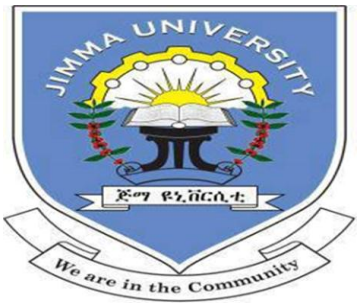

JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL

ENGINEERING HIGHWAY ENGINEERING

STREAM

CASE STUDY ON THE PERFORMANCE ASSESSMENT OF ADDIS ABABA CITY ROAD NETWORK

A Project submitted To School Of Graduate Studies Of Jimma University In Partial Fulfillment Of Requirements For Degree Of Masters Of Engineering in HIGHWAY ENGINEERING

BY: - Mohammed Aydahis

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Jimma, Ethiopia

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ACKNOWLEDGMENT

I would like to express my deepest regard and thanks to our sponsorship ERA and also to thanks JIT. I would like to thanks to our Chairman of Highway Engineering Mrs. Tarekegn for encouraging me during the progress of this project and for his unlimited support through supervision to carry out the project.

Finally, my special thanks go to my parents, General Manager of Afro-Tsion Construction plc. Eng. Sisay Desta who are always been there in times of difficulties and giving me moral support to complete this research work.

ABSTRACT

The study is carried out for Addis Ababa city, which is the capital city of Ethiopia, with population over 3.0 million. It is situated on mountainous landscape at an allitted of about 2,500 meters above mean sea level and extends over 500km^2 .The road network of Addis Ababa is limited in extent and right of way. Its capacity is low, on-street parking is prevalent, and the pavement condition is deteriorating. Despite a large volume of pedestrians, there are no walkways over a large length (63%) of the roadway network. This is a major concern because it contributes to the increased pedestrian involvement in traffic accidents (10,189 accidents occurred in 2004).

The main objective of this project is to evaluate/assess the performance of road network in Addis Ababa.

The scope of the project is to evaluate case study on the performance assessment of Addis Ababa city road network.

The use of secondary source (literatures, books) as a source of information and data collection direct from case study area.

The trend in change of road density from 1997 E.C up to 2005 E.C. is increasing significantly on average annual growth of 8.9%. So this result means the ratio of the area covered with road in the city is increasing which in other words enhancing mobility and accessibility in the city. The trend in road performance is constant in some years like from 1997 E.C. to 2000 E.C. and then gradually increases starting from 2000 E.C. So based on the evaluation indicator of road performance, increasing the total length of paved roads will increase road performance then the road network performance will be good. The road serviceability in the city is increasing gradually from 1999E.C. up to 2005 E.C. but the rate in change is very low which means the construction of new roads is not much reachable by the peoples and to increase the accessibility/serviceability of roads in the city we have to work hard in developing good road network in which it increases peoples benefit and development of the city. The percentage of accidents occurred in straight and flat slope part of the road from the network is around 90.05% [(38397/42640)*100] this shows that even we construct a comfortable road for the drivers it may reduce the performance of the road when we evaluate according to safety. Also when we see the percentage of accidents occurred in the road with good asphalt condition is 96.3% [(41060/42640)*100] which is even higher the former. This shows that connecting the city with new asphalt roads may reduce the performance of the road in respect of safety. All sub-cites will have greater than one beta index which shows a better connectivity in the sub city.

The overall results of traffic distribution show those peripheral areas of the cities prohibited from enjoying an acceptable level of connectivity. these areas have low density of road network and, as expected this city are physically close to each other, peoples still have to travel longer distances to their destination.

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LISTS OF ABBREVATION AND DEFFINATION

ERA: Ethiopian Road Authority

JIT: Jimma Institute of Technology

AACRA: Addis Ababa City Road Authority

UNECA: United Nation Economic Commission for Africa.

LRT: Light Rail Transit

BRT: Bus Rapid Transit

FASC: Federation of African Societies of Chemistry

HAPI: Horn of Africa Press Institute

CHAPTER ONE

INTRODUCTION

1.1. Back Ground

Addis Ababa is the capital city of Ethiopia founded in 1886 it is the largest city in Ethiopia, with a population of 3,384,569 according to the 2007 population census with annual growth rate of 3.8%. This number has been increased from the originally published 2,738,248 figure and appears to be still largely under estimated (`Central Statistical Agency of Ethiopia(from the original on 18 December 2008. Retrieved 2008-12-07).

As chartered city (ras gez astedader), Addis Ababa has the status of both a city and state . It is where the African union is and its predecessor the AAU was based .It also hosts the headquarters of the United Nations Economic Commission for Africa (ECA) and numerous other continental and international organizations. Addis Ababa is therefore often referred to as "the political capital of Africa' due to historical, diplomatic and political significance for the continent .(United Nation Economic Commission for Africa. (UNECA. Retrieved 5 May 2012).

The city with is populated by people from different regions of Ethiopia .The country has as many as 80 nationalities speaking 80 languages and belonging to wide variety of religious. It is home to Addis Ababa university. The Federation of African Societies of Chemistry (FASC) and Horn of Africa Press Institute (HAPI) are also head quartered in Addis Ababa .

Addis Ababa lies at an elevation of 2,300 meters and grassland biome, located at 9^0 1'48" N $38^0$44'24" E /9.03000 N^0 38. 74000^{0}E.(Earth _info.nga.mil.Retrievedd May 2012).

The expansion of Addis Ababa along the five radial roads has posed many challenges for the city, especially in terms of increased transportation costs, congestion, and delivery of public infrastructure services. Additionally, there is a lack of coordination between transport investments and urban development. Indeed, housing and land-use decisions are taken on the basis of where available land resources are, with almost no assessment of transport impacts, thereby missing the opportunity to integrate public transport modes in terms of coverage, routes,

fares, schedules and facilities. Low coverage of streets and a lack of street grid network and associated infrastructure has resulted in further in efficiency of mobility and associated issues of productivity, quality of life, and social inclusion.

Over the past few years, Addis Ababa has been making a concerted effort to improve the urban transport situation, largely through large investments in new infrastructure, including roads, a new Light Rail Transit (LRT) system (under construction) and plans for a new Bus Rapid Transit (BRT) system, and improved standards and practices for improving and integrating pedestrian facilities in major transport capital projects. However, for both the LRT and BRT, the operations and maintenance oversight responsibility have not been decided, and it is not clear whether these would be a city or national function (City Strength Resilient Cities Program, Addis Ababa, July 2015).

Public transport in the city consists of conventional bus services provided by the publicly owned Anbessa City Bus Enterprise, taxis operated by the private sector, and buses used exclusively for the employees of large government and private companies. The role of bicycles in urban transport is insignificant (World Bank African Region Scoping Study 2002). The road network of Addis Ababa is limited in extent and right of way. Its capacity is low, on-street parking is prevalent, and the pavement condition is deteriorating. Despite a large volume of pedestrians, there are no walkways over a large length (63%) of the roadway network. This is a major concern because it contributes to the increased pedestrian involvement in traffic accidents (10,189 accidents occurred in 2004) (Ethiopian Roads Authority, Journal of Public Transportation 2005).

1.2. Statement of the problem

In a resilient city, the transport system offers multiple modes of transport to its users to ensure the continuity of mobility in the event of disruptions, and to ensure access to transportation for all population groups. It takes a flexible approach and proactive coordination with other agencies to be able to divert user traffic to different modes of transport based on changing conditions. In a resilient city, the planning for and investments in the transport sector are based on an assessment of past shocks and stresses and are closely aligned with other departmental plans and overall key priorities of the city. The expansion of Addis Ababa along the five radial roads has posed many challenges for the city, especially in terms of increased transportation costs, congestion, and delivery of public infrastructure services (City Strength Resilient Cities Program, Addis Ababa, July 2015).

Additionally, there is a lack of coordination between transport investments and urban development. Indeed, housing and land-use decisions are taken on the basis of where available land resources are, with almost no assessment of transport impacts, thereby missing the opportunity to integrate public transport modes in terms of coverage, routes, fares, schedules and facilities. Low coverage of streets and a lack of street grid network and associated infrastructure has resulted in further in efficiency of mobility and associated issues of productivity, quality of life, and social inclusion. Over the past few years, Addis Ababa has been making a concerted effort to improve the urban transport situation, largely through large investments in new infrastructure, including roads, a new Light Rail Transit (LRT) system (under construction) and plans for a new Bus Rapid Transit (BRT) system, and improved standards and practices for improving and integrating pedestrian facilities in major transport capital projects. However, for both the LRT and BRT, the operations and maintenance oversight responsibility have not been decided, and it is not clear whether these would be a city or national function (City Strength Resilient Cities Program, Addis Ababa, July 2015).

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"In the planning of a transport network, most efforts by the planning authorities are geared towards increasing the capacity and building new transport networks, but little attention is given to the structure of the network. To evaluate the spatial structure and form of the transport network is relevant to the performance and the utilization of the network; this is because traffic Congestion is an issue of concern in many cities."***(8)*** Kofi (2010), **Network Based Indicators for Prioritizing the Location of a New Urban Transport Case Study in Istanbul**, Turkey, 2010.

1.3. Research Question

- What moods can be used for estimation of travel demand in urban area?
- What are the road network performance indicators?
- What are the recommendations for improving road performance networks?

1.4. Objective of Study

1.4.1. General Objective

The main objective of this project is to evaluate/assess the performance of road network in Addis Ababa.

1.4.2. Specific Objectives

The specific objectives of the present research work include the following:

- To identify potential travel demand and current network.
- To assess road network performance using indicators for sub Cities/networks in Addis Ababa.
- To make recommendations for policy makers to improve performance of road networks based on the outcome of the study for the concerned bodies.

1.5. Scope

The scope of the project is to evaluate case study on the performance assessment of Addis Ababa city road network.

1.6. Limitation

The use of secondary source (literatures, books) as a source of information and data collection direct from case study area.

CHAPTER TWO

LITREATURE REVIEW

2.1. Back Ground of Addis Ababa City Road Development

Addis Ababa city was founded by Minellik II and Empress Taitu in 1886. The history of the city‘s road development also begins from the inception of the city. Minellik II constructed the first ever two roads in the city as well as in the country that stretch from Addis Ababa to Addis Alem and from his palace to British embassy in 1902. In 1904 the first roller was imported by the Emperor and was pulled by many people for its operation. Emperor Minellik was also believed to be the first in importing cars in Addis Ababa and introduced the car technology in the city for the first time in 1907 E.C. The country’s modern road construction in general and Addis Ababa in particular is highly interlinked with Emperor Haile Sellase’s ruling period. During the regime of Haile Sellase a number of contractors were organized to carry out road construction. ***((*** Addis Ababa City Road Authority Bulletin (2000 - 2004), Addis Ababa, 2004).

The first agency to be established by the Government to construct roads was the Public Works Department. It was established to construct roads in Addis Ababa and in its surrounding. After a few years this Department was raised to a ministerial level and Addis Ababa also got the chance to establish its road development organizational structure. When it was decided for Addis Ababa to have a mayor and a council in 1942, the city roads construction and maintenance was organized under the municipality. To fulfill the road construction activities together with building works, the “Road and Building Works” Department was established. This Department stayed till the replacement of the Haile Sellase regime by the Derge regime performing its duties. But no fundamental organizational change of the department was observed during the Derg regime.***(*** Addis Ababa City Road Authority Bulletin (2000 - 2004), Addis Ababa, 2004).

In 1993 the existing government established regional governments and gave them power to administer their regions with autonomy. During this time Addis Ababa was also established as one of regions. The Addis Ababa administration during this period established the “Bureau of Works and Urban Development” and the bureau organized a department under it to carry out the road construction and maintenance works. The newly established road department constructed

and maintained the City's roads till the establishment of the Addis Ababa City Roads Authority in march 15,1998 by regulation no 7/1998 to be administrated by board of directors to construct, maintain and administer the road works in Addis Ababa by the city administration. The total length of roads constructed in the city till the establishment of the authority in March 15, 1998 was 1300km of which 900 km was gravel road and the remaining 400 km was Asphalt surfaced road. The Addis Ababa City Roads Authority has done remarkable progress in the city roads expansion and upgrading in the last 11 years since its establishment*(* Addis Ababa City Road Authority Bulletin (2000 - 2004), Addis Ababa, 2004).

A significant share of the urban growth is taking place in large cities like Addis Ababa. Especially, the number of conglomerates with more than 5 million inhabitants will grow. Middle and low income countries show the highest urban population increase, especially in Sub Saharan Africa *(*Gwilliam, K. (2003), **Urban Transport in Developing Countries**, Transport Reviews: A).

(Transnational Trans disciplinary Journal*).* Despite some economic benefits, the rapid urban growth in developing countries is outstripping the capacity of most cities to provide adequate services for their citizens (Cohen, 2004) **Urban Growth in Developing Countries: a Review of Current Trends and a Caution Regarding Existing Forecasts**, World Development, 2004, Germany). A high urbanization rate in combination with the intense desire for car ownership in developing countries causes a rapid growth of motorization *(* Gakenheimer, R. (1999), **Urban Mobility in the Developing World**, Transportation Research Part A: Policy and Practice, Netherlands).

On the other hand, a lack of infrastructure and weak road network maintenance put extra stress on growing traffic flows with congestion , pollution and a low road safety level as a result *(*Gakenheimer, R. (1999), **Urban Mobility in the Developing World**, Transportation Research Part A: Policy and Practice, Netherlands*).*

2.2. Transport Infrastructure-Addis Ababa Road Network and Pedestrian facilities

Addis Ababa has 5 major arterial gate roads that radiate from the city center to different parts of the country. The five regional gate roads of the city and other arterial roads are linked to each

other by the 8 lanes ring road that circumscribes the city (figure 3-4). The Addis Ababa road network has increased from 2,200km in 2005 (Meron, 2007) to 2,657km in 2010 (Assegid3, 2010) of which 42.75 % (1,136km) is paved asphalt and the remaining 57.25 % (1,521km) is gravel road. As of 2010, the road network makes up 10% of the total urban built up area of the city (Assegid, 2010). The counterpart figure in western European cities ranges from 15 % to 25% of the urban surface (Rodrigue, 2009).

During the last few years massive road construction and improvement works have been going on in the city. This has contributed to the efficiency of transport mobility and has changed the image of the city as well as facilitating other socioeconomic developments. The road length envisaged by the Addis Ababa 2003 Master plan was 800 km. As of April 2010, constructed road and pedestrian walkway were 620km. and 423km respectively. Currently the road coverage of the built area is 11.3% and it is envisioned to have the road network coverage about 20% by the year 2020. Due to lack of a rail way and other effective mass transport system, the city mobility needs are mostly covered by road based few number of buses and taxis. Moreover, there is no sufficient and comfortable pedestrian walkway. As far as the city development process is concerned, the infrastructure construction and the transport services are not in accordance with the transport plan.

This is best explained in the following main challenges listed under:

- Roads capacity and traffic flow does not work in a modern and coordinated manner,
- The increasing trend of traffic congestion,
- Lack of sufficient traffic signals, road signs and markings; coupled with non-functioning and ineffective feature of the existing ones,
- Lack of dedicated bus and bicycle lanes
- Lack of parking facilities and over utilizing of on road parking(Transport Policy of Addis Ababa, August 2011,Addis Ababa).

2.3. General Conditions of Traffic and Transport Development

A mixture of ownership structures, of which public and private operators are predominantly contenders for business, carries urban transport in Addis Ababa. The modes of urban transport

system in the Addis Ababa are categorized in to motorized and non- motorized traffic. As such the modes of transport include public bus; minibus; taxis and the non-motorized transport, while walking and animal carts dominant the periphery. Currently, taxis, city bus and private cars altogether cover 30 percent of the urban mobility, that is, 26% bus, 72% taxis and 4 % private cars.While 70% of urban mobility is covered on foot (Vasconcellos EA. *Urban transport, environment and equity: the case for developing countries.* London, Earthscan Publications, 2001).

Many of the traffic congestions and road safety problems in Addis Ababa may be attributed to inefficient use of road networks, weak enforcement capability and poor design of roads. As such Road Traffic Safety Regulations have been issued in the 1998 by the Council of Addis Ababa Administration. Accordingly, who so ever, by omission, contravenes what is laid down depending on the gravity of the offence committed is obliged to be punished (Smeed R. Some statistical aspects of road safety research. *Journal of the Royal Statistical Society*, 1949,112(Series A):1–34).

2.4. FUNCTIONAL CLASSIFICATION OF ROAD NETWORK

(The federal *democratic republic of Ethiopia, ERA, Road sector development program (1997-2007)).*

TRUNK ROADS:

Routes handling a significant proportion of through traffic. They pass through several regions, starting with the capital city and terminating at border city/exit points or at ports. This is a type of interregional highway.

MAJOR LINK ROADS:

Main links to the Trunk Road and often traverse two regions. Carries significant inter-regional long distance traffic.

REGIONAL ROADS:

Main regional roads, carrying mainly regional traffic, connect regional and zonal centres. Connects or links Trunk Roads and Major Link Roads to important agricultural, mining, power plants Etc.

VILLAGE ROADS:

These are village access roads, important for evacuation of crops from farm gate to markets, or special purpose roads. Means of transport on these routes need not be necessarily motorized.

SPECIAL PURPOSE ROADS:

These types of roads are built to serve certain land uses such as providing access to microwave stations, commercial farms, agricultural research stations, etc. Normally these roads are built by agencies or organizations responsible and involved in the undertaking of that activity (project).

Note: - The Administrative category of these roads is presented as follows:

Trunk and Major Link Roads: - Federal Government (Ethiopian Roads Authority)

Regional Roads: - Regional Government (Regional Roads Department)

Village Roads: - Community

Special Purpose Roads:- Concerned owners of the roads (Agencies, Community, Individuals, etc)

2.5. CLASSIFICATION OF ROAD NETWORK BY SURFACE TYPE

(The federal democratic republic of Ethiopia, ERA, Road sector development program (1997-2007)).

I. Asphalt Concrete: Semi rigid pavement used for heavy traffic with a cumulative number of above 10 million standard axles; pavement with a base of bound material such as dense bitumen macadam, lean concrete or cement stabilized gravel, covered with a thick bitumen surfacing.

II. Surface Dressing: Flexible pavement used for light and medium traffic with a cumulative number of standard axles above 1 million and less than 10 million standard axles. The pavement is composed of a base made of fairly deformable material, such as gravel graded crushed stone or cement or lime-improved material, with a thin bituminous surfacing.

III. Gravel Surface: (Grade I)

Flexible pavement capable of carrying standard axles between 0.5million and 1 million. The road is normally to be provided with a bottom layer of gravel or crushed rock up to 150 mm

thick, over the full width of the formation. Additionally, 30 mm thick crushed aggregate will be laid as wearing course.

IV. Gravel Surface (Grade II)

This is capable of accommodating cumulative standard axles of less than 0.5million. It is normally to be provided with a running surface of gravel or crushed material up to 150 mm thick, over the full width of the formation, with no wearing course. Bridges and culverts will be provided at streams or river crossings.

V. Gravel Surface: (**Grade III)** It is an all-weather gravel surface road, for a traffic level up to 50 vehicles per day (vpd). The surface is constructed of up to 150 mm thick gravel or crushed rocks over 6m. Formation width. The cross-drainage is generally by means of culverts; and bridges will be provided at non-fordable streams or river crossings. The maximum allowable gradient is 10% and the minimum horizontal curve radius shall be 20m.

VI. Gravel Surface: (**Grade IV)**

This rural road is constructed for a traffic level up to 30 vpd, and provides for limited wet-weather vehicular movements. The running surface normally consists of in-situ sub-grade material, strengthened in areas of weak local soil by a layer of selected material over the full 6m. Formation width. A 150 mm. surfacing of gravel or crushed rock is required in particular sections, to be applied to the centre 3.5m of the formation only. The maximum gradient is 12% and minimum horizontal curve radius 15m. Cross-drainage is by means of culverts or paved fords, and bridges are built at non-fordable streams or rivers.

VII. Earth Road :

This road is constructed to minimum standards capable of carrying up to 10 vpd during dry weather, and closed to traffic during periods of heavy rain. The formation width of this road is 6m. and may be reduced to 4m. Pavement is not provided, but may be necessary over sections of steep gradient or where soils are particularly poor. The maximum gradient is 14%, and the minimum horizontal curve radius shall be 10m. Cross-drainage is generally by means of simple structures (e.g.ford, paved drifts); and bridges shall not normally be provided, but if necessary built by timber deck on masonry piers and abutments.

VIII. Track: It is a route where motorized vehicles could pass on, however is not engineered for use of such vehicles and has no ditches.

IX. Trail: Could be similar to track, and it is normally beyond the frequent use of day to day activity, having no clearing and no ditch.

X. Paths:

It is a route passable by pedestrians, annimals and animal-drawn or hand carts or the like, which a motorized vehicle could not use.

2.6 Lists of Addis Ababa City Road Network Progress *(Yonas Minalu, July 2014)* (Yoans Minalu, 2014)

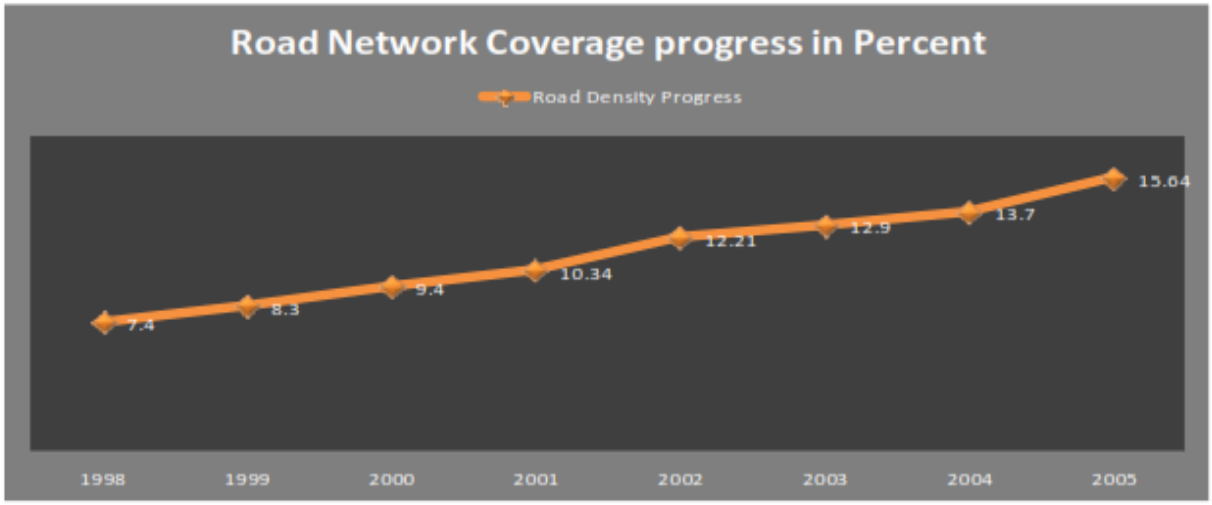


Figure 1– Road network coverage progress in Addis Ababa (1998 -2005) **(Yoans Minalu, 2014)**

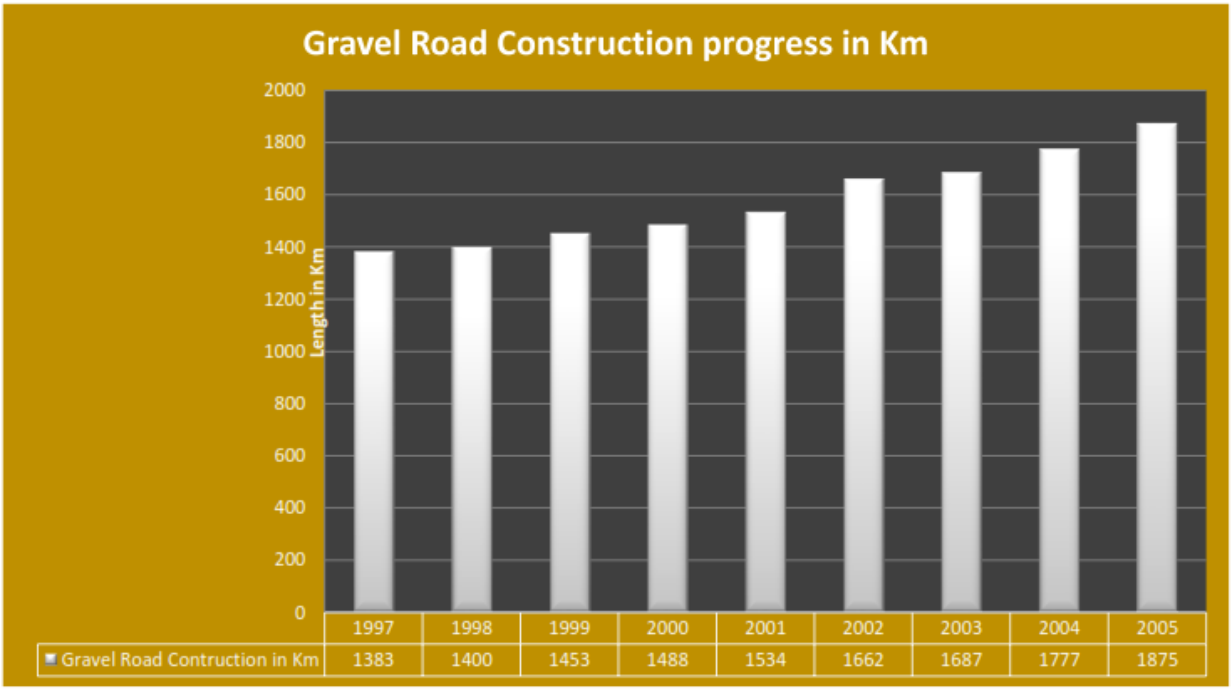


Figure 2– Gravel Road Construction Progress (1997 -2005) **(Yoans Minalu, 2014)**

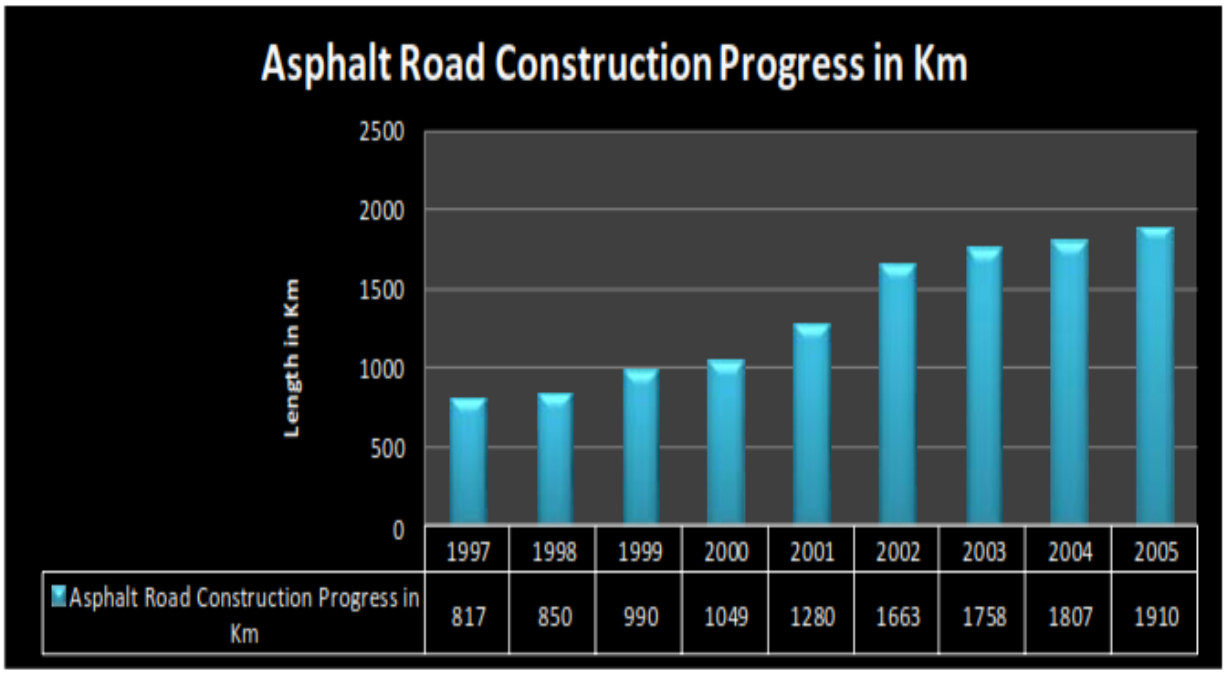


Figure 3 – Asphalt Road Construction progress (1997 -2005) **(Yoans Minalu, 2014)**

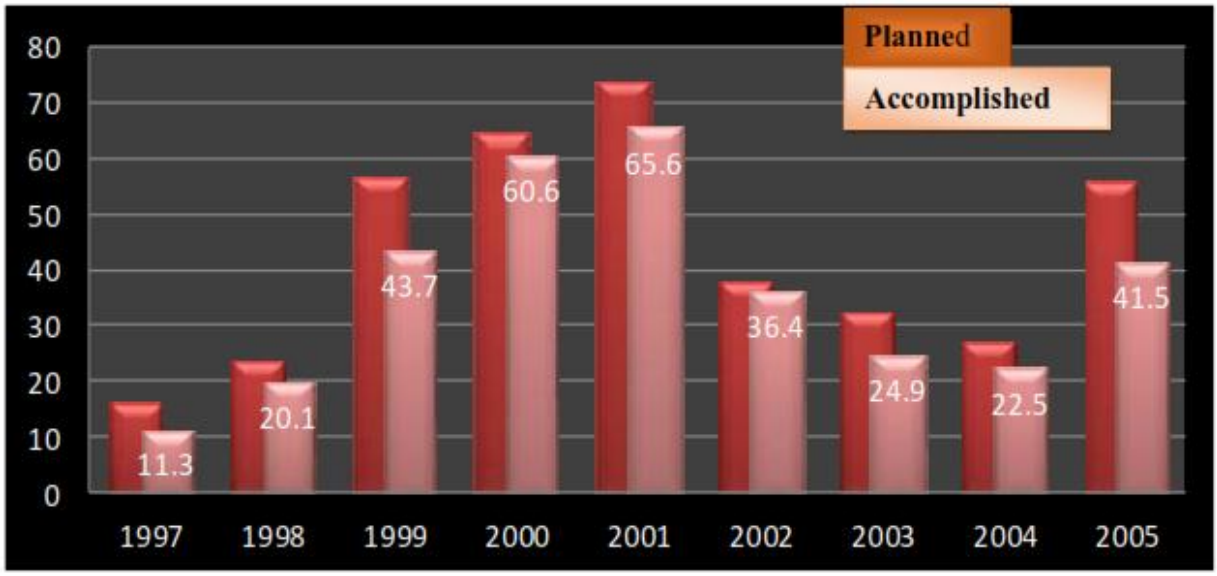


Figure 4- New Asphalt Road Construction Progress in Km planned vs Accomplished **(Yoans Minalu, 2014)**

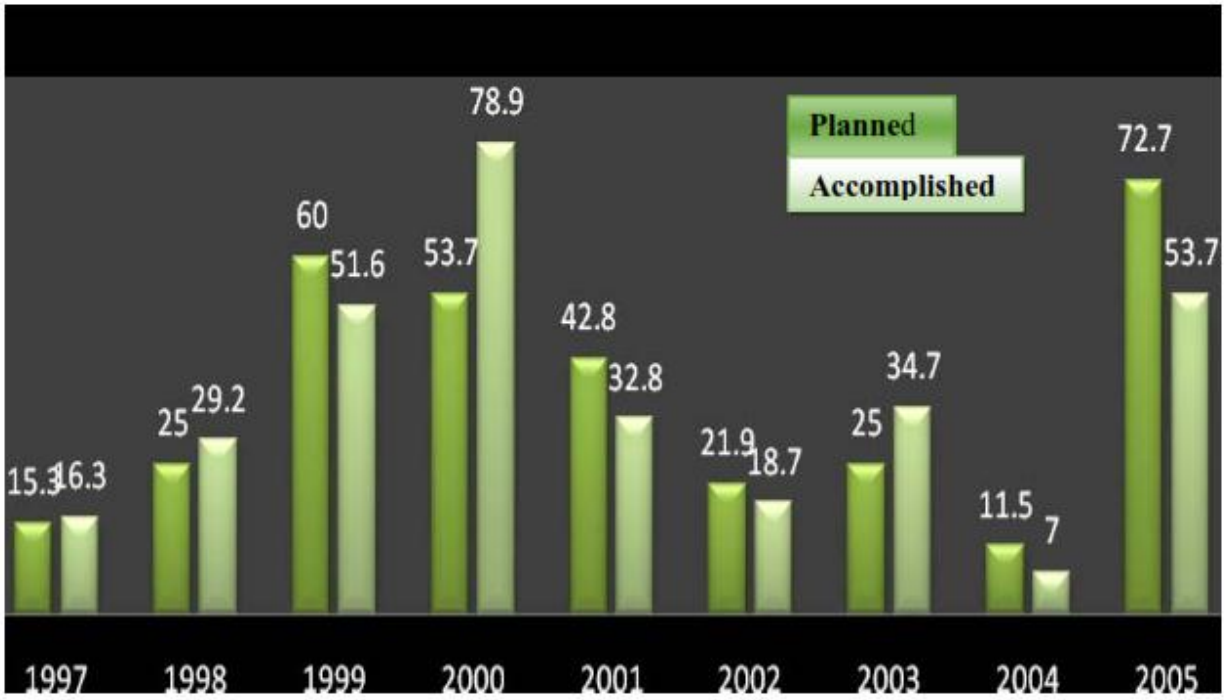


Figure 5- New Gravel Road Construction Progress in Km planned vs Accomplished **(Yoans Minalu, 2014)**

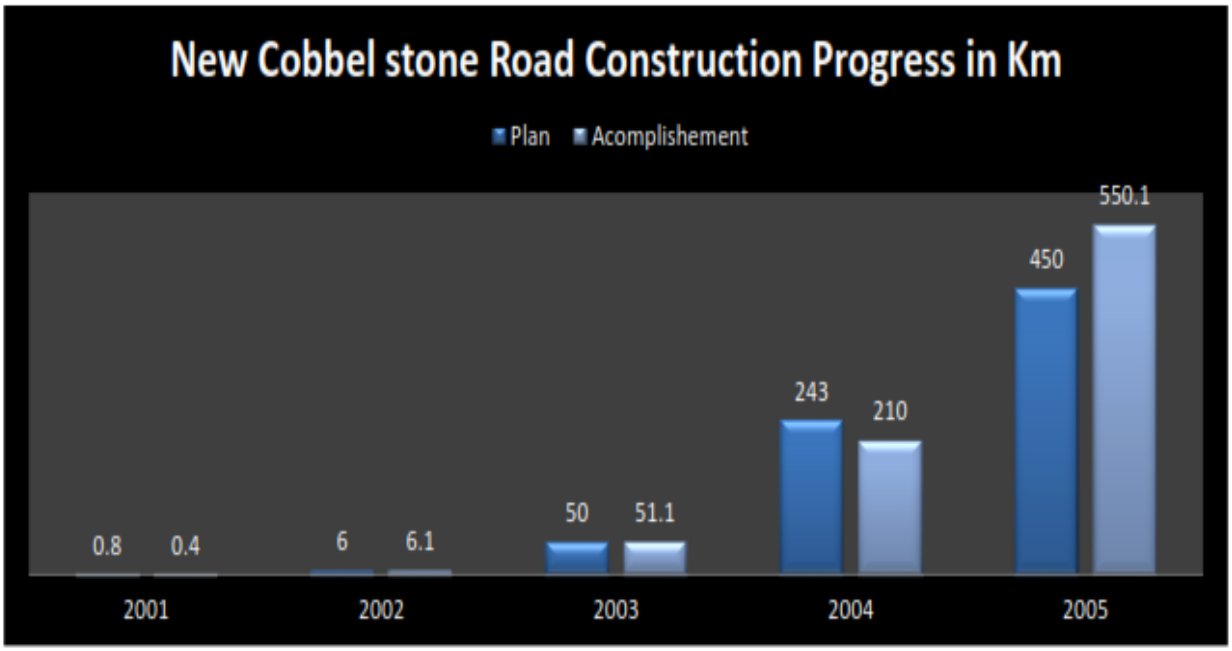


Figure 6 – Cobbel stone road Construction progress (2001 -2005) **(Yoans Minalu, 2014)**

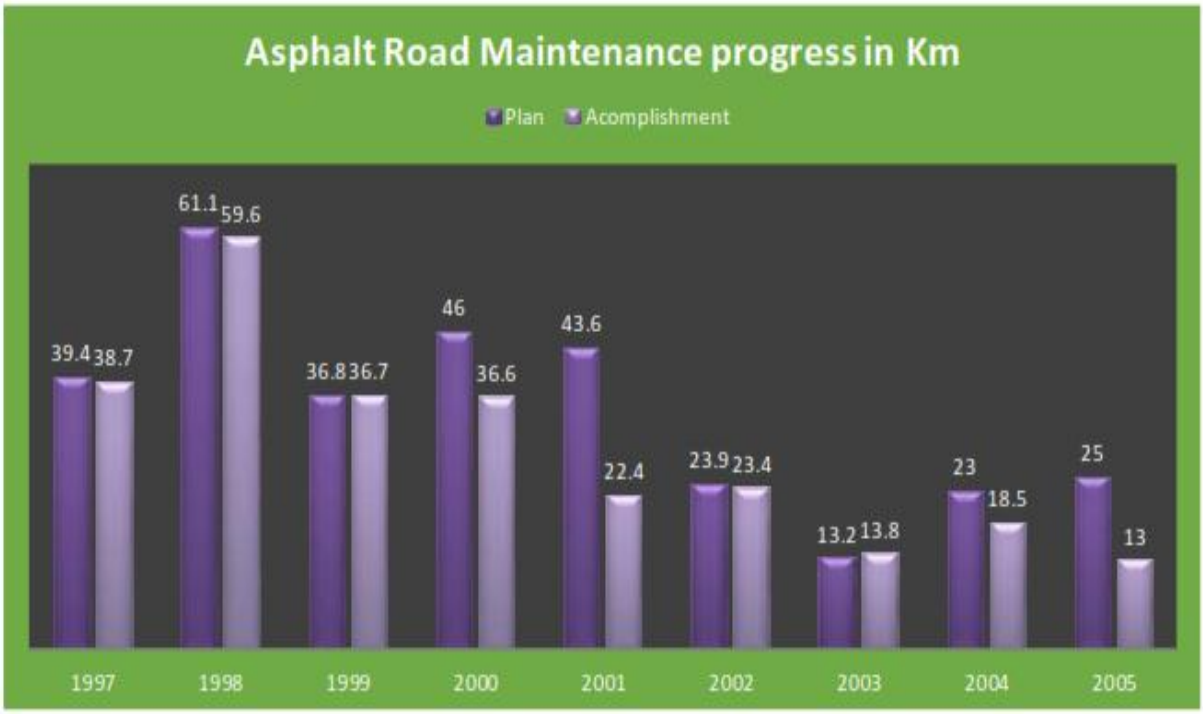


Figure 7 – Asphalt road maintenance progress (1997 -2005) **(Yoans Minalu, 2014)**

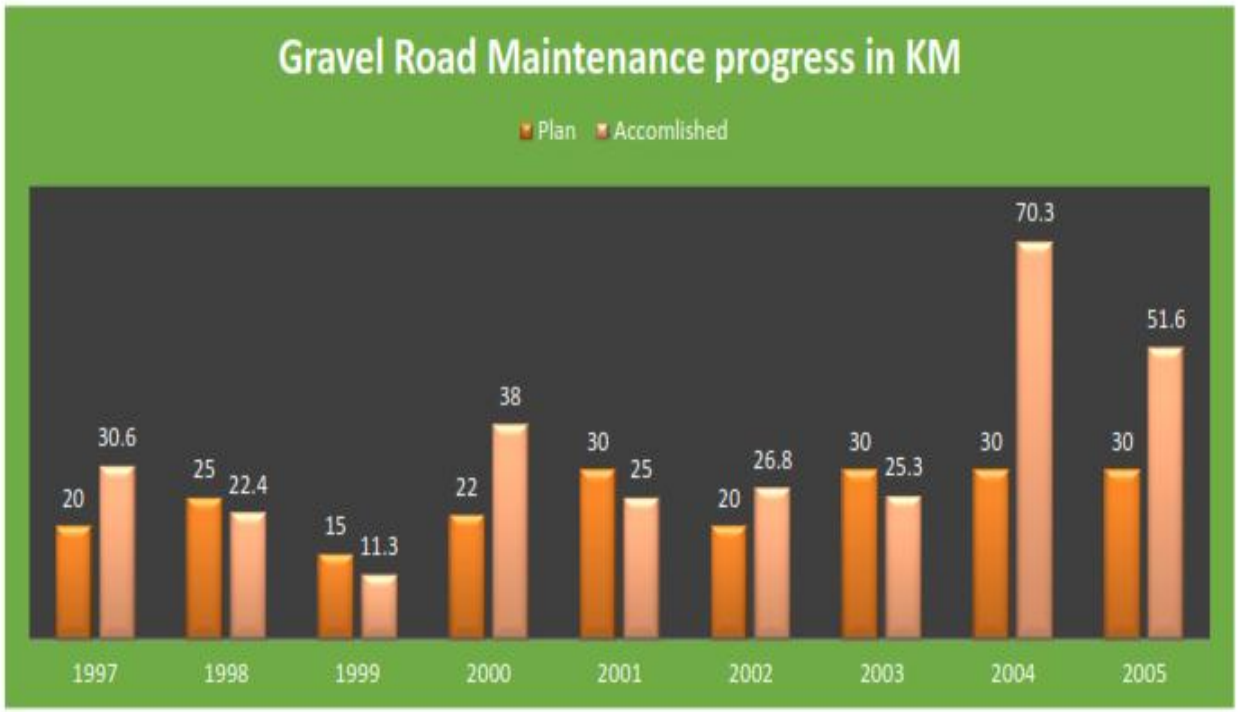
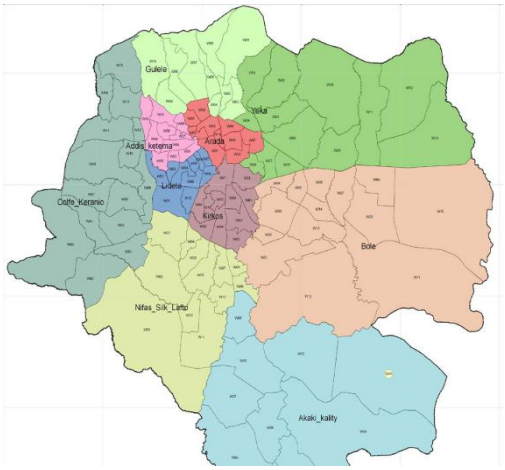


Figure 8– Gravel Road Maintenance progress (1997 -2005) **(Yoans Minalu, 2014)**

CHAPTER THREE

METHODOLOGY

3.1 Study Area



3.1.1 Topography

Addis Ababa lies at an elevation of about 2,500 meters and grassland biome, located at 9^0 1'48" N $38^0$44'24" E /9.03000 N^0 38. 74000^{0}E. (Earth _info.nga.mil.Retrievedd May 2012).This case study focuses on performance assessment of Addis Ababa City road network.

3.1.2 Climate

Addis Ababa has subtropical highland climate(Climate-Data.org., Retrieved 6 February 2015). The city has a complex mix of highland climate zones, with tempreture differences of up to 10^0C(18^0F), depending on elevation and prevailing wind patterns**.**

Table. 1 Monthly Minimum and Maximum Temperature (0c) (Awoke Sime,2006)

Month	Addis Ababa	
	Minimum	Maximum
January	8.1	13.2
February	9.5	24.0
March	10.8	24.5
April	11.5	23.5
May	11.7	21.3
June	10.7	22.9
July	10.8	20.2
August	10.8	20.2
September	10.5	20.9
October	9.1	22.2
November	7.8	22.5
December	7.5	23.6

Table .2 Means Monthly Rainfalls (mm) (Awoke Sime, 2006)

Month	Addis Ababa
January	16.8
February	39.5
March	68.2
April	94.5
May	77.0
June	118.9
July	253.8
August	279.2
September	173.5
October	37.4
November	8.9
December	8.9

3.2 Study Design

Secondary Source (literatures, journal, Books) of data was design to get information about the Case study.

3.4. Road Network of Study Area

a. Road availability/Road density; a ratio between total road lengths with area width. Road availability has a unit km/km2. The road density explains how dense the road network is in the study area and we have to compare the result with some standards. If the value of road density shows increasing through years which means construction of new roads in the city giving more access to the peoples. The data needed to compute road density are the trend of total road length constructed which is collected from AACRA and total area of the city collected from the sub-cities and when we divide the two numbers we will get the road density of the city (AACRA, 2014).

Table 3. Addis Ababa and area

Subcity	Area (km^2)	Population	Density
Addis Ketema	7.41	271,644	36,659.10
Akaky Kaliti	118.08	195,273	1,653.70
Arada	9.91	225,999	23,000
Bole	122.08	328,900	2,694.10
Gullele	30.18	284,865	9,438.90
Kirkos	14.62	235,441	16,104
Kolfe Keranio	61.25	546,219	7,448.50
Lideta	9.18	214,769	23,000
Nifas Silk-Lafto	68.3	335,740	4,915.70
Yeka	85.98	368,418	4,284.92
Total	526.99	3,007,268	

Road availability/road density =Total road length in km/526.99 km^2

c. Road performance; a ratio between lengths of road in stable condition with total road length. Road performance has no unit. This indicator shows the proportion of roads which are in good condition/stable condition which means they didn't need maintenance and also in other words the comfortable or high mobility and movement of vehicles in the road network of the city. The data needed to compute this indicator is total length of roads constructed in the city from

AACRA and total length of roads in unstable/bad condition which means uncomfortable roads like roads in maintenance and gravel roads (AACRA, 2014).

c. Traffic volume load; a ratio between total lengths of road with number of vehicles. This indicator has a unit km/no of vehicle. This indicator shows percentage usage of constructed roads by vehicles in the city. The data needed to compute this indicator are total length of road constructed in the city from AACRA and total number of registered vehicles in the city with Addis Ababa (AA) plate label from Addis Ababa Transport Office (AACRA, 2014).

D. Road serviceability; a ratio between total lengths of road with number of population in that region. The unit of this index is km/people. This indicator shows the easily availability of roads for peoples in the city. The data needed to compute this indicator are total length ofroad constructed in the city and total number of population of the city (AACRA, 2014).

E.Road safety; the percentage of accidents occurred. Using this indicator we will try to assess the effect of the construction of the roads in the network related to accident and this **shows** the trend how road network development affect safety. This indicator needs recorded accident rates in different categories with their causes which are found from Addis Ababa Police Commission office (AACRA, 2014).

F. Road Connectivity; Connectivity (also called permeability) refers to the directness of links and the density of connections in path or road network. A well-connected road or path network has many short links, numerous intersections, and minimal dead-ends. The connectivity in the road network of the study area was tested using Beta index of connectivity in which by dividing the total number of arcs or straight line roads found in the road network by nodes or junctions in the road network. To use this first the total number of nodes in the road network and the straight line roads between the nodes must be determined which is obtained manually by counting from the master road network (AACRA, 2014).

CHAPTER FOUR

RESULT AND DISCUSSION

A. Determination of the Road Density

From the above data, the total area of Addis Ababa is 526.99 km and the total road length constructed until 2005 E.C including asphalt, gravel and cobble stone is shown in the data analysis part on chart 4, chart 5 and chart 8.

Road availability/road density =Total road length in km/526.99 km^2

Table 4 – Addis Ababa City Road Density Trend(Yoans Minalu, 2014)

Year	Road Density
1997 E.c or 2004/05 G.C	4.17
1998 E.C or 2005/2006G.C	4.27
1999 E.C or 2006/2007 G.C	4.64
2000 E.C or 2007/2008 G.C	4.81
2001 E.C or 2008/2009 G.C	5.34
2002 E.C or 2009/2010 G.C	6.32
2003 E.C or 2010/2011 G.C	6.63
2004 E.C or 2011/2012 G.C	7.20
2005 E.C or 2012/2013 G.C	8.23

Average annual growth rate of the road density is 8.9 percent

So from the above result the trend in change of road density from 1997 E.C up to 2005 E.C. is increasing significantly on average annual growth of 8.9%. So this result means the ratio of the

area covered with road in the city is increasing which in other words enhancing mobility and accessibility in the city.

B. Determination of road performance

Road performance = (Total road length-Total gravel road and asphalt roads under maintenance)/total length of road in km

Table 5– Road performance Trend

Year	Road performance
1997 E.c or 2004/05 G.C	0.35
1998 E.C or 2005/2006G.C	0.35
1999 E.C or 2006/2007 G.C	0.39
2000 E.C or 2007/2008 G.C	0.40
2001 E.C or 2008/2009 G.C	0.45
2002 E.C or 2009/2010 G.C	0.49
2003 E.C or 2010/2011 G.C	0.51
2004 E.C or 2011/2012 G.C	0.53
2005 E.C or 2012/2013 G.C	0.56

From the above results the trend in road performance is constant in some years like from 1997 E.C. to 2000 E.C. and then gradually increases starting from 2000 E.C. So based on the

evaluation indicator of road performance, increasing the total length of paved roads will increase road performance then the road network performance will be good.

C. Determination of Traffic load/Traffic Density

Traffic load= Total length/Total number of vehicles

Table 6 – Traffic load Trend (1999 -2003*)*

Year in Ethiopian Calander	Traffic load
1997	
1998	
1999	0.0139
2000	0.0135
2001	0.0158
2002	0.0169
2003	0.0174

D. Determination of Road serviceability

Road serviceability = Total road length/population

Table 7 – Road serviceability Trend (1999 -2005)

Year in Ethiopian Calander	Road serviceability
1997	
1998	
1999	0.0009
2000	0.0009
2001	0.0010
2002	0.0011
2003	0.0011
2004	0.0011
2005	0.0013

From the result, road serviceability in the city is increasing gradually from 1999E.C. up to 2005 E.C. but the rate in change is very low which means the construction of new roads is not much reachable by the peoples and to increase the accessibility/serviceability of roads in the city we have to work hard in developing good road network in which it increases peoples benefit and development of the city.

E. Road safety

From the above data the percentage of accidents occurred in straight and flat slope part of the road from the network is around 90.05% [(38397/42640)*100] This shows that even we construct a comfortable road for the drivers it may reduce the performance of the road when we evaluate according to safety. Also when we see the percentage of accidents occurred in the road with good asphalt condition is 96.3% [(41060/42640)*100] which is even higher the former. This shows that connecting the city with new asphalt roads may reduce the performance of the road in respect of safety.

F. Determination of Road Connectivity

The connectivity in the road network of the study area was tested using Beta index of connectivity and to use this, first the total number of nodes in the road network and the straight lines between the nodes must be determined which were obtained manually by counting from the master road network.

Beta index =Arc/Node

Table 8 - Road connectivity beta index value for sub cities

Sub city	Number of nodes	Number of straight lines between nodes	Beta Index
Akaki Kality	60	75	1.25
Bole	85	157	1.85
Yeka	63	107	1.70
Nefas Silk Lafto	68	120	1.76
Kolfe Keranio	74	126	1.70
Adis Ketema	26	51	1.96
Arada	38	70	1.84
Lideta	19	35	1.84
Kirkos	44	83	1.89
Gulele	38	68	1.79
Overall	***515***	***892***	***1.76***

The above data shows all sub-cites will have greater than one beta index which shows a better connectivity in the sub city.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

- The overall result of traffic distribution shows that the peripheral areas of the city are prohibited from enjoying an acceptable level of connectivity.
- These areas have a low density of road network and, as expected these city are physically close to each other, people still have to travel longer distance to their destinations.
- All in all the current transport road network of the city suffered from different infrastructure inadequacies.
- The absence of road infrastructure cause people travel unnecessary distance to reach their destination. This restricts the level of mobility of people and goods with in certain region.

5.2. Recommendation

- Upgrading of the road network and introduction of low priced mass transport system in the city and development of new roads in peripheral areas.
- AACRA has to work on the performance of road network
- The total length of the paved roads and pedestrians of the road in the city must be increase to attain optimum road network.
- AACRA has to give attention for the master plan of the road network because the population, the way of living and socio economic activity is changing dynamically..

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