodola pavement design which is overestimated future traffic and result high capital cost of construction (increase use of construction materials, resources). The other two projects Alemgena-Butajira and Debrebrihan-Karakore pavement design are underestimated future traffic and it pre-matured pavement failure which results a high capital cost of maintenance and increases vehicle operation cost.

This study assesses the existing practice of traffic forecasting for pavement design and recommend potential improvements of procedures. This process and its results have been coordinated in order to be incorporated in traffic volume estimation. Two traffic growth rate estimation method is adopted i.e, Regression and Elasticity Analysis from traffic counts and for determination of forecasted traffic volume.

The study result indicates, the change between actual traffic volume which is counted during the road service time by Ethiopian Roads Authority and traffic volume estimation of using the above methods is within 0% to 4% whereas, the change between actual traffic and design traffic is -87% to 51%.

From the result of calculated cumulative standard axel load and determining traffic class of the pavement, analyzing the difference in traffic class of the design traffic and study traffic is carried out. Finally determining the impact of inaccurate traffic volume and loading estimation on pavement performance and analyses additional cost of construction and maintenance due to inaccurate traffic volume estimation.

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List of Abbreviations

AACRA	Addis Ababa city Road Authority
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation officials
DBST	Double bitumen surface treatment
DF	Directional Distribution factor
EC	Elasticity coefficient
ERA	Ethiopian Roads Authority
ESAL	Equivalent Single Axel Load
FDRE	Federal Democratic Republic of Ethiopia
GDP	Domestic Growth Product
HCV	Heavy Commercial vehicle
HTG	Historical Traffic Growth
PCI	per Capital Income
PGR	Population Growth Rate
R	Traffic Growth Rate
RSDP	Road Sector Development Program
TC	Traffic class

CHAPTER ONE INTRODUCTION

1.1 Background of the Research

According to Federal Democratic Republic of Ethiopia ministry of transport Road Sector Development Program (RSDP) phase 5 October, 2015 report, Ethiopia invest high capital cost to enhance development objectives and the living standard of the population all over the country. Accordingly, Ethiopian Roads Authority (ERA), on behalf of the Federal Democratic Republic of Ethiopia (FDRE) is implementing various road projects including new road construction and rehabilitation to expand the Road Network all over the country.

According to three cycle traffic count report of ERA, Traffic levels across Ethiopia vary considerably from region to region and roads are normally designed for 20- 30-year life expectancy. However, some of the constructed roads will lose their ride ability due to poor performance of pavement structures resulted from inaccurate estimation of traffic volume and loading and thus will causes premature pavement failure. when constructed road will subjected to lower traffic than that of estimated traffic this also cause high cost of Pavement construction.

One of the largest challenges facing Local Authorities is the rapidly growth of Heavy Commercial Vehicle (HCV) number being carried on the roads which were not considered during design to carry this increase in traffic and estimating reliable percentage of generated and diverted traffic. A better understanding of the impact of traffic on pavement damage will provide useful information on pavement design methods.

Traffic forecast is routinely used to justify and to dimension the construction of transportation infrastructure project. In order to estimate the accuracy of such forecast it is necessary to compare forecasted with actual traffic. Actual traffic is counted for the year of operation and forecasted traffic is the traffic estimate for the year of operation as estimated at the time of design

The need for improved traffic estimation procedures has been emphasized by several studies that have found that previously available data was not adequate. This deficiency has been attributed to limit the amount of data not representative of the actual traffic condition because of overloaded trucks avoiding weighting scales and inaccurate traffic volume forecast. In addition, forecasting procedure did not reflect the increases in legal load limit, the significance increases in number of heavy truck or the shift toward larger vehicle type that have occurred in recent year.

From assessment of actual traffic volume and loading with design/forecasted traffic volume and loading data collected from Ethiopian Road Authority result shows, some of the road project in Ethiopia traffic forecasting procedure is improbable with actual traffic volume and axel load distribution during the service life. These critically affect pavement design and

performance during the design service life. Reliable estimation of traffic loading is needed for a better design of cost-effective pavement structures, easy of construction and maintenance.

To reduce errors in pavement design and axel load distribution level of accuracy for data collection and reliability forecasting methodology is mandatory.

1.2 Statement of the Problem

In pavement design, overestimation of design traffic may lead to incorrect selection of pavement type, overdesign of pavement thickness which in turn lead to high capital cost of construction (increase use of construction materials, resources). On the other hand, underestimation of design traffic may lead the pavement for pre-matured failure which causes a high capital cost of maintenance and increases vehicle operation cost.

From the study of selected three road project the one Shashemene-Dodola is overestimate future traffic which directly increases thickness of sub layer material tends to increases quantity of work and results increase initial cost of construction. And the other two project i.e Alemgena-Butajira and Debrebrihan-Kara kore are underestimated the future traffic this results, increase vehicle operation cost, increases road deterioration, lower design speed, ensuing in higher time costs and also subject the road to routine maintenance actions are condition responsive and also reduced pavement life.

Excess traffic load will lead to the road authority remedying the damage by reconstruction/rehabilitation at an earlier date than would have not been the case without overloading vehicles.

The impact of excess traffic on a pavement is to accelerate its deterioration and to cause the pavement to reach its terminal level, usually as a result of unacceptably high levels of rutting and roughness, much sooner than would have been without excess traffic. This implies significant portion of the damage caused by inaccurate traffic estimation.

1.3 Significant of the Study

Need for traffic data is one of the basic data in the design of highway system, which provides movement of people and/or goods from one point to another. The designers attempt to provide both highway geometries to satisfy future capacity needs and a pavement system to support traffic volume and loading throughout the design period.

Improved estimates of current traffic loadings based on accurate traffic data would lead to improved estimates of historical traffic loadings and better forecasts of traffic loadings during the design period. Thus, accurate estimation of traffic loading is needed for a better design of cost-effective pavement structures, easy of construction and maintenance.

Several traffic parameters and statistics were identified as important factors to be considered in forecasting future traffic demands. However, forecasting procedures may sometimes not reflect change in legal load limits, availability of alternative routes, introduction into the overall transportation system of alternative modes of transport, development and road network master plan, the significant increase in the number of heavy trucks, or the shift toward larger vehicle types, overloaded trucks avoiding weighing scales, inadequate traffic sampling programs and soon.

ERA and other local authority have no prepared manuals and guidelines which explains method of traffic growth rate estimation and calculating directional distribution factor. In most case due to lack such manuals and guidelines, traffic class estimated for engineering design study may reduce accuracy of future traffic estimation. Here, in this study two methods of traffic growth rate estimation and directional distribution factor is adopted.

Accordingly, local and regional road authority has to develop as well update manuals and guidelines for realistic traffic volume forecasting method, including the method used in this study.

1.4 Objective of the Study

The major objective of this study is to assess the existing practice of traffic forecasting in pavement design and recommend potential improvements of procedures. This process and its results have been coordinated in order to be incorporated in traffic volume estimation.

Specifically, to address:

1. Reliability of factors used for traffic forecast i.e.
 - Traffic growth rate
 - Directional distribution factor
2. To identify factors that affect traffic growth and establish to what extent is there effect on traffic volume study.
3. To suggest on if any additional factor that affecting traffic study

1.5 Scope & Limitation of the study

Road is one of the main factors in the development of a society/community and huge financial amount is invested in the design, construction and maintenance of road projects.

Among others factors, traffic forecast is used to dimension the construction of transportation infrastructure project. Accuracy in traffic forecast is considerable point to the effective allocation of scarce budget. Incorrect traffic forecasting will result wrong thickness design and inadequate materials component which directly affect the durability /serviceability of pavement.

Traffic growth rate (r) and directional distribution (D) are two of major factors in traffic forecasting and pavement design. Implementing realistic method of estimation for growth rate and directional distribution in pavement design saves initial investment cost or cost of maintenance this also increases serviceability of pavement and reduces vehicle operation and maintenance cost.

However, other factors account in traffic forecast for pavement design i.e seasonal conversion factor, night factor and equivalency factor are considered to be the same to that of used in design. To overcome with this limitation, further study on checking reliability of seasonal conversion factor, night factor and equivalency factor has to be entitled.

Finally, the study at hand directs its attention to determine up-to-date growth factors for traffic which are calculated from the change between the reference year traffic Volume obtained from Ethiopian Roads Authority and estimate traffic volume during design stage and to check the reliability of directional distribution factor.

1.6 Structure of the thesis

This thesis has been divided in to five chapters. The first chapter is the introductory part which includes general background, significance, objective and scope of the study. A brief literature review on fundamental principle of pavement design, global and local existing traffic forecasting guideline and practice, effect of traffic volume and loading on pavement service life has been discussed in the second chapter. Third chapter research methodology describes study area, research approach and variables, data requirement and analyses. The fourth chapter includes research result by means of comparing design traffic with actual and method adopted in the thesis also include research analysis and discussion. In the last chapter, chapter five conclusions and recommendation which are from this research are given. Finally, appendices and reference material are attached at the end of the thesis.

CHAPTER TWO LITERATURE REVIEW

2.1 Introduction

Transportation involves the movement of people and goods from one place to another. It is indispensable as it connects peoples' destinations. The activities in a particular location affect the volume of transport demand; hence transport is seen as a derived demand. The transport subsystem includes the transport networks, the vehicles, operating regimes, policies, regulations and the infrastructures that facilitate effective movement of people and goods from their origins to their preferred destinations. Roads or highways are transport infrastructures and they are key aspects of the transport system, because the well-being, growth and expansion of any city, whether developed or developing is mainly related to the prevailing road developments.

Traffic forecasting have steps and procedure to estimate and consider different factors, accordingly Ethiopian Road Authority (ERA) and Addis Ababa city Road Authority (AACRA) pavement design manuals, International Manuals and others forecasting procedure will be referenced.

2.2 Principles of Pavement Design

2.2.1 Function of Road Pavement

The road pavement must serve two basic functions: it must perform structurally and at the same time meet functional and operational requirements.

In terms of structural performance, it must be strong enough to support the axle loading from traffic using the road and in terms of functional and operational performance, the road pavement must be wide enough and of suitable geometry to permit all vehicles to safely operate at an acceptable speed.

Therefore, road pavements designed to carry the forecasted traffic and to operate in the gradual deterioration phase. If the pavement loading increases due to increased loading, this will shorten the gradual deterioration phase, which in turn brings forward the rapid deterioration phase of the pavement. The result is a corresponding decrease in the pavement life. As a result, the amount of maintenance required to maintain the road in acceptable condition will increase substantially, and the pavement will require reconstruction or rehabilitation to strengthen it to carry the additional loading earlier in the life of the pavement.

2.3 Traffic Analysis in pavement design

Traffic analysis is needed for a variety of purposes; including planning, design, priority setting and improvement as well as allocation of expenditures of maintenance. Traffic analysis is the result of ESAL, which is the base of determining traffic class and pavement design. It is also the process of collecting traffic data (traffic count), equivalency factor determination of different vehicle types, traffic forecast and finally converting traffic load to cumulative single axle load.

In the process of converting AADT to ESAL estimation of traffic growth rate (r) of design period (n), equivalency factor (ef), seasonal conversion factor (sf), directional distribution (d) and lane distribution factor (ld) determination is taken out. Accuracy of traffic analysis is a point of considerable importance to effective allocation of scarce funds for pavement design, geometric design and impacts of mode of transport. Therefore, selection of these factors accurately is very critical, if small change in factors may result in wrong estimation of traffic class as well as pavement design.

2.4 Future Traffic Generators

1. Vehicle Ownership

Overall Growth - The national vehicle fleet has shown a constant growth. The estimate average annual growth since 2004 is:

- 7.2% - All vehicles, including motorcycles
- 3.6% - All vehicles, excluding motorcycles

Although the National fleet is relatively small (about 27 vehicles, excluding motorcycles, per thousand population), the Timorese economy is growing rapidly, and so is its vehicle fleet. (Timor Leste Road Network Upgrading Project (RNUP) ADB LOAN NOS: 2857-TIM)

2. Motorcycles

The increase in personal income, attributed to growth in the Petroleum Sector, results in increased vehicle ownership, in particular of motorcycles, by first-time vehicle owners. Motorcycles are favoured because they: (i) Can operate off-road, in areas where other vehicles cannot operate; (ii) Can travel over bad roads, in essence serving as a cheap personal substitute to 4WD; and (iii) Are relatively cheap to buy and operate. (Timor Leste Road Network Upgrading Project (RNUP) ADB LOAN NOS: 2857-TIM)

3. Trucks

There has also been quite an increase in Truck ownership and truck traffic, which seems to be attributed to growth in construction. And it is expected to grow even further, as

infrastructure/ construction expands, in particularly of the Petroleum Sector. (Timor Leste Road Network Upgrading Project (RNUP) ADB LOAN NOS: 2857-TIM)

4. Private Cars

Growth in purchase of private cars (salon) has not materialized yet. In fact, car usage, due to poor road conditions, has fallen, replaced by 4WD. However, experience shows that with further increase in personal income, and improved road conditions, some individual already owning motorcycles will shift to cars. And eventually, within the next few years (say 2015-16) private car ownership will increase as well. (Timor Leste Road Network Upgrading Project (RNUP) ADB LOAN NOS: 2857-TIM)

5. Transport Growth with the GDP

Typically, in developing economies, starting from a low base, such as Timor Leste, vehicle ownership growth rate increases faster than the GDP. A “rule of thumb” sets this ratio to be 1.2-1.5 faster than the GDP. Based on past performance, it is expected that the GDP (excluding oil) of the Timorese economy will continue to grow at about 10% per annum. (Timor Leste Road Network Upgrading Project (RNUP) ADB LOAN NOS: 2857-TIM)

2.5 Existing practice of traffic forecasting

The traffic forecast for the expected future traffic along the route has been established using the base year traffic that is the established AADT for the proposed road the traffic growth rate estimates with respect to each vehicle group. (ERA pavement design manual, 2013)

The estimation of traffic growth rates has been based on the review of trends in the economic development and historical traffic. The required Macro economic data were collected from secondary sources that include the Ministry of Finance and Economic Development (MoFED) and Central Statistics Authority (CSA). The following parameters were thus considered for the estimation of traffic growth rates, used in the traffic projection for the proposed road that are often considered in traffic projection practices. (ERA pavement design manual, 2013)

- Historical traffic growth trend on the existing over the last 10 years period where data is available from ERA;
- Trend in economic development in terms of growth in Gross Domestic Product (GDP) and per capita income and their relationship with traffic growth.

From trend in economic development in terms of growth in Gross Domestic Product (GDP), three traffic forecast scenarios measured:

High forecast: this scenario assumes average economic growth rate higher in real terms, as realised during the years.

Medium forecast: this scenario assumes average economic growth rate average in real terms, as realised during the years.

Low forecast: this scenario assumes average economic growth rate lower in real terms, as realised during the years.

The medium traffic growth scenario is considered in the traffic forecast that represents the most likely alternative reflecting the true trend in the estimation of traffic growth rates used to forecast future traffic over the two forecast periods defined. The growth rate of other recent feasibility study has been studied from adjacent road of those has the similar scope. The other two scenarios would certainly bias the traffic forecast as they are established based on extreme assumptions. Based on above two analyses the consultant considers reasonable to adopt a traffic growth rate for the project road for design life. (ERA pavement design manual, 2013)

Final traffic growth rate estimated by vehicle type the medium traffic growth rate scenario is considered in traffic forecast that represent the most likely alternative reflecting the realistic trends in the estimation of growth rate used to forecast future traffic over the design period. (ERA pavement design manual, 2013)

In forecasting traffic growth rates for freight traffic volume is given by, a simple model that combines the effect of GDP growth on travel demand and for passenger traffic were computed using a model that combines the effect on travel demand of population growth and of changes in per capita incomes. (Feasibility study report, CWCE section 3. Traffic data)

Other things being equal, travel demand can be expected to grow in line with growth in population. With a rise in disposable income (i.e. when GDP growth exceeds growth in population), travel demand will be expected to be stimulated even further. Income elasticity is a measure of responsiveness of demand to change in per capital income; generally, a given rise in per capita income is expected to result in increased volume of traffic by a higher margin than the rise in per capita income. In the same manner, demand for freight transport is related to growth in national income, measured in terms of GDP growth. (Feasibility study report, CWCE section 3. Traffic data)

Two models of the following forms were, therefore, applied:

$$\Delta FT = e (\Delta GDP)$$

Where, ΔFT fright traffic

e income elasticity of fright traffic

ΔGDP change in GDP

$$\Delta PT = \Delta P + e (\Delta C)$$

Where,

Δ PT passenger traffic

Δ P change in population

e income elasticity of passenger traffic

Δ C change in per capital income

The structural number is an abstract number expressing the structural strength of a pavement required for given combinations of soil support (MR), total traffic expressed in equivalent 18-kip single axle loads, terminal serviceability, and environment. The required SN must be converted to actual thickness of surfacing, base and sub base, by means of appropriate layer coefficients representing the relative strength of the construction materials. (AASHTO design of pavement structure part one, section one)

The basic design equations used for flexible and rigid pavements in this Guide are as follows: (AASHTO design of pavement structure part one, section one)

Flexible Pavements

$$\text{Log}_{10}(w_{18}) = ZR * S_0 + 9.36 * \log_{10}(SN+1) - 0.2 + \frac{\log_{10}(\Delta PIS / 4.2 - 1.5)}{0.4 + (1094 / (SN+1))^{5.19}} + 2.32 * \log_{10}(MR) - 8.07$$

Where

w₁₈= predicted number of 18-kip equivalent single axle load applications

ZR = standard normal deviate,

S₀ = combined standard error of the traffic prediction and performance prediction,

Δ PIS=difference between the initial design serviceability index po the design terminal serviceability index pt and,

MR=resilient modules (psi)

SN is equal to the structural number indicative of the total pavement thickness required:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

a_i= ith layer coefficient

D_i=ith layer thickness

m_i=ith layer drainage coefficient

TAFIS applies Model 3.1 on sites with a non-significant regression, with less than five historical traffic count data points. Sites surrounding the non-significant regression area must have a significant regression. Model 3.1 functions by taking an average of the AADT at the two surrounding sites and then finds a proportional relationship to the AADT estimates at the non-significant site. Therefore, the equation for Model 3.1 is: (Wisconsin Department of Transportation, Transportation Planning)

$$\text{FORECAST} = \left(\frac{((\text{AADT}_0 / \text{AADT}_{0-1}) + (\text{AADT}_0 / \text{AADT}_{0+1}))}{2} \right) \text{Average AADT}_x$$
$$\left(\frac{(\text{AADT}_0 + \text{AADT}_{0-1})}{2} \right)$$

The exercise of traffic growth rate estimation has been carried out by us using the elasticity approach. The elasticity method relates traffic growth to changes in the related economic parameters. According to IRC-108-1996, elasticity based econometric model for highway projects could be derived in the following form: (Hemanth. M Kamplimath, Varuna. M, Vijay Kumar, Yashas Bhargav, 2013)

$$\text{Log } e(P) = A_0 + A_1 \text{Log } e(EI)$$

Where:

P = Traffic volume (of any vehicle type)

EI = Economic Indicator (GDP/NSDP/Population/PCI)

A₀ = Regression constant;

A₁ = Regression co-efficient (Elasticity Index)

Based on the moderated elasticity values and the projected economic/demographic indicators and with the given model as follows, the future average annual compound traffic growth rates by vehicle type are estimated.

Passenger Vehicles:

$$\text{Traffic Growth Rate} = [(1+rp) (1+ rpci \times Em) - 1]$$

Goods Vehicles:

$$\text{Growth Rate for Goods Vehicles} = \text{Elasticity Value} * \text{NSDP Growth Rate}$$

Where,

rp= Population Growth,

rpci= Per capita Income Growth,

Em= Elasticity

2.6 pavement design procedure

➤ ERA design procedure

In order to determine the cumulative number of vehicles over the design period of the road, the following procedure should be followed: (ERA pavement design manual, 2013)

Determine the initial traffic volume, AADT(m)₀, of each traffic class (m) using the results of the traffic survey and any other recent traffic count information that is available. (ERA pavement design manual, 2013)

Estimate the annual growth rate “i” expressed as a decimal fraction, and the anticipated number of years “n” between the traffic survey and the opening of the road.

For each vehicle class, estimate the traffic in the first year that the road is opened to traffic, this is given by (ERA pavement design manual, 2013)

$$AADT(m)_1 = AADT(m)_0 (1+i)^n$$

For each vehicle class, add the estimate for diverted traffic and for generated traffic if any are anticipated.

For structural pavement design the cumulative traffic loading of each of the motorized vehicle classes over the design life of the road in one direction is required. For a given class, m, this is given by the following equation: (ERA pavement design manual, 2013)

$$T(m) = 0.5 \times 365 \times AADT(m)_0 [(1+i/100)^n - 1]/(i/100)$$

Where

T (m) = the cumulative traffic of traffic class m

AADT (m) 1 = The AADT of traffic class m in the first year

n = the design period in years

i = the annual growth rate of traffic in percent

➤ AASHTO Design Procedure

The AASHTO methodology and design procedures for rehabilitation of existing pavements is presented in PART III of the Guide [AASHTO 93] and would apply to the design of final pavement structures. The design steps to determine the required final stage pavement thickness as outlined in the Guide are:

1. Assessment of existing pavement design and construction
2. Traffic analysis
3. Condition survey
4. Deflection testing
5. Coring and materials testing
6. Determination of required structural number for future traffic (SN_f). The effective design subgrade modulus is determined by back calculation from deflection data.
7. Determination of effective structural number (SN_{eff}) of the existing pavement. The determination of SN_{eff} is based upon an assumption that the structural capacity of the pavement is a function of its total thickness and overall stiffness. The effective modulus of the pavement layers is back calculated from FWD deflection data.
8. Determination of overlay thickness. The thickness of the AC overlay is computed as follows:

DARWin 3.0 [DARWIN 97] is used to analyze the FWD deflection data to determine the back calculated subgrade and pavement moduli. These values along with other required design inputs are used to determine pavement overlay requirements in accordance with the design methodology presented in the AASHTO Guide. Familiarity with the AASHTO Guide and knowledge of the requirements of this design manual, AASHTO design principle sand FWD testing methods are required in order to use the DARWin program as an effective design and analysis tool.

➤ **British road design**

The thicknesses of a road pavement are dependent upon the number, weight and speed of load repetitions from the tyres of commercial vehicles. This has led to the concept of millions of standard axles during the design life of the road (m.s.a.) as the parameter for thickness design, though for very lightly trafficked applications the number of commercial vehicles may be more appropriate. The total number of Standard Axles is built up of four factors: - (Kent County Council: Road Pavement Design Guide)

- (1) Number of commercial vehicles per lane per day.
- (2) Their vehicle wear factor i.e. how many standard axles per vehicle.
- (3) The design life of the pavement.
- (4) The anticipated growth in commercial vehicles over the design life.

The speed of load repetitions has more effect on the performance of the materials in the surfacing layer rather than its thickness and is taken into account in designing the required deformation resistance. (Kent County Council: Road Pavement Design Guide)

➤ **South Africa pavement design**

Pavement Design covers many aspects of pavement design, including design considerations, estimating design traffic, pavement investigation and design processes, structural capacity estimation, and software available for pavement design. (South African Pavement Engineering Manual Chapter 10)

Economic assessments necessary for evaluating alternative pavement designs. The structural capacity estimation methods for flexible pavements are described, including the South African Mechanistic-empirical Design Method and the Pavement Number method, as well as other methods used in South Africa. For concrete and block pavements, the Mechanistic-empirical method is described, with other older methods. The suitability of all the structural capacity estimation methods for particular applications is provided. (South African Pavement Engineering Manual Chapter 10)

Appropriate structural design methods for new design include: (South African Pavement Engineering Manual Chapter 10)

- TRH4 (1996) catalogue and other industry catalogues
- DCP method
- SAMDM for flexible pavements
- Mechanistic-empirical design method for concrete pavements
- Pavement Number method
- Mechanistic-empirical design method for block pavements

2.6 Impact of traffic volume and loading on pavement service life

Significantly increasing traffic volume is a serious problem in many of developing country because it incurs huge cost in term of maintenance and rehabilitation of road network (chan, 2008). Based on Africon (2011) report 15-20% of pavement is exposed to high traffic volume had caused 57% of the damage to the road. This implies significant portion of the damage caused by inaccurate traffic estimation.

Over estimation of traffic also increase severity of traffic hazard, especially regarding heavy vehicles braking system and additional braking involved. Major impact of traffic volume and loading includes:

2.6.1 Economic impact

The marginal cost associated with unexpected traffic on a road comprise three main components. The first one is increase vehicle cost to other vehicles (Africon Ltd, 2011). This increase in vehicle operation costs reflect road deterioration resulting in increased vehicle operation costs and lower speed, ensuing in higher time costs. It should be noted that vehicles operation costs and transport costs are not the same. Transport costs incorporate VOCs, environment, accident, etc. while vehicle operating costs are costs incurred by vehicle owners excluding external costs. Secondly assuming that routine maintenance actions are condition responsive, excess traffic load on a road would lead to earlier and more frequent maintenance intervention. The third cost is reduced pavement life. Excess traffic load will lead to the road authority remedying the damage by reconstruction/rehabilitation at an earlier date than would have not been the case without overloading vehicles.

When both time and cost factors are combined, excess traffic loading results in increased cost to road agencies. When this adverse impact is extrapolated to a large proportion of the country's road network, road agencies costs are uncertainly high (Michaeil lan pinard, 2010). As a result of excess traffic, the actual service life performance of the pavement is reduced. This in turn results in major reconstruction/ rehabilitation work to be carried out sooner that the intended design life.

2.6.2 Reduction of Pavement life

The impact of excess traffic on a pavement is to accelerate its deterioration and to cause the pavement to reach its terminal level, usually as a result of unacceptably high levels of rutting and roughness, much sooner than would have been without excess traffic (Michael lan pinar,2010).

2.6.3 Increase in maintenance and rehabilitation cost

Chan (2008) also made assessment was on future annual periodic maintenance required with excess traffic. A road section, G206, in Anhui province, china was considers analyzing economic loss due to excess traffic. Study additional cost of excess traffic management was also included. However, increase in vehicle operating cost associated with increase in roughness of the road due to excess traffic was not included.

2.7 Source of Error in Traffic Forecasting

The science and art of travel forecasting immersed in period of transition equally for the dissatisfaction with model performance as for the inherent interest in building a better mouse trap. However, the conventional modelling process is so firmly institutionalized that only a full replacement for the system, or modular and integrable component parts, could be accepted in practice and satisfy institutional constraints. The institutional inertia placed much of onus for model improvement in academia, where well-defined contributors to the state of the art often provide only marginal value to the state of the practice or to any comprehensive innovation (McNally, 2007)

“forecasters generally do poor job of estimating the demand for transportation infrastructure projects” (Flyvbjerg et al.,2006)

Very little ex-post analysis has been done on the accuracy of forecast; first because data that allow the calculation of inaccuracies in traffic forecast unfortunately are relatively rare. For public sector projects, often the data are simply not produced. And even where the intention is to produce the data, projects may develop in ways that it is difficult to impossible to compare forecast with actual traffic (Flyvbjerg et al.,2006). Quinet (1998) argues that when the topic is traffic, it is difficult to compare comparable things; the situation in which the project is implemented is often different from that defined for the forecast.

Transport forecasts result from the combination of different models, for different purpose and of different nature, in which each one has number of parameters. Data source estimation procedures and hypothesis.

Quinet (1998) distinguishes three sources of inaccuracy: the inadequacy of the model structure; the inaccuracy of the current data; and the uncertainty of prediction of the future value of exogenous variables.

Flyvbjerg et al. (2003) in different way, classify the sources of inaccuracy in seven groups: methodology applied; poor database; discontinuous behavior and influence of complementary factors; unexpected change of exogenous factors; unexpected political activity or missing realization of complementary policies; implicit appraisal bias of the consultant; and appraisal bias of the project promoter.

Three main groups of source of inaccuracy in traffic forecast: the pure uncertainty, related to the fact that the future is uncertain by its nature; data and methodological sources, associated with the availability and quality of data the model and assumptions used; and the behavioral sources, namely optimism and opportunism (Antonio NUNEZ, 2007).

2.7.1 Uncertainty about the future

One of the problems with the forecast assessment of model is that it is very difficult to predict the future values of the explanatory variables. Growth factors are used to estimate future year trip matrix. The development of appropriate growth factors depends on forecasts of demographic and economic variables such as population, employment, household income and gross domestic product for the study area. Errors in such assumption can have a significant impact on growth forecast (Antonio NUNEZ, 2007).

Sudden change of exogenous factors can hardly be controlled by demand modelling and scenario techniques. For instance, abrupt social and political change such as breakdown of the communist regimes in the east-west relationship in Europe are predictable. Another example is the development of energy prices, which underlies influences that are hard to predict, as for instance in the cases of the two oil crises in 1973 and 1979 (Flyvbjerg et al., 2003).

2.7.2 Methodology assumption and data

2.7.2.1 Model Weaknesses and Inadequacies

Models are simplifications by definition. The level and way of simplifying the reality can strongly affect the result a model is able to produce. Different models are used in transportation demand modelling. Each parameter, each functional form specification will impact the result in a certain way. Moreover, models rely on numerous hypotheses about human behavior that are seldom validated (Antonio NUNEZ, 2007).

Furthermore, the sequential and aggregate nature of transportation forecasting has come under much criticism. While improvement have been made, in particular giving an activity-base to travel demand, much remains to be done (Antonio NUNEZ, 2007).

Ascher (1978) has pointed out that forecasting is critically dependent on the use of assumptions. He wrote that:

The core assumption undelaying a forecast, which represent the forecaster's basic outlook on the context within the specific forecast trend develop, are the major determinants of forecast accuracy. Methodologies are basically the vehicle for determining the consequences or implications of core assumptions that have been chosen more or less independent of the specific methodologies. When the core assumptions are valid, the choice of the methodology is either secondary or obvious. When the core assumption fails to capture the reality of the future context, other factors such as methodology generally make little difference; they cannot "save" the forecast.

2.7.2.2 Data Availability and Quality

In the field of transportation research, nothing is more valuable yet simultaneously more limiting to the valuation of theory and models than are data (McNally, 2007). Data are seldom or never of the quality we would like them to be. The quality of data as traffic forecast model input represent one of the major sources of potential forecasting error. These data include traffic counts, transportation network characteristics, travel cost, the location and size of household and car ownership to list a few.

Flyvbjerg et al. 2(2003) claims that poor data is a more important reason for prediction failures than methodology used in pavement design. They argue that in many countries there is no continuous generation of field data. This means that traffic demand models cannot be calibrated on the basis of observed traffic behavior (the revealed preference approach). This gap can partly, but not completely, be close by stated preference analysis. The problem is that actual behavior of people many, and often does, deviate substantially from the started preference.

2.7.3 Behavioral sources

Although the forecasting exercise is about understanding and modelling human (user) behavior, some biases and error are directly related to the agents involved in the forecasting processes. In this sense, transport forecasts can include or reflect some forecasters' or decision makers' biases. Whenever this occurs, the forecast produced will not represent the forecaster's true expectations as assumed (Antonio NUNEZ, 2007).

Before discussing the behavioral sources of errors and biases we want to clarify an important aspect of demand overestimating. Many authors argue that the absence of strategic or optimism biases, traffic forecast error should be equally distributed above and below zero error;

- "Significant errors, and furthermore biases in the sense of overestimation, show strategic biases from analysis."

- “Although scientific uncertainty should be, a priori, evenly distributed between under and over-estimation [...]” (Trujillo et al., 2002).
- “Instead of being random errors, however (with the possibility of canceling each other out), these are systematic errors reflecting optimism bias” (standard and poor’s, 2002).

Most of forecast contains some error. Positive errors enhance the probability of launching projects and the forecast survives to be tested. Negative errors enhance the probability of not launching, and the forecast remain untested. Those projects surviving the screening process, by exceeding the critical value, are more likely to have positive errors because projects with negative errors may not survive to be tested. Here, the bias (expected error) across all forecast is zero, but the bias for tested forecasts is positive. So, survivors tend to disappoint (Antonio NUNEZ, 2007).

All survey data are subject to errors. Traffic data, in particular, can be very inaccurate and predictions about traffic growth are also prone to large errors. Accurate calculations of cumulative traffic are therefore very difficult to make. To minimize these errors there is no substitute for carrying out specific traffic surveys for each project for the durations suggested. Additional errors are introduced in the calculation of cumulative standard axles because any small errors in measuring axle loads are amplified by the fourth power law relationship between the two. (ERA pavement design manual, chapter two traffic)

As long as the estimate of cumulative equivalent standard axles is close to the center of one of the ranges, any errors are unlikely to affect the choice of pavement design. However, if estimates of cumulative traffic are close to the boundaries of the traffic ranges, then the basic traffic data and forecasts should be reevaluated and sensitivity analyses carried out to ensure that the choice of traffic class is appropriate. Depending on the degree of accuracy achieved, higher traffic class may be appropriate for some cases. (ERA pavement design manual, chapter two traffic)

It is recommended that for the highest traffic class for unpaved roads (T4), a verification of the cumulative number of equivalent axle loads be carried out as for paved roads, in order to determine in which traffic class of paved road a particular road project would fall. Consideration should be given to paving if the evaluation indicates a traffic class of paved road higher than T1. No strict higher limit of traffic is given for the traffic class T4 for unpaved roads, but the recommendations given herein are generally considered to be for traffic levels below an AADT of 500 vehicles per day in both directions. (ERA pavement design manual, chapter two traffic)

CHAPTER THREE RESEARCH METHODOLOGY

3.1 Introduction

Two forecasting methods will be investigated in this study. In the first method, multivariate aggregate regression analysis was carried out to develop forecasting models for estimating traffic volume as a function of domestic growth product, historical traffic data and demographic variables. In the analysis, a correlation matrix was established to identify variables that had an effect on traffic volume and to check possible multi-collinearity between pairs of independent variables. Data for 1991 through 2001 were used in model development. The second method, elasticity analysis was carried out to develop forecasting model for estimating traffic volume as a function of domestic growth product, historical traffic data, demographic variables and per-capital income. In this analysis, significance of each variable to the future traffic was carried out.

This chapter compares the actual with design traffic where, actual data is collected from ERA three seasonal traffic count data during service operation and design traffic from consultant's final engineering report and traffic study report. It also aims to investigate the most appropriate method for estimation of future traffic. Case study is carried out by analysing data on three roads. The estimation accuracy of the design traffic forecasting method is compared with the one obtained by regression and elasticity approach. The results show that the approach used in this case study show more reliable traffic volume estimation to the actual traffic volume to that of design traffic volume. The proposed methods are economically feasible and have potential applications in cities of the developing countries such as Ethiopia.

This chapter presents and discusses the research method and procedures employed to collect the data, the results of the traffic investigations and findings on the individual road projects. The First Section will discuss the criteria for selecting road projects to participate in the study. And next describe research methodology and data collection (AADT) of the road project incorporated in the study finally, data analysis with the collected data and proposed method is done.

3.2 Study area

3.2.1 Selection of road projects

The road projects were chosen for their relevance to the conceptual questions rather than their representativeness. From research of Traffic Forecasting Accuracy Assessment (University of Kentucky Research Foundation), three road projects were selected for the study based on:

- Road with unexpected traffic volume
- Road that account for large portion of heavier vehicle
- Functional class and topography
- Road with available Traffic data during service period

Accordingly, these road projects were selected for the study:

- ✚ Shashemene-Dodola (69.3km)/ New Road Construction
- ✚ Alemgena-Hossana-Sodo(310Km)/ Road Upgrading
- ✚ Addis Ababa-Desse-Woldiya (513km)/Rehabitation

3.3 Project description

3.3.1 Shashemene-Dodola Road Project

Shashemene – Dodola section (69.3km) has a DBST (double bitumen surface treatment), with a width of 8m from shoulder to shoulder. As a result of poor performance and to improve operations with the operation of day-to-day transportation was necessary. Hence, ERA proposed to construct Shashemene-Dodola road project and the construction was started on 2001 E.C (final Engineering design report, Shashemene-Dodola)

3.3.2 Alemgena-Hossana-Sodo Road Project

Project is located in Oromia Regional and South Nation and Nationalities Region. Area through which the road passes is characterized by extensive small-scale agricultural activity, which results in the continuous movement of produce along the road, especially during the harvest seasons. Generally poor condition of the road results in low operating speeds and difficult operating conditions, particularly during wet weather.

3.3.3 Addis Ababa-Desse-Woldiya Road Project

The road serves the traffic from Addis Ababa to the northern regions of the country (Tigray and Gondar). Due to the significant difference in traffic volumes within the borders of Addis Ababa and just outside the design consultant has introduced extra traffic link from the Megenagna roundabout and up to Kara (km 15) considered. Due to excessive defect on pavement surface that increase vehicle maintenance and operation cost pavement ERA proposed rehaitation project of Addis Ababa-Dessie-Woldiya.

3.4 Research approach

In this study of checking the reliability of traffic forecasting and its impact on pavement design and service life three projects is selected one of new construction project, upgrading project and rehabilitation project. Through this, to check reliability of traffic growth rate factor two methods are using in this study:

1. Regression analysis
2. Elasticity analysis

3.4.1 Regression Analysis

3.4.1.1 Multiple regression analysis

Multiple Regression Analysis refers to a set of techniques for studying the linear relationships among two or more variables. It is analysis studies the relationship between a dependent (response) variable and p independent variables (predictors, repressor's). The sample multiple regression equation is:

$$Y=b_0 +x_1b_1+x_2b_2\dots+x_p b_p$$

3.4.1.2 Variable Selection or Screening

In this case, to determine independent variables that explain a significant amount of the variation in the dependent variable review of previous finding were carried out. In most applications, this is not a one-time process but a continual model building process. This purpose is manifested in other ways, such as using historical data to identify factors for future experimentation.

The first step in multiple regression analysis is to determine dependent variable (y) and independent variable (x) next and the designer should have to take care is determining significance level of those independent variable and determining the relation between the variable is positive or negative relation.

There are many factors which are thought to influence traffic growth, including:

- Population Growth/Migration
- Land Use Changes
- National/Regional Economy
- Vehicle Operating Costs

- Capacity Restraints
- Induced Traffic due to new road facilities nearby
- Vehicle ownership levels
- Availability of alternative transport modes

3.4.1.3 Significance of Factors Affecting Traffic Growth

According to Jim Higgin, 2005 study on multiple regression analysis, Level of significances is determining to what extent the independent variable affect the dependent variable. All correlations—even multiple correlations must be between + or – 1.00. A Multiple Correlation, just like any other correlation, of 1.00 mean that the two independent variables, when taken together have a perfect relationship with Traffic Growth Rate. If “R = 0.00” that would mean that there is no relation between regressor and predictors. As the value of R goes down to zero the significance level is small and may the predictor ignore.

3.4.2 Elasticity analysis

3.4.2.1 Elasticity coefficient

Transport demand elasticity is one of the methods of establishing relationships between transport demand (i.e. number of registered vehicles) and the growth parameter (i.e. GDP) affecting the demand for vehicles. This relationship may remain static or may change in the future due to disproportionate changes in the future growth or parameters and/or technological changes in vehicle characteristics. Transport elasticity is a measure of the percentage change in transport demand with respect to percentage change in the parameters influencing the demand. The predictor formula is as below;

$$\text{Elastic coefficient value (e)} = \frac{\text{Percentage change in transport indicator.....Eq (1)}}{\text{Percentage change in economic indicators}}$$

Where,

Transport indicator: number of registered vehicles

Economic indicator: Gross Domestic Product (GDP)

From the above equation transport demand elasticity coefficient is the ratio of change in traffic volume and gross domestic product growth rate for the last 10 years before construction is started. (Hemanth. M Kamplimath, Varuna. M, Vijay Kumar, Yashas Bhargav, 2013)

In this research, passenger and freight traffic volume and GDP in different regions are used to calculate transportation elasticity coefficient. Elasticity coefficient can be divided into static and dynamic elasticity coefficient, depending on different methods of calculation. The

calculation for static elasticity coefficient is relatively simple and used more frequently because developing country like Ethiopia economy is difficult to predict and change very fast.

3.4.2.2 Elasticity Empirical Formula

There are many factors which are thought to influence traffic growth, including: population growth rate, change in per-capital income, change in gross domestic product, technology, development growth rate, vehicle ownership. Generally, traffic growth rate empirical formula is:

$$GR = (((1 + \%po) * (1 + \%pi) * (1 + \%dv) * (1 + \%vg) \dots)) - 1) * EC \dots Eq (2)$$

Where,

GR= traffic growth rate,

%po= % population growth rate,

%pi=%per capital income growth rate,

%dv=%development growth rate,

%vg= %vehicle ownership growth rate,

EC=elasticity coefficient

Factors these affect growth of traffic and significance level is different for projects. Depending on characteristics of traffic growth in the past and scope of project designer estimate the significance level of these factors is needed in traffic growth rate finding.

Elasticity coefficient is numerical representation that implies the effect of historical growth rate relative to GDP growth of the county. Traffic growth rate by using elasticity demand equation is dependent on the factors that affect the growth of traffic. Basically to determine those factors directly related to the scope and the necessity of the project.

3.4.3 Directional Distribution Factor

The usual procedure for determining directional traffic is to assume a 50/50 split. However, traffic on some highways has a different directional distribution, e.g. 60 percent northbound, 40 percent southbound. In some cases, loaded trucks travel one direction while empty trucks travel in the opposite direction [For example, according thesis study on "Benefit of shifting freight delivery to night time, considering routing and environmental effects of Addis Ababa" directional distribution factor at debrezeyt road kality gate is 45/55.] A directional traffic split may have a definite effect on the accumulated ESAL's in these cases.

By realizing accuracy the factor that has been considered previously and there significance to estimate directional distribution factor and by considering additional factor, determine reliable directional distribution factor.

$$D1 = \frac{\sum_{k=0}^n \text{one lane ESAL}}{\sum_{k=0}^n \text{both lane ESAL}} \dots \dots \dots \text{Eq (3)}$$

$$\sum_{k=0}^n \text{average weight of one lane}$$

$$\sum_{k=0}^n \text{average weight of both lane}$$

$$D2 = 1 - d1 \dots \dots \dots \text{Eq (4)}$$

3.5 Research variables

For structural pavement design the cumulative traffic loading of each of the motorized vehicle classes over the design life of the road in one direction is required. For a given class, m, this is given by the following equation:

$$T(m) = 0.5 \times 365 \times \text{AADT}(m)^0 \left[\frac{(1+i/100)^n - 1}{i/100} \right] \dots \dots \dots \text{Eq (5)}$$

Where

$T(m)$ = the cumulative traffic of traffic class m

$\text{AADT}(m)^1$ = The AADT of traffic class m in the first year

n = the design period in years

i = the annual growth rate of traffic in percent

as we see from the above equation, independent variable in cumulative traffic class are: traffic growth rate, seasonal conversion factor, night conversion factor, truck equivalency factor, lane distribution and directional distribution factor.

In this study only traffic growth rate (i) and directional distribution (DD) factor reliability in the traffic forecast and the impact on pavement design and service life will be assessed.

3.6 Data requirement

Traffic data is the foundation of highway transportation planning and design and is used in making numerous decisions. Since accurate traffic data is a very crucial element in the transportation planning and design process, understanding and implementing the data collection process and method of forecasting accurately can lead to better decisions. The aim

of traffic survey is to capture data that accurately reflects the real-world traffic situation in the area. It may be counting the number of vehicles using a road, studying historical traffic growth and collecting journey time information, to estimate the cumulative traffic volume over the design period of the road project.

Traffic forecasts can be carried out using traffic counts or annual average daily traffic (AADT) as the main inputs to roadway design because, one of the major indicator level of service for the road is its structural strength to carry the upcoming traffic load. In the road projects selected for this study the traffic studies were carried out in two stages:

Stage 1 (Traffic Study) involved the determination of the historical traffic growth as well as the current traffic volume in each vehicle category as defined by ERA.

Stage 2 (Design Traffic) involved the determination of the cumulative equivalent traffic over the structural design period.

Due to the type of research, which is mainly quantitative type, as far as data collection tool the use of secondary data was involved and the methods employed for selecting the road project for the study was based on non-probability sampling (Convenience Sampling). Secondary data sources mainly covered government publications (from Ethiopian statistical agency, National bank of Ethiopia & road Development Program report) technical document, and design reports of the consulting companies. Secondary data helped to cross-check official information, learn about major events, technical details, and historical decisions.

The method used for data collection was secondary data sources mainly covered government publications, technical document, and design reports of the consulting companies. This section briefly summarize data used in this study of each road project separately, these data includes:

3.6.1 Historical traffic data

The 10-year annual average daily traffic volume data were analysed for traffic growth and vehicle category composition. Detailed results of historical traffic for the three projects are given in Annexure 3A.

3.6.2 Traffic count data

Having studied the available information the Consultant identified the need for the following supplementary traffic information. And the traffic count was conducted as 7 days, 24 hours classified traffic counts at the project location during engineering design study and Detail traffic count result is attached on Annexure 3B.

3.6.3 Design traffic data

Table gives the AADT data for different sections of the project road. The future projected traffic in ESAL for the design life is tabulated by the Review Consultants adopting the revised truck factors. The pavement design life has been taken as 20 years by the design consultants, the year that the first part of the construction will be completed. The Consultants have accordingly calculated traffic projections. Result with traffic class selection is presented attached to Annexure 3C.

3.6.4 Actual traffic

The ERA carried out the classified volume counts three times a year. The periods are termed as cycle counts and each cycle count is organized for the first seven days of February, July, and November. The twelve-hour classified count made on each day between 6:00 AM and 6:00 PM is supplemented by a full 24-hour count on two of the weekdays to determine the value of the “factor” for the “night” flows. The three seasonal counts are averaged to obtain the Average Annual Daily Traffic (AADT). Traffic count on service period of pavement are given in Annexure 3D.

3.6.5 Domestic Growth Product (GDP)

Investment in the transport sector improves access to economic opportunities by reducing transport costs. These include lower market prices for final products (both rural products and consumer goods), spatial extension of the market (due to the transport-induced changes in production and consumption patterns), higher personal mobility, and stimulation of socioeconomic activities.

The correlation as well as the responsiveness of transport demand to GDP taking data for the last 37 years up to year 2017 attached on Annexure 3E.

3.6.6 Ethiopian Population Growth Rate

Transportation network are one of the fundamental tools for human society. Population growth will have dramatic effect on the increased demand for jobs, housing, food, transportation infrastructure and social service. Increases population mobility, encouraging more people to move on cities and suburbs this will affect transportation demand. Population growth and density will greatly impact the transportation system since, most population growth will be located in metropolitan areas, and growth in vehicle travel will likely disproportionately affect fast-growing metropolitan areas.

Data from Ethiopian Statistical agency report, population growth rate of the city around road project is collected and attached on Annexure 3F.

3.6.7 Axel load survey data

Determining realistic directional distribution factor for opposite direction traffic movement that has not always be considered as 50/50 directional split. To estimate future traffic loading on the pavement and to measure the effect of load distribution on the pavement performance, ERA established 9 bridge stations at different location of the country. Accordingly, I have collected axel load of the heavy vehicles (10-11 to 16-17 tone) from Mojo, Alemgena and Combolcha bridge station and detailed result of axel load survey of attached on Annexure 3G.

3.7 Data analysis

3.7.1 Actual Traffic with Design Traffic Volume

Actual Traffic Volume: The ERA carries out the classified volume counts three times a year. The periods are termed as cycle counts and each cycle count is organized for the first seven days of February, July, and November. The twelve-hour classified count made on each day between 6:00 AM and 6:00 PM is supplemented by a full 24-hour count on two of the weekdays to determine the value of the “factor” for the “night” flows. The three seasonal counts are averaged to obtain the Average Annual Daily Traffic (AADT).

Forecasted Traffic Volume: Transportation forecasting is the process of estimating the number of vehicles that will use a specific transportation facility in the future. Transportation forecasts can be utilized in a variety of different situations and with different modes of transport, from estimating traffic volumes on a specific segment of road or highway, to estimating ships in a port, or passenger volumes on a city’s buses.

Hence, the table below shows future traffic estimated for the design period of the road with actual traffic count record during the service time of the road for the selected three projects.

Shashemene-Dodola Road Project

Table 1 forecasted traffic with actual traffic Annual Average Daily Traffic Volume (2001-2018)

Year	AADT		Change in traffic Volume
	Forecasted	Actual	
Shashemene – Dodola			
2001	197	197	0
2002	209	208	1

2003	221	312	-91
2004	235	343	-108
2005	249	258	-9
2006	267	449	-182
2007	328	576	-248
2008	403	518	-115
2009	497	490	7
2010	611	559	52
2011	751	544	207
2012	924	524	400
2013	1137	885	252
2014	1399	885	514
2015	1720	702	1018
2016	2216	493	1723
2017	2602	465	2137
2018	3201	470	2731

Source (final Engineering design report and ERA traffic count data)

Alemgena-Butajira Road Project

Table 2 forecasted traffic with actual traffic Annual Average Daily Traffic Volume (2001-2018)

Year	AADT		Change in traffic volume
	Forecasted	actual	
Alemgena-Butajira			
2001	330		
2002	349	237	112
2003	370	335	35
2004	392	423	-31
2005	415	521	-106
2006	441	531	-90
2007	467	1448	-981
2008	495	1190	-695
2009	525	1636	-1111
2010	556	1212	-656
2011	590	2133	-1543
2012	625	1800	-1175
2013	663	2539	-1876
2014	702	3348	-2646
2015	745	4231	-3486

2016	789	5102	-4313
2017	837	6464	-5627
2018	887	18648	-17761

Source (final Engineering design report and ERA traffic count data)

Debrebrihan- KaraKore Road Project

Table 3 forecasted traffic with actual traffic Annual Average Daily Traffic Volume (2001-2011)

Year	AADT		Change in traffic Volume
	Forecasted	actual	
Debrebrihan- KaraKore			
2001	608		
2002	638	432	206
2003	670	440	230
2004	703	513	190
2005	738	529	209
2006	775	745	30
2007	814	800	14
2008	855	924	-69
2009	897	1009	-112
2010	942	945	-3
2011	990	1332	-342

Source (final Engineering design report and ERA traffic count data)

3.7.2 Significance of factor used in traffic growth rate estimation

3.7.2.1 Shashemene-Dodola

From the feasibility study report of Shashemene-Dododla road project, is constructed with the major aim to improve day to day transport operation and to increases performance level of the road. Also according the living standard and sources of income of the community living around the road project, here are listed Significance of Factors Affecting future Traffic Growth:

- 1 Significance of population growth
- 2 Significance of GDP change
- 3 Significance of historical traffic growth

Table 4 Significance factor of population growth rate on future traffic

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.222296709
R Square	0.049415827
Adjusted R Square	0.056204637
Standard Error	70.49550093
Observations	11

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	2325.096	2325.096	0.467862	0.511198
Residual	9	44726.54	4969.616		
Total	10	47051.64			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	159.1389582	22.81932	6.973869	6.51E-05	107.5181	210.7599	107.5181	210.7599
X Variable 1	1.985356644	2.902549	0.684005	0.511198	-4.58067	8.551378	-4.58067	8.551378

Table 5 Significance factor of GDP change on future traffic

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.141058185
R Square	0.019897412
Adjusted R Square	-0.089002876
Standard Error	71.58167875
Observations	11

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	936.2057717	936.205	0.18271	0.679097702
Residual	9	46115.43059	5123.93		
Total	10	47051.63636	7		

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	164.8181818	21.58268821	7.63659	3.2E-05	115.9947491	213.641614	115.994749	213.641614
X Variable 1	0	0	65535	#NUM!	0	0	0	0

Table 6 Significance factor Historical Growth Rate on future traffic grow

<i>Regression Statistics</i>	
Multiple R	0.839555979
R Square	0.704854241
Adjusted R Square	0.672060268
Standard Error	39.28116726
Observations	11

<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	33164.5455	33164.545	21.4934	0.00122602
Residual	9	13887.0909	1543.0101		
Total	10	47051.6364			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-34493.0000	7475.6528	-4.6140	0.0013	51404.1016	-17581.8984	51404.1016	17581.8984
X Variable 1	17.3636	3.7453	4.6361	0.0012	8.8912	25.8361	8.8912	25.8361

Level of significance of population growth, GDP change and historical traffic on future traffic growth is R^2 is 0.049, 0.0198 and 0.704 respectively.

3.7.2.2 Alemgena-Hossana-Sodo Road Project

Factor Affecting future Traffic Growth Alemgena-Butajira includes:

- 1 Significance of population growth
- 2 Significance of per-capital income
- 3 Significance of vehicle ownership growth rate
- 4 Significance of development growth rate

Significance of population growth

The major aim of car/bus transport is to transport people from one place to the other (origin-destination). Hence, population growth increases consequently volume of traffic mostly number of cars/buss increases.

From consultant traffic count report, the Average percentage of car/bus is about 60% of total traffic (ref Annexure 3B), from this large percentage of traffic used along the road project is passenger transportation. And according to historical traffic study report, annual growth rate of car/bus is about 8%.

As a result of Population growth around the road project area total number of car/bus increase significantly and annual growth of car/bus traffic high, future traffic growth rate greatly affected by population growth rate.

Significance of per-capital income

Growth of Per-capital income is the result of growth in production rate and increases of profit with individual income grow.

Production is overwhelmingly of a subsistence nature, and a large part of commodity exports are provided by the small agricultural, cash-crop, sector. Principal crops include coffee, pulses, oilseeds, cereals, potatoes, sugarcane and vegetable are major agricultural products nearby the road project area. According to ministry of Agriculture report, production rate around the project area increases minimum of 5% per/hectare.

Increasing production rate/hectare of agricultural product directly increase truck number used to transport goods and product in identified. Therefore, growth of per-capital income significantly increases traffic in the future.

Significance of vehicle ownership & development growth rate

Increase in the demand for transportation and particularly in the number of road vehicles and development growth rate has influence on the growth of future traffic. However, finding registered vehicle ownership and regional development growth rate is impossible. Afterwards, determining the significance level of vehicle ownership and development to future traffic growth rate is impossible.

Future Traffic growth traffic growth rate is given by:

$$r = (((1 + \%p) * (1 + \%pci)) - 1) * E_c * 100 \dots \dots \text{Eq (5)}$$

3.7.2.3 Addis Ababa-Desse-Woldiya Road Project

Factor Affecting future Traffic Growth Addis ababa-Desse-Woldiya includes:

- 1 Significance of population growth
- 2 Significance of per-capital income
- 3 Significance of vehicle ownership growth rate
- 4 Significance of development growth rate

Significance of population growth

The major aim of car/bus transport is to transport people from one place to the other (origin-destination). According to consultant's traffic count study (ref Annexure 3B), the Total traffic volume of car/buses is about 30% and from historical traffic count study (Annexure 3A), traffic growth rate of car/buses is about 3.9%.

As a result, historical traffic growth rate of car/bus is low and percentage volume of car/buss relative to truck is small, effect of population growth rate to the future traffic is minor/insignificant.

Significance of per-capital income

Growth of Per-capital income is a result of growth in production and increases of profit of production with individual income grow. Due to Increasing of per-capital income and development growth, total quantity of product increases. This trunk road is a part of import-export corridor of the country which links the northern and north-eastern regions hence, increasing export product results in increasing of truck volume.

According to World Bank report of, export rate increases with minimum of 5% per year. Increases in quantity of product exports and imported results individuals per capital income grow and increases total traffic volume significantly. Therefore, growth of per-capital income significantly increases traffic in the future.

Significance of vehicle ownership & development growth rate

Increase in the demand for transportation and particularly in the number of road vehicles and development growth rate has influence on the growth of future traffic. However, finding registered vehicle ownership and regional development growth rate is impossible. Consequently, determining the significance factor is impossible

Future Traffic growth traffic growth rate is given by:

$$r = ((1 + \%pci) - 1) * Ec * 100 \dots \dots \dots \text{Eq (6)}$$

CHAPTER FOUR RESEARCH RESULT and ANALYSIS

4.1 Introduction

The task of transport planning is primarily to determine cost effective solutions for achieving and maintaining a reasonable level of mobility for people and goods. In order to assess the performance of the transportation network, there is a need to collect a time-series traffic data for network evaluation and monitoring purpose.

A major problem often faced in transport planning is the lack of estimating precise future traffic volume, which is one of the most important components of the information necessary for the planning, design and operation of transportation network.

Traffic volume data are collected from various short and permanent traffic counters over a number of years. Methods for collecting traffic counts vary widely, ranging from mechanical fixed counters to electric contact, and magnetic devices. Since there is no a permanent traffic counter installed in our country Ethiopia, Road Authorities and Highway consulting companies routinely use sample traffic counts. The sample traffic counts are obtained by using traffic counters for short periods at selected locations. The data collected from the short period traffic counts is routinely used to estimate important traffic parameters for new road construction and rehabilitation project.

4.2 Research Result

4.2.1 Shashemene- Dodola

4.2.1.1 Traffic Growth Rate

According to section 3.7.2.1 regression analysis result, the Level of significance of population growth, GDP change and historical traffic on future traffic growth is R2 is 0.049, 0.0198 and 0.704 respectively. Therefore, variables population growth and GDP removed from the preliminary model were useless in predicting reading scores and historical traffic growth rate is account for future traffic growth. From regression analysis output result, the future traffic volume formula is given by:

$$Y = -34493 + X17.3636$$

Table 7 future traffic growth rate

year	b1*X	Bo	y=a+bx	%growth
2001	34744.64	-34493	251.64	
2002	34760.73	-34493	267.73	6.39
2003	34778.09	-34493	285.09	6.48
2004	34795.45	-34493	302.45	6.09
2005	34812.82	-34493	319.82	5.74
2006	34830.18	-34493	337.18	5.42
2007	34847.54	-34493	354.54	5.14
2008	34864.9	-34493	371.90	4.89
2009	34882.27	-34493	389.27	4.66
2010	34899.63	-34493	406.63	4.46
2011	34916.99	-34493	423.99	4.269
2012	34934.36	-34493	441.36	4.09
2013	34951.72	-34493	458.72	3.93
2014	34969.08	-34493	476.08	3.78
2015	34986.45	-34493	493.45	3.64
2016	35003.81	-34493	510.81	3.51
2017	35021.17	-34493	528.17	3.39
2018	35038.53	-34493	545.53	3.28
Average traffic growth rate = 4.66				

Table 8 Annual Average Daily Traffic volume

Annual Average Daily Traffic in Vehicles per day by Regression			
Year	Shashemene - Dodola	Year	Shashemene - Dodola
2001	251.64	2010	406.63
2002	267.73	2011	423.99
2003	285.09	2012	441.36
2004	302.45	2013	458.72
2005	319.82	2014	476.08
2006	337.18	2015	493.45
2007	354.54	2016	510.81
2008	371.9	2017	528.17
2009	389.27	2018	545.53

4.2.1.2 Directional Distribution factor

By realizing accuracy the factor that has been considered previously and there significance to estimate directional distribution factor and by considering additional factor, determine reliable directional distribution factor. Here, the table below shows summarized axel load in ton of heavy vehicles.

$$D_1 = \sum_{k=0}^n \text{one lane ESAL} / \sum_{k=0}^n \text{both lane ESAL}$$

Table 9 Axel load survey data

Axel load in ton	Origin	Destination	no. of vehicle	total axel weight (ton)
10.1-11	Awassa	Dodola	4	151832
11.1-12			4	62468
12.1-13			4	32708
13.1-14			4	14902
14.1-15			4	9718
15.1-15			4	2087
Total			24	273715
10.1-11	Dodola	Shashemene	4	163230
11.1-12			4	55384
12.1-13			4	31282
13.1-14			4	15150
14.1-15			4	5228
15.1-15			4	2004
Total			24	272278

$$\sum_{k=0}^n \text{one lane ESAL} = 273715$$

$$\sum_{k=0}^n \text{both lane ESAL} = 273715 + 272278 = 545993$$

$$D_1 = 273715 / 545993 = 0.501$$

$$D_1 = 50.1\%$$

$$D_2 = 1 - d_1$$

$$D_2 = 1 - 0.501 = 0.499$$

$$D_2 = 49.9\%$$

$$D_1 / D_2 = 50 / 50$$

4.2.2 Alemgena-Hossana-Sodo

4.2.2.1 Traffic Growth Rate

From 10 years historical traffic growth rate and GDP growth rate for the same years from table 3.6 and 3.16, transport elasticity coefficient is calculated as the ratio of change in historical traffic and GDP:

$$\text{Elastic coefficient value (e)} = \frac{\text{Percentage change in transport indicators}}{\text{Percentage change in economic indicators}}$$

Where,

Historical Traffic Growth (1986-1995) = 7.8 %.....(ref Annexure 3A)

And average GDP Growth (1986-1995) =3.32 %.....(ref Annexure 3E)

$$E_c = 7.8/3.32 = 2.349$$

Historical traffic growth by vehicle type is here shown on Annexure 3A

Average population growth rate from (1984-1994)..... (ref Annexure 3F)

@ Addis Ababa= 4.2%

And @ Butajira =4.2%

Average population growth between two cities is =4.2%+4.2%/2 =4.2%

Average per-capital income growth (1984-1994) is 3.32 %.....(ref Annexure 3E)

Population growth and per-capital income growth rate are significant factor influence future traffic volume. Accordingly, Future Traffic growth traffic growth rate that is derived from equation (5) is given by:

$$r = (((1+\%p) * (1+\%pci)) - 1) * E_c * 100$$

Where:

%p= population growth rate= 4.2%

%pci=per capital income growth rate=3.32%

EC=Elasticity coefficient =2.349

r=traffic growth rate

$$r = (((1+4.2\%) * (1+3.32\%)) - 1) * 2.349 * 100$$

$$r = 18.02\%$$

Table 10 Annual Average Daily Traffic volume

AADT by Elasticity analysis			
Year	Alemgena-Butajira	Year	Alemgena-Butajira
1995		2007	1684
1996	273	2008	1987
1997	322	2009	2345
1998	380	2010	2767
1999	448	2011	3265
2000	528	2012	3852
2001	624	2013	4546
2002	736	2014	5364
2003	868	2015	6329
2004	1025	2016	7469
2005	1209	2017	8813
2006	1427	2018	10399

4.2.2.2 Directional Distribution factor

The table below shows summarized axel load in ton of heavy vehicles.

$$DI = \frac{\sum_{k=0}^n \text{one lane ESAL}}{\sum_{k=0}^n \text{both lane ESAL}}$$

Table 11 Axle load survey data

Axel load in ton	Origin	Destination	no. of vehicle	total axel weight (ton)
10.1-11	Addis Ababa	Hossana	4	13155
11.1-12			4	10094
12.1-13			4	7006
13.1-14			4	3767
14.1-15			4	787
15.1-15			4	475
Total			24	35284
10.1-11	Sodo	Addis Ababa	4	13634
11.1-12			4	10726
12.1-13			4	6245
13.1-14			4	3262
14.1-15			4	600
15.1-15			4	315
Total			24	34782

$$\sum_{k=0}^n \text{one lane ESAL} = 35284$$

$$\sum_{k=0}^n \text{both lane ESAL} = 35284 + 34782 = 70066$$

$$D1 = 35284 / 70066 = 0.50335$$

$$D1 = 50.35\%$$

$$D2 = 1 - d1$$

$$D2 = 1 - 0.50335 = 0.4965$$

$$D2 = 49.65\%$$

$$D1 / D2 = 50.35 / 49.65$$

$$D1 / D2 = 50 / 50$$

4.2.3 Addis Ababa-Dessie-Woldiya

4.2.3.1 Traffic Growth Rate

Transport elasticity of demand for measuring the relative change in travel/transport demand due to change in GDP by using 10 years historical traffic growth rate and GDP growth rate for the same years from Annexure 3A and 3E.

$$\text{Elastic coefficient value (e)} = \frac{\text{Percentage change in transport indicators}}{\text{Percentage change in economic indicators}}$$

Where

$$\text{Historical Traffic Growth (1986-1996)} = 5\% \dots\dots\dots (\text{Ref Annexure 3A})$$

$$\text{And average GDP Growth (1986-1996)} = 3.5\% \dots\dots\dots (\text{Ref Annexure 3E})$$

$$E_c = 5 / 3.5 = 1.428$$

According to section 3.7.2.3 of chapter three the significant factor influence the future traffic is Per-capital income growth. Accordingly, Future Traffic growth traffic growth rate that is derived from equation (5) is given by

$$r = (\%pci) * E_c * 100$$

Where:

$$\%pci = \text{average per capital income growth rate (1986-1996)} = 4.2\% \dots\dots\dots (\text{ref Annexure 3E})$$

$$E_c = \text{Elasticity coefficient} = 1.428$$

r=traffic growth rate

$$r = (1 + 4.2\%)^{-1} * 1.428 * 100$$

r=6%

Table 12 Annual Average Daily Traffic volume

AADT by static Elasticity analysis			
year	Debrebrihan-Karakore	year	Debrebrihan-Karakore
1996	400	2004	637
1997	424	2005	675
1998	449	2006	716
1999	476	2007	759
2000	505	2008	804
2001	535	2009	853
2002	567	2010	904
2003	601	2011	958

2 Directional Distribution factor

The table below shows summarized axel load in ton of heavy vehicles.

$$DI = \frac{\sum_{k=0}^n \text{one lane ESAL}}{\sum_{k=0}^n \text{both lane ESAL}}$$

Table 13 Axel load survey data

Axel load in ton	Origin	Destination	no. of vehicle	total axel weight (ton)
10.1-11	Addis Ababa	Debrebrihan	4	138368
11.1-12			4	83146
12.1-13			4	25788
13.1-14			4	16758
14.1-15			4	972
15.1-15			4	344
Total			24	265376
10.1-11	Debrebrihan	Addis Ababa	4	179892
11.1-12			4	94762
12.1-13			4	71880
13.1-14			4	25454
14.1-15			4	10372
15.1-15			4	4230
Total			24	386590

$$\sum_{k=0}^n \text{one lane ESAL} = 265376$$

$$\sum_{k=0}^n \text{both lane ESAL} = 35284 + 34782 = 651966$$

$$D1 = 265376 / 651966 = 0.407$$

$$D1 = 40.7\%$$

$$D2 = 1 - d1$$

$$D2 = 1 - 0.407 = 0.593$$

$$D2 = 59.30\%$$

$$D1 / D2 = 40 / 60$$

4.3 Research Analysis & Discussion

4.3.1 Shashemene-Dodola

Traffic volume

The actual average traffic growth is about 5% and average traffic growth rate by regression analysis is 4.8% which is approximately equivalent to the actual growth rate. By using regression analysis correlating time as independent variable (X) and future traffic as dependent variable (Y) future traffic volume is resulted. Here, the table below shows actual design traffic with forecasted and study traffic:

Table 14 design traffic with actual and study traffic

Year	forecasted AADT	Actual AADT	AADT Regression
2001	197	197	251.64
2002	209	208	267.73
2003	221	312	285.09
2004	235	343	302.45
2005	249	258	319.82
2006	267	449	337.18
2007	328	576	354.54
2008	403	518	371.90
2009	497	490	389.27
2010	611	559	406.63
2011	751	544	423.99
2012	924	524	441.36
2013	1137	885	458.72

2014	1399	885	476.08
2015	1720	702	493.45
2016	2216	493	510.81
2017	2602	465	528.17
2018	3201	470	545.53

Figure 4 design traffic with actual and study traffic

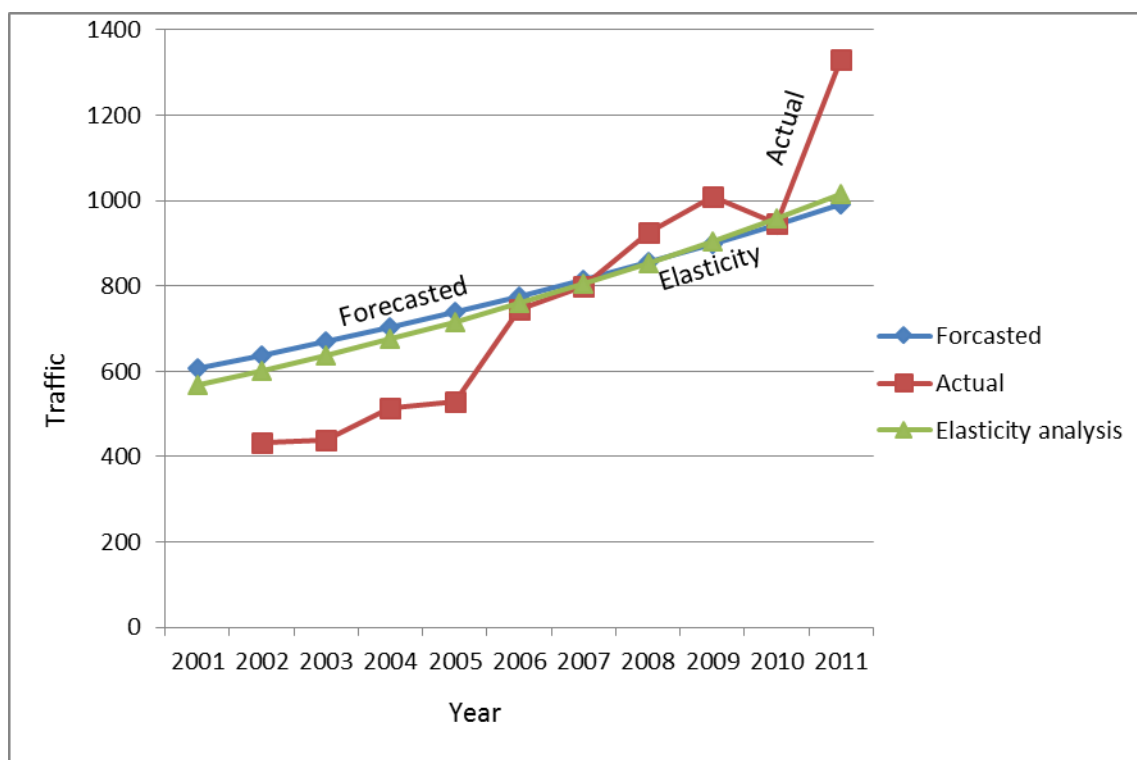


Table 15 cumulative ESAL of design traffic

project name	Vehicle	AAD	Yearly Traffic	Truck Factor	Growth Factor of design traffic	Growth Factor of regression analysis	Cumulative ESAL of design traffic	Cumulative ESAL of regression analysis
	Classification	-2006						
Shashemene - Dodola	L/Bus	46	16790	0.47	23.28	20.6	183709	162560.78
	M/Truck	46	16790	0.8	23.28	20.6	312697	276699.2
	H/Truck	46	16790	3.14	23.28	20.6	1227335	1086044.4
	T/Trailer	29	8760	6.01	23.28	20.6	1480976	1084540.6
Total							3204717	2609844.9

Table 16 Design traffic

Road Section	Directional Distribution	ESAL in million (One direction).	Traffic Class
Shashemene - Dodola design traffic	0.5	1.6	T4
Shashemene - Dodola regression analysis	0.5	1.3	T3

4.3.2 Alemgena-Hossana-Sodo

Traffic volume

The actual average traffic growth is about 18.9% and average traffic growth rate by elasticity analysis is 18.1% which is approximately equivalent to the actual growth rate. By using Elasticity analysis correlating population growth rate, per capital income, GDP and historical traffic growth rate estimated future traffic volume. Here, the table below shows actual design traffic with forecasted and study traffic:

Table 17 design traffic with actual and study traffic

Year	Forecasted AADT	Actual AADT	AADT Elasticity analysis
2001	330		623
2002	349	237	735
2003	370	335	868
2004	392	423	1024
2005	415	521	1208
2006	441	531	1425
2007	467	1448	1682
2008	495	1190	1985
2009	525	1636	2342
2010	556	1212	2763
2011	590	2133	3261
2012	625	1800	3848
2013	663	2539	4540
2014	702	3348	5358
2015	745	4231	6322
2016	789	5102	7460
2017	837	6464	8803
2018	887	18648	10387

Figure 5 design traffic with actual and study traffic

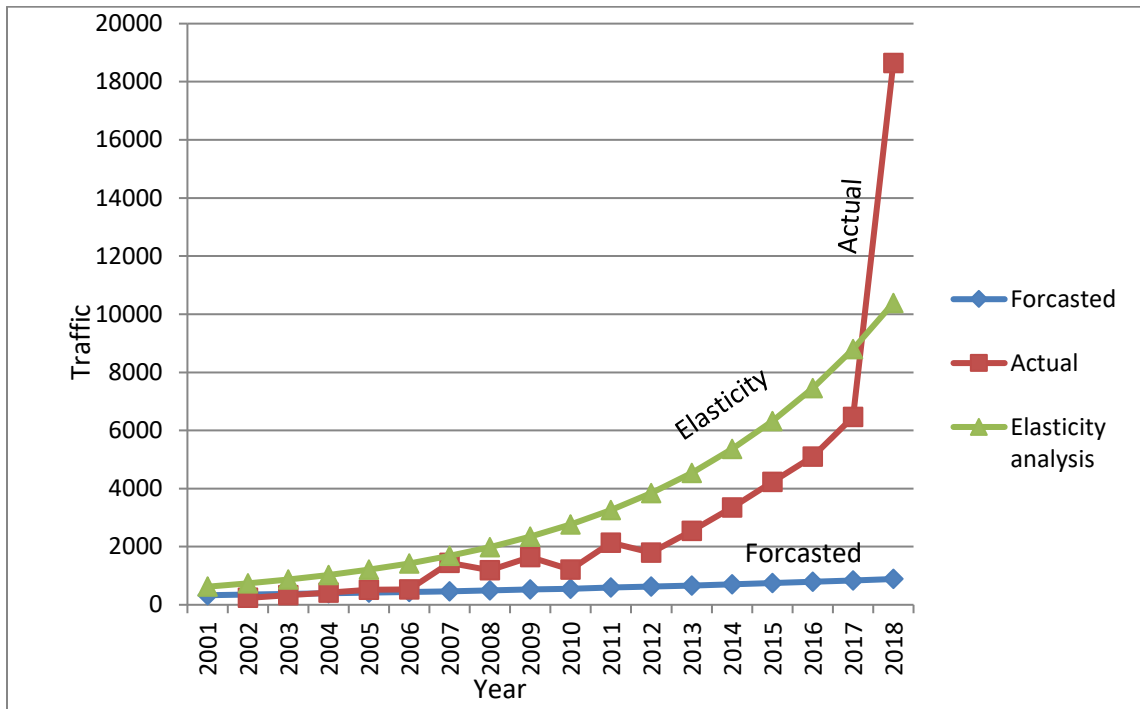


TABLE 18 cumulative ESAL of design traffic

project name	Vehicle	AAD	Yearly Traffic	Truck Factor	Growth Factor of design traffic	Growth Factor of Elasticity analysis	Cumulative ESAL of design traffic	Cumulative ESAL of Elasticity analysis
	Classification	1997						
Alemgena-Butajira	L/Bus	52	18980	1.4	40.6	150.16	1078823.2	3990180
	M/Truck	54	19710	0.5	40.6	150.16	400113	1479874.451
	H/Truck	110	40150	2.4	40.6	150.16	3912216	14469883.52
	T/Trailer	11	4015	4.5	40.6	150.16	733540.5	2713103.159
Total							6124692.7	22653041.13

Table 19 design traffic

Road Section	Directional Distribution	ESAL in million (one Direction)	Traffic Class
Alemgena-Butajira design traffic	0.5	3.05	T4
Alemgena-Butajira Elasticity examination	0.5	11.3	T7

4.3.3 Addis Ababa-Dessie-Woldiya

Traffic volume

The actual average traffic growth is about 6.2% whereas average traffic growth rate by elasticity analysis is 6.2% which is approximately equivalent to the actual growth rate. By using Elasticity analysis correlating per capital income, GDP and historical traffic growth rate estimated future traffic volume. Here, the table below shows actual design traffic with forecasted and study traffic:

Table 20 design traffic with actual and study traffic

Year	forecasted AADT	Actual AADT	AADT by Elasticity analysis
2001	608		567
2002	638	432	601
2003	670	440	637
2004	703	513	675
2005	738	529	716
2006	775	745	759
2007	814	800	804
2008	855	924	853
2009	897	1009	904
2010	942	945	958
2011	990	1332	1015

Figure 6 design traffic with actual and study traffic

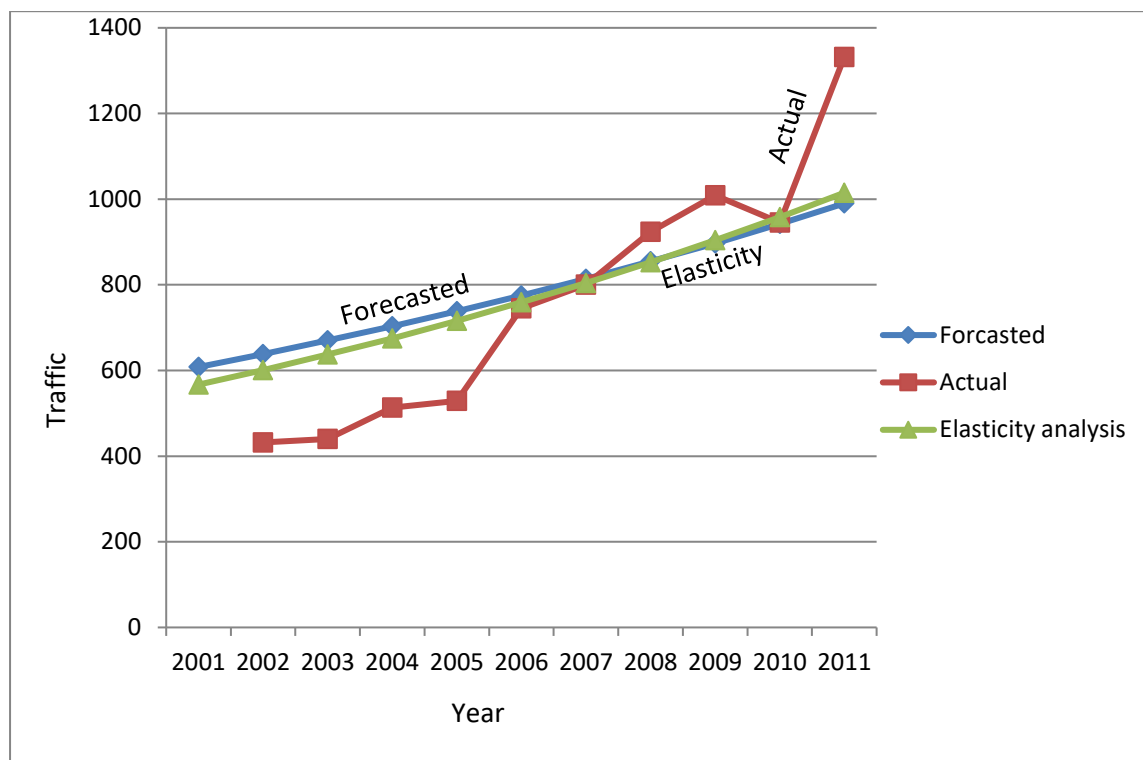


Table 21 cumulative ESAL of design traffic

	Vehicle	AAD	Yearly Traffic	Truck Factor	Growth Factor of design traffic	Growth Factor of regression analysis	Cumulative ESAL of design traffic	Cumulative ESAL of regression analysis
project name	Classification	-1996						
Debirebrhan-Karakore	L/Bus	108	39420	0.62	23.28	23.27	568972.512	568728.11
	M/Truck	156	56940	0.34	23.28	23.27	450691.488	450497.89
	H/Truck	62	22630	2.69	23.28	23.27	1417163.02	1416554.3
	T/Trailer	144	52560	6.6	23.28	23.27	8075738.88	8072269.9
Total							10512565.9	10508050

Table 22 Design traffic

Road Section	Directional Distribution	ESAL in million (One Direction)	Traffic Class
Debrebrihan-Karakore design traffic	0.5	5.1	T6
Debrebrihan-Karakore Elasticity analysis	0.6	6.3	T5

4.4 Impact of Inaccurate Traffic Forecast on Pavement Design and Service Life

The value of ESAL represents annual cumulative axel load of vehicle in million per one direction. According to the value of ESAL, traffic class is determined on pavement design which is selection of type and thickness of subgrade material.

Traffic data, in particular, can be very inaccurate and predictions about traffic growth are also prone to large errors. Accurate calculations of cumulative traffic are therefore very difficult to make however, to minimize these errors improving the methods of data collection and method of forecast is necessary. Additional errors are introduced in the calculation of Cumulative standard axles because any small errors in measuring axle loads are amplified by the fourth power law relationship between the two.

Estimates of cumulative traffic are close to the boundaries of the traffic ranges, then the basic traffic data and forecasts should be reevaluated and sensitivity analyses carried out to ensure that the choice of traffic class is appropriate.

Inaccurate traffic forecast has an impact on pavement design and service life the two major impacts are:

4.4.1 Economic/cost Impact

In pavement design, overestimation of design traffic may lead to incorrect selection of pavement type, overdesign of pavement thickness which in turn lead to high capital cost of construction (increase use of construction materials, resources).

From ERAMS (Ethiopian Road Authority Management System) annual report, Most of ERA construction projects are design build (DB) contract type, which the payment is totaled by quantity of each work item executed. Here increasing thickness of sub layer material directly increases the quantity of work executed which results increase initial cost of construction. Fatherly, increasing investment cost of construction unnecessarily will affect over all future country plan in transport minister sector.

On the other hand, underestimation of design traffic may lead the pavement for pre-matured failure which causes a high capital cost of maintenance and increases vehicle operation cost.

Underestimation in pavement design cause premature failure, as result rehabitaion and maintenance work is necessary to rectify defects & increases level of service. This results to cost high capital of maintenance and rehabilitation cost.

Cost Analysis

According to engineering design report of selected road, the design of flexible pavement is based on the catalogue of pavement structure published in TRL's oversea road not 31. This study used pavement design method that of the same in the design and the proposed traffic class is as shown below:

Table 23 traffic class

Road Section	Surface type	Design traffic class	Study traffic class
Shashemene-Dodola	DBST	T4	T3
Alemgena-Butajira	DBST	T4	T7
Debrebrihan-Karakore	AC	T6	T5

Shashemene-Dodola

Proposed design and study pavement subgrade material with thickness is given below:

Table 24 subgrade material thickness

Layer	Design material thickness (mm)	Study material thickness (mm)
Granular road base	200	200
Granular sub base	225	175
Selected subgrade	200	200

Here, thickness of road base and subgrade is the same which mean, the quantity of work execute for subgrade and road base are the same whereas, thickness of sub base increased by 50mm at initial design. These unnecessary increases in thickness inure additional cost in construction result high initial construction cost.

4.4.2 Decreases performance of pavement

Mostly when the actual traffic volume and loading is higher that design traffic and loading the pavement starts to fall at earlier stage. Significantly, this reduces pavement service level/performance, consequently increases vehicle operation and maintenance cost, reduce design speed and accelerate road accident.

Alemgena-butajira and Debrebrihan-Karakore

Proposed design and study pavement subgrade material with thickness is given below:

Table 25 subgrade material thickness

Alemgena-Butajira		
Layer	Design material thickness (mm)	Study material thickness (mm)
Granular road base	150	150
Capping layer	-	125
Granular sub base	200	175
Selected subgrade	200	200

Table 26 subgrade material thickness

Debrebrihan-Karakore		
Layer	Design material thickness (mm)	Study material thickness (mm)
Granular road base	150	150
Capping layer	-	125
Granular sub base	250	175
Selected subgrade	200	200

From the above table of both project, road base and subgrade material thickness are the same in design and study pavement design whereas, study pavement design traffic class has additional capping layer between road base and sub base which is used as base course with thickness of 125mm.

The capping layer is majorly used to transfer coming load from road base to sub base layer which helps to prolong pavement service life and protect pavement from earlier pavement failure. Accordingly, it reduces vehicles operation and maintenance cost as well increases level of performance. And this maintenance project costs the employer, proposed additional cost for rehabilitation/overlaying project.

Therefore, to reduce unnecessary additional cost of construction, maintenance cost and to increases level of performance, reliable estimation of future traffic and pavement design is necessary.

CHAPTER FIVE CONCLUSION and RECOMMENDATION

5.1 Conclusion

The major objective of this research was to develop an improved method of estimating AADT for local roads by applying different modeling techniques. In this paper, the Regression and Elasticity Analysis methods are adopted for the estimation of AADT from short period counts and for the determination of the most appropriate forecasted traffic volume. Case study is carried out by analyzing data at three road projects located in different parts of the country namely, South Nation Nationalities and People Region (SNNP), Oromia Regional State, Addis Ababa City Administration and Amhara Regional State.

- The result shows traffic growth rate of Shashemene-Dodola, Alemgena-Butajira and Debrebrihan-Karakore is 4.66%; 18.02% & 6% respectively and directional distribution factor of these project is 50/50, 50/50 & 60/40 respectively.

The estimation accuracy is also compared with the one obtained from Ethiopian Roads Authority traffic count data. The results show that the Regression and Elasticity Analysis is the most appropriate for the estimation of AADT than medium scenario selection implemented to forecast traffic volume during design stage.

- The estimation results from short period of counts by Regression and Elasticity model indicated that the error of the estimation of the AADT from actual traffic volume count carried by Ethiopian Roads Authority is within 0% to 4%.

Therefore, the proposed methods are feasible in practice. This study is valuable in guidance of estimating future traffic volume in Ethiopia in order to supplement the existing data sources and to ensure the variation of the traffic flows with in the service period of the roads.

5.2 Recommendation

More attention should be devoted to predicting future traffic volume for traffic planning and assessing the cumulative impact of traffic axle load distribution on the road. It is observed that in some cases, forecasted traffic volume is higher than the actual traffic volume, in other lower than actual traffic volume and sometime equal with the actual traffic volume. The proposed calculation method allows forecasting traffic flows on three road project and resulted a better estimation of future traffic volume.

Moreover, directional distribution factor may not be 50/50 for all road segments; it is dependent on purpose of the trip. Mostly for road segment which serve for the transportation of agricultural and industrial products, directional distribution factor is dependent on the material type that is transported and applicability of load limit.

Based on the results of this study the following points are recommended,

- For road project which is constructed with the aim of accessibility for the community living around simple multiple regression model has to be used for traffic forecasting to the design life of the road. Mostly this is for new road construction.
- Whereas, if road upgrading is due to rapid growth of traffic which is caused by fast development and rapid population growth then, elasticity of those factors will be taken in to account and then growth rate is calculated accordingly.
- Instead of assuming 50/50 Directional distribution it has accurately calculated from the data ERA weight bridge station and realistic distribution factor should has to be account for design of equivalent axle load.
- Further research on assessing reliability factors to estimate future traffic volume for the likes of seasonal conversion, lane distribution and others used for traffic forecasting and as well pavement design.

Historical Traffic (Annexure 1A)

Year	AADT Shashemene-Dodola
1991	43
1992	106
1993	107
1994	112
1995	162
1996	147
1997	253
1998	237
1999	238
2000	225
2001*	183

Year	AADT Alemgena-Butajira
1986	57
1987	78
1988	102
1989	105
1990	150
1991	197
1992	203
1993	218
1994	230
1995	231
1996	249

Year	AADT Debrebrihan-Karakore
1986	197
1987	218
1988	245
1989	270
1990	289
1991	315
1992	343
1993	341
1994	370
1995	400
1996	420

Traffic count (Annexure 1B)

Shashemene-Dodola					
Year	Car	Large Bus	Mid. Truck	Large Truck	Truck Trailer
2001	78	33	34	34	18
2006	104	46	46	46	24

Alemgena-Hossana-Sodo								
Counting Location	Car	Land Rover	Small Bus	Large Bus	Small Truck	Med. Truck	Large Truck	Truck Trailer
Alemgena (South)	25	82	3	54	41	53	50	11
Butajera (South)	2	44	6	69	2	27	34	4
Hosana (South)	5	38	11	41	29	2	34	5
Sodo (North)	0	108	6	19	0	18	35	5

Debrebrihan-Karakore								
Counting Location	Car	Large car	Small Bus	Large Bus	Small Truck	Med. Truck	Large Truck	Truck Trailer
Alemgena (South)	415	2592	701	684	399	986	391	913

Design traffic (Annexure 1C)

Shashemene – Dodola					
Vehicle Classification	AADT (2006)	Yearly Traffic	Truck Factor	Growth Factor	Cumulative ESAL
L/Bus	46	16790	0.47	23.28	183709
M/Truck	46	16790	0.80	23.28	312697
H/Truck	46	16790	3.14	23.28	1227335
T/Trailer	29	8760	6.01	23.28	1480976
					3204717

Section	Car/land rover	buses	Trucks	Truck Trailers	Total volume
Alemgena-Butajira					
Project data	89	78	116	6	288
Era data	46	62	110	13	231
Average	67.5	70	113	9.5	259.5
Butajira-Hossana					
Project data	53	74	75	5	207
Era data	48	48	114	12	222
Average	50.5	61	94.5	8.5	214.5
Hosanna-Sodo					
Project data	89	46	71	6	211
Era data	55	50	116	4	225
Average	72	48	93.5	5	218

Debrebrihan-Karakore				
Year	GDP in Fixed Prices	Cars and Busses	Trucks and Trailers	Total
Central	5.6%	3.9%	5.6%	4.9%
High Forecast	6.7%	4.7%	6.7%	5.8%
Low Forecast	4.5%	3.2%	4.5%	3.9%

Actual Traffic (Annexure 1D)

Shashemene - Dodola			
Year	AADT	Year	AADT
2001	197	2010	559
2002	208	2011	544
2003	312	2012	524
2004	343	2013	885
2005	258	2014	885
2006	449	2015	702
2007	576	2016	493
2008	518	2017	465
2009	490	2018	470

Alemgena-Butajira			
year	AADT	Year	AADT
2002	237	2011	2133
2003	335	2012	1800
2004	423	2013	2539
2005	521	2014	3348
2006	531	2015	4231
2007	1448	2016	5102
2008	1190	2017	6273
2009	1636	2018	16672
2010	1212		

Debrebrihan-Karakore			
Year	AADT	Year	AADT
2002	432	2011	1332
2003	440	2012	1376
2004	513	2013	1363
2005	529	2014	1283
2006	745	2015	1445
2007	800	2016	1628
2008	924	2017	1721
2009	1009	2018	2,474

Debrebrihan-Karakore			
Year	AADT	Year	AADT
2010	945	2012	

GDP change and Per-Capital growth rate (Annexure 1E)

Year	GDP (in Bil. US\$ PPP)	GDP per capita (in US\$ PPP)	GDP growth (real)	Inflation rate (in Percent)	Government debt (in % of GDP)
1980	10.8	313	▲4.0 %	▲12.4 %	n/a
1981	▲11.8	▲335	n/a	▲1.9 %	n/a
1982	▲12.6	▲349	▲1.0 %	▲7.7 %	n/a
1983	▲14.1	▲379	▲7.8 %	▲3.6 %	n/a
1984	▲14.3	▼372	▼-2.3 %	▼-0.3 %	n/a
1985	▼13.1	▼329	▼-11.4 %	▲18.4 %	n/a
1986	▲14.6	▲356	▲9.7 %	▲5.6 %	n/a
1987	▲17.1	▲403	▲13.9 %	▼-9.1 %	n/a
1988	▲17.8	▲405	▲0.6 %	▲2.2 %	n/a
1989	▲18.4	▲406	▼-0.5 %	▲9.6 %	n/a
1990	▲19.6	▲418	▲2.6 %	▲5.2 %	n/a
1991	▼18.8	▼388	▼-7.2 %	▲20.9 %	n/a
1992	▼17.5	▼349	▼-8.9 %	▲21.0 %	87.1 %
1993	▲20.3	▲392	▲13.4 %	▲10.0 %	▲141.0 %
1994	▲21.5	▲401	▲3.5 %	▲1.2 %	▲155.2 %
1995	▲23.3	▲421	▲6.1 %	▲13.4 %	▼146.6 %
1996	▲26.9	▲473	▲13.5 %	▲0.9 %	▼132.8 %
1997	▲28.1	▲481	▲2.8 %	▼-7.2 %	▼80.3 %
1998	▼27.3	▼453	▼-4.2 %	▲3.6 %	▲89.3 %
1999	▲29.4	▲475	▲6.3 %	▲7.9 %	▲97.8 %
2000	▲33.0	▲520	▲9.8 %	▲0.7 %	▼93.6 %
2001	▲36.2	▲554	▲7.4 %	▼-8.2 %	▲97.3 %
2002	▲37.4	▲556	▲1.6 %	▲1.7 %	▲107.4 %
2003	▼37.3	▼523	▼-2.1 %	▲17.8 %	▼103.7 %
2004	▲42.8	▲584	▲11.7 %	▲3.2 %	▼103.1 %
2005	▲49.7	▲661	▲12.6 %	▲11.7 %	▼78.2 %
2006	▲57.0	▲740	▲11.5 %	▲13.6 %	▼70.0 %
2007	▲65.5	▲828	▲11.8 %	▲17.2 %	▼46.8 %
2008	▲74.2	▲924	▲11.2 %	▲44.4 %	▼41.7 %
2009	▲82.3	▲1,008	▲10.0 %	▲8.5 %	▼37.8 %
2010	▲92.1	▲1,110	▲10.6 %	▲8.1 %	▲40.5 %
2011	▲104.7	▲1,243	▲11.4 %	▲33.2 %	▲45.3 %
2012	▲116.0	▲1,355	▲8.7 %	▲24.1 %	▼37.7 %
2013	▲129.7	▲1,491	▲9.9 %	▲8.1 %	▲42.9 %

2014	▲145.8	▲1,650	▲10.3 %	▲7.4 %	▲46.8 %
2015	▲162.7	▲1,812	▲10.4 %	▲10.1 %	▲54.0 %
2016	▲177.6	▲1,947	▲8.0 %	▲7.3 %	▼53.2 %
2017	▲200.6	▲2,165	▲10.9 %	▲9.9 %	▲54.2 %

(Source: National Bank of Ethiopia)

Population growth (Annexure 1F)

Name	Administration	population growth rate (84/94)
Addis Ababa	<i>Addis Ababa</i>	0.042
Butajira	<i>SNNP Region</i>	0.042
Dessie	<i>Amhara Region</i>	0.04
Woldiya	<i>Amhara Region</i>	0.045
Shashemene	<i>SNNP Region</i>	0.052
Dodola	<i>SNNP Region</i>	0.051

Size and weight control station axle load report (Annexure 1G)

Origin	Destination	AXLE LOAD IN Ton	AXLE DISTRIBUTION OF VEHICLES										TOTAL AXLE WEIGHT: NO OF VEHICLES				Total
			F1	F2	R1	R2	R3	R4	R5	R6	R7	FRONT		REAR			
												LEGAL	ILLEGAL	LEGAL	ILLEGAL		
Addis Ababa	Dessie	10.1-11	3		1470	1217	2687	831	196					3		6401	12808
Dessie	Addis Ababa	11.1-12			2197	2563	388	259	50					0		5457	10914
Dessie	Addis Ababa	12.1-13			4311	2140	126	88	36					0		6701	13402
Addis Ababa	Combolcha	13.1-14			2850	190	35	41	15							3131	6262
Addis Ababa	Debre Birhan	14.1-15			1197	15	12	18	3							1245	2490
Combolcha	Addis Ababa	15.1-16			499	3	4	4	3							513	1026
Woldiya	Addis Ababa	10.1-11			1013	922	1308	358	59					0		3660	7320
Addis Ababa	Woldiya	11.1-12			1520	1119	140	91	9					0		2879	5758
Woldiya	Addis Ababa	12.1-13			1332	145	23	27						0		1527	3054
Woldiya	Addis Ababa	13.1-14			998	17	14	11	2							1042	2084
Addis Ababa	Combolcha	14.1-15			149	13	2	4								168	336

Dessie	Addis Ababa	15.1-16			48	3		3						54	108
Woldiya	Addis Ababa	10.1-11			711	810	1015	270	107				0	2913	5826
Addis Ababa	Woldiya	11.1-12			1447	926	134	53	22				0	2582	5164
Addis Ababa	Woldiya	12.1-13			1009	239	27	22	3					1300	2600
Woldiya	Addis Ababa	13.1-14			984	48	22	12						1066	2132
Woldiya	Addis Ababa	14.1-15			75	28	25	2						130	260
Addis Ababa	Combolcha	15.1-16			14									14	28
Dessie	Addis Ababa	10.1-11			2020	1974	915	503	136					5548	11096
Debre Birhan	Addis Ababa	11.1-12			1743	1395	465	342	106					4051	8102
Woldiya	Addis Ababa	12.1-13			1357	341	301	253	52					2304	4608
Combolcha	Addis Ababa	13.1-14			505	70	63	14	4					656	1312
Addis Ababa	Woldiya	14.1-15			92	3	5	2						102	204
Debre Birhan	Addis Ababa	15.1-16			31									31	62
Woldiya	Addis Ababa	10.1-11	3		1535	1762	1739	598	48				3	5682	11370
Addis Ababa	Woldiya	11.1-12			2460	2444	316	179	5				0	5404	10808
Addis Ababa	Debre Birhan	12.1-13			1803	245	147	162	5					2362	4724

Addis Ababa	Woldiya	13.1-14			431	22	22	11	1						487	974
Combolcha	Addis Ababa	14.1-15			84	1		1							86	172
Woldiya	Addis Ababa	15.1-16			64	3	1	1							69	138
Addis Ababa	Combolcha	10.1-11	1		1649	1565	887	313	15				1		4429	8860
Addis Ababa	Woldiya	11.1-12			2337	1470	80	51	1				0		3939	7878
Addis Ababa	Woldiya	12.1-13			703	84	40	19	2				0		848	1696
Combolcha	Addis Ababa	13.1-14			135	26	10	8	2				0		181	362
Woldiya	Addis Ababa	14.1-15			32	4	2		3						41	82
Combolcha	Addis Ababa	15.1-16			28	3		3	1						35	70
Dessie	Addis Ababa	10.1-11	7	0	1949 6	1949 4	13825	4235	1124	0			7		58174	11636 2
Addis Ababa	Debre Birhan	11.1-12	0	0	1689 0	1219 6	1723	1099	265	0			0		32173	64346
Dessie	Addis Ababa	12.1-13	0	0	1184 0	3492	717	620	105	0			0		16774	33548
Woldiya	Addis Ababa	13.1-14	0	0	6299	434	180	117	25	0					7055	14110
Addis Ababa	Combolcha	14.1-15	0	0	1737	71	48	30	6	0					1892	3784
Dessie	Addis Ababa	15.1-16	0	0	735	12	5	12	4	0					768	1536
Dessie	Addis Ababa	10.1-11	8	0	2513 5	2490 6	15345	5159	1756	0			8		72301	14461 8

Woldiya	Addis Ababa	11.1-12	0	0	1702 2	1227 6	1772	1124	275	0			0		32469	64938
Woldiya	Addis Ababa	12.1-13	0	0	1195 0	3592	731	635	110	0			0		17018	34036
Addis Ababa	Woldiya	13.1-14	0	0	6509	619	191	138	31	0					7488	14976
Addis Ababa	Woldiya	14.1-15	0	0	1808	111	52	31	6	0					2008	4016
Addis Ababa	Woldiya	15.1-16	0	0	762	17	7	12	5	0					803	1606

(Source: Ethiopian Road Authority Combolcha weight bridge station)

Origin	Destination	Axel Load in Ton	AXEL DISTRIBUTION OF VEHICLE									TOTAL AXEL WEIGHT: NO OF VEHICLE				Total
			F1	F2	R1	R2	R3	R4	R5	R6	R7	FRONT		REAR		
												LEGAL	ILLEGAL	LEGAL	ILLEGAL	
Awassa	Dodola	10.1-11			2875	2168	896	472	256				0		6667	13334
Shashemene	Robe	11.1-12			4430	2212	450	305	68				0		7465	14930
Awassa	Bekoji	12.1-13			6474	695	102	52	16				0		7339	14678
Dodola	Awassa	13.1-14			2149	85	27	18	6				0		2285	4570
Shashemene	Dinsho	14.1-15			401	26	6	1							434	868
Dodola	Awassa	15.1-16			146	12									158	316
Robe	Awassa	10.1-11	6		6259	5018	3082	1294	577				6		16230	32472
Robe	Shashemene	11.1-12	1		6232	3412	953	536	196				1		11329	22660
Dodola	Shashemene	12.1-13			7527	899	134	167	63				0		8790	17580
Dodola	Shashemene	13.1-14			4219	208	39	48	15						4529	9058
Robe	Awassa	14.1-15			1309	82	10	14	1						1416	2832
Awassa	Robe	15.1-16			395	17	3	4							419	838
Dodola	Awassa	10.1-11	5		8241	6463	4196	1976	804				5		21680	43370
Shashemene	Bekoji	11.1-12	1		9160	5034	1101	824	219				1		16338	32678
Robe	Awassa	12.1-13			5089	857	192	156	73				0		6367	12734
Awassa	Robe	13.1-14			1407	355	67	73	9				0		1911	3822
Awassa	Dodola	14.1-15			262	110	27	33	2				0		434	868
Dodola	Shashemene	15.1-16			137	33	6	8	3						187	374
Robe	Shashemene	10.1-11	11		12834	11236	3192	1861	482				11		14843	44470
Dodola	Awassa	11.1-12	1		10157	3533	650	422	81				1		3965	18810
Robe	Shashemene	12.1-13			3397	353	118	82	15				0		1021	4986
Awassa	Bekoji	13.1-14			705	201	65	44	6				0		407	1428
Robe	Shashemene	14.1-15			275	76	34	21	1						253	660
Shashemene	Dodola	15.1-16			217	20	8	7	1						180	433
Awassa	Dinsho	10.1-11	8		17173	14820	2795	1511	720				8		37019	74054
Awassa	Dinsho	11.1-12	3		4383	1662	274	187	51				3		6557	13120
Dodola	Shashemene	12.1-13			1652	499	132	59	7				0		2349	4698
Robe	Awassa	13.1-14			273	98	19	26	5				0		421	842
Dodola	Shashemene	14.1-15			224	45	9	5	1				0		284	568
Robe	Shashemene	15.1-16			99	9	2	2					0		112	224
Robe	Awassa	10.1-11	6		21074	19607	3095	1870	753				6		46399	92810
Awassa	Robe	11.1-12	3		4240	1420	176	123	71				3		6030	12066

Shashemene	Dodola	12.1-13			1390	487	60	56	16					2009	4018
Shashemene	Bekoji	13.1-14			346	282	28	39	5					700	1400
Shashemene	Dinsho	14.1-15			165	113	16	16	3					313	626
Robe	Awassa	15.1-16			66	25	4	4	2					101	202
Dodola	Awassa	10.1-11	14	0	1838	1811	637	311	217			14		4814	9656
Dodola	Shashemene	11.1-12	3	0	281	269	231	72	68			3		921	1848
Robe	Shashemene	12.1-13	0	0	720	575	215	141	52			0		1703	3406
Robe	Awassa	13.1-14	0	0	1606	1500	118	154	40			0		3418	6836
Awassa	Robe	14.1-15	0	0	1380	1387	96	115	14					2992	5984
Shashemene	Dodola	15.1-16	0	0	246	235	37	34	5					557	1114
Shashemene	Dodola	10.1-11	4	0	841	647	472	239	245	0		4		2444	4896
Shashemene	Dinsho	11.1-12	0	0	298	238	179	93	62	0		0		870	1740
Robe	Shashemene	12.1-13	0	0	365	361	97	96	26	0		0		945	1890
Dodola	Awassa	13.1-14	0	0	471	427	48	84	18	0		0		1048	2096
Dodola	Awassa	14.1-15	0	0	609	578	36	34	13	0				1270	2540
Robe	Shashemene	15.1-16	0	0	140	121	11	15	8	0				295	590

(Source: Ethiopian Road Authority Modjo Weight bridge station)

Origin	Destination	AXLE LOAD	AXLE DISTRUBUTION OF VEHECLIES									TOTAL AXLE WEIGHET: NO OF VEHICLES				Total
			F1	F2	R1	R2	R3	R4	R5	R6	R7	LEGAL	ILLEGAL	LEGAL	ILLEGAL	
Addi Ababa	Hossana	10.1-11			550	302	84	52	25				0		1013	1013
Sodo	Addi Ababa	10.1-11			1805	1000	338	243	45				0		3431	3431
Addi Ababa	Hossana	10.1-11	1		1226	830	325	200	35				1		2616	2617
Addi Ababa	Hossana	10.1-11	1	1	1328	777	281	289	36				2		2711	2713
Sodo	Addi Ababa	10.1-11			2289	1068	382	209	42				0		3990	3990
Addi Ababa	Addi Ababa	10.1-11	1		3846	2016	527	388	34				1		6811	6812
Sodo	Addi Ababa	10.1-11			2987	1679	309	188	31				0		5194	5194
Sodo	Addi Ababa	10.1-11			503	466	24	6	20				0		1019	1019
Addi Ababa	Hossana	11.1-12			1642	494	71	55	10				0		2272	2272
Addi Ababa	Hossana	11.1-12			1572	539	58	41	4				0		2214	2214
Addi Ababa	Hossana	11.1-12	1		1933	681	81	56	7				1		2758	2759
Sodo	Addi Ababa	11.1-12			2773	405	71	65	11				0		3325	3325
Sodo	Addi Ababa	11.1-12			2535	478	131	115	9				0		3268	3268
Addi Ababa	Hossana	11.1-12			2293	426	67	59	4				0		2849	2849
Sodo	Addi Ababa	11.1-12	0	0	2837	1000	94	66	23	0			0		4020	4020
Sodo	Addi Ababa	11.1-12	1	0	78	30	2	1	1				1		112	113
Sodo	Addi Ababa	12.1-13			1740	20	18	9	2				0		1789	1789
Sodo	Addi Ababa	12.1-13			3527	146	14	15	1				0		3703	3703
Addi Ababa	Hossana	12.1-13			2909	141	11	10	1				0		3072	3072
Addi Ababa	Hossana	12.1-13			913	95	13	16					0		1037	1037
Addi Ababa	Hossana	12.1-13			511	70	4	6	3	0			0		594	594
Sodo	Addi Ababa	12.1-13	0	0	406	79	7	2	2	0			0		496	496
Addi Ababa	Hossana	12.1-13			686	1598	8	7	4				0		2303	2303
Sodo	Addi Ababa	12.1-13	0	0	128	127	1	1	0				0		257	257
Sodo	Addi Ababa	13.1-14			1190	49		6					0		1245	1245

Addi Ababa	Hossana	13.1-14			1321	23	2	1					0		1347	1347
Addi Ababa	Hossana	13.1-14			884	26	2	3					0		915	915
Sodo	Addi Ababa	13.1-14			1548	16	1	6	1				0		1572	1572
Sodo	Addi Ababa	13.1-14			247	17	8	6							278	278
Sodo	Addi Ababa	13.1-14			125	33	4	5							167	167
Addi Ababa	Hossana	13.1-14			186	852	3	7	1				0		1049	1049
Addi Ababa	Hossana	13.1-14			241	192	7	16							456	456
Addi Ababa	Hossana	14.1-15			262	10									272	272
Sodo	Addi Ababa	14.1-15			216	2	1						0		219	219
Addi Ababa	Hossana	14.1-15			134	4	1						0		139	139
Sodo	Addi Ababa	14.1-15			126	7	1	2							136	136
Addi Ababa	Hossana	14.1-15			85	14	1	3							103	103
Sodo	Addi Ababa	14.1-15	0	0	59	6	0	0	0	0			0		65	65
Addi Ababa	Hossana	14.1-15			69	198	3	3					0		273	273
Sodo	Addi Ababa	14.1-15			85	75	6	13	1						180	180
Addi Ababa	Hossana	15.1-16			76	2									78	78
Addi Ababa	Hossana	15.1-16			153	7		1					0		161	161
Addi Ababa	Hossana	15.1-16			121	5									126	126
Sodo	Addi Ababa	15.1-16			119	2	1	1							123	123
Sodo	Addi Ababa	15.1-16			38	14	3	3							58	58
Sodo	Addi Ababa	15.1-16	0	0	31	2	0	0	0	0			0		33	33
Sodo	Addi Ababa	15.1-16			34	67									101	101
Addi Ababa	Hossana	15.1-16			73	22	8	7							110	110

(Source: Ethiopian Road Authority, Alemgena weight bridge station)

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Approval Page

This thesis paper entitled on " _____
Assessment of the reliability of
traffic forecast and its Impact on pavement design and service life", case study on three
Ethiopian Roads through this, has been approved by the following examiners in partial
fulfillment of the requirement for the degree of master of Engineering in **Road and
Transport Engineering**.

Mihiret Tesfaye
MSC Candidate Name

Signature

Date

Dr. Bekila Teklu

Advisor

Signature

Date

School Dean

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Associated Director PG program

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Date