ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

Performance Evaluation of Addis Ababa City Road Network

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in a Partial Fulfillment of the Requirements for the Degree of Master of Science in Road and Transport

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October 2014
Addis Ababa

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Acknowledgments

I feel like I am just starting when I finish. I still feel the search for orientation in my life continues. However, I would like to express my deepest gratitude to those who made orientation in my life's journey much easier so far.

I would like to express my heartfelt thanks to GOD and then appreciation to my advisor Dr.Bikila Teklu, for all his unfailing coaching. It is not only for his contributions towards the academic achievements but also for pointing out my weakness and enabling me to use my potential. In doing so he brought out the best in me. I really appreciate his patience and unreserved dedication towards the betterment of this research. I take responsibility for mistakes that might appear.

Special thanks goes to all the staff in School of Civil and Environmental Engineering in AAU.

Thanks to all government officers who help me by giving different documents relevant for this research and any resources available in good will without reservation.

Finally, my special appreciations are to my family, for being there without any precondition. Gratitude fails to say it all.

Abstract

The specific objective of this study was to determine evaluation of road network performance using indicators such as road availability, road performance, traffic load, road serviceability, connectivity and safety for sub cities/networks in Addis Ababa and to make recommendations for policy makers to improve performance of road networks based on the outcome of the study.

These objectives were addressed by detail review of literatures about the subject matter and also by collecting relevant data which used for computation of the performance evaluation indicators in the results and discussion part. The trend change for some years for this performance indicators for the city is also assessed.

In conclusion it is mentioned that currently the construction of new roads and maintaining the existing ones is increasing throughout years us we observe from the result but it needs more effort and successive evaluation of the road network performance to gain a good road network in the city.

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Acronyms

AACRA- Addis Ababa City Roads Authority

AACRNR- Addis Ababa city Road Network Report

AAUTS- Addis Ababa Urban Transport Study

CDP- City Development Plan

CRDP- City Road Development Program

ERA- Ethiopian Roads Authority

FHWA- Federal Highway Administration

GRDP- Gross Regional Domestic Product

LOS- Level of Service

OECD- Organization for Economic Cooperation and Development

PCU- Passenger Car Unit

RSDP- Road Sector Development Program

TAC- Transportation Association of Canada

TQM- Total Quality Management

TRB- Transportation Research Board

VPD- Vehicle per Day

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1. Introduction

1.1 Background

"Addis Ababa, the capital city of the Federal Democratic Republic of Ethiopia, is located in the center of the country. Established in 1886, the city has experienced several planning changes that have influenced its physical and social growth. As a chartered city (rasgez astedader), Addis Ababa has the status of both a city and a state. It is where the African Union and its predecessor the OAU are based. Addis Ababa is therefore often referred to as the political capital of Africa, due to its historical, diplomatic and political significance for the continent. The city is populated by people from different regions of Ethiopia – the country has as many as 80 nationalities speaking 80 languages and belonging to a wide variety of religious communities. It is home to Addis Ababa University. The Federation of African Societies of Chemistry (FASC) and Horn of Africa Press Institute (HAPI) are also headquartered in Addis Ababa."***(1)***

"Addis Ababa lies at an altitude of 7,546 feet (2,300 metres) and is a grassland biome, located at 9°1′48″N 38°44′24″E9.03°N 38.74°E9.03; 38.74Coordinates: 9°1′48″N 38°44′24″E9.03°N 38.74°E9.03; 38.74. The city lies at the foot of Mount Entoto. From its lowest point, around Bole International Airport, at 2,326 metres (7,631 ft) above sea level in the southern periphery, the city rises to over 3,000 metres (9,800 ft) in the Entoto Mountains to the north." ***(1)***

The area of Addis Ababa is 530.14 square kilometers. Its current population is about 2.57 million (2005 estimate), about 3.9 percent of the population of Ethiopia. It also represents about 26 percent of the urban population of Ethiopia. Addis Ababa has an aggregate population density of 4,847.8 persons per square kilometer. ***(1)***

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

The objective of road transport services is to form the traffic flow and road transport safe, secure, fast ,environmental friendly, orderly and regular, comfort and efficient, integrated with other modes, accessible by all land region and support fair distribution, development and stability to drive vehicles , to motor and to support national development with nearby cost by community.

"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)***

When justify the research in which the shape and structure of the network in a region or cities like Addis Ababa will affect the likely characteristics of a Cities' economy, social development, accessibility, mobility, security and safety. Also it can give an understanding of spatial variations within a region. The research done in turkey by Gavu Emmanuel mention that topological and geometrical complexities are involved in the navigation or movement in urban transport networks. It also states that additional network connections may have complex impacts on accessibility on all locations in the network, So we have to evaluate and asses frequently the performance of road network in cities in addition to constructing new roads.

According to that objective, by reviewing some documents, there is a study on the whole network analysis for Ethiopian roads done by Shelidia consultants and also the master road network for Addis Ababa which is developed in 2001 G.C. in which it is planned to work until 2010 G.C. but we are now in 2014 G.C and when I reviewed different documents there is no document which shows the performance of this road network but in some other countries they do performance evaluation of the road networks (for example, Indonesia, Canada, Turkey) therefore a performance evaluation is needed which considers,

- Accessibility distribution
- Safety,
- Efficiency,
- Effectiveness, and
- Reasonable cost and integrity with others transport system

Using the following selected Road network performance indicators the research try to evaluate the performance of the road network.

Selected performance indicators are:

- Road availability/Road density
- Road performance
- Traffic load
- Road serviceability
- Road safety
- Road connectivity

1.3 OBJECTIVES

The general objective of this study is to evaluate the performance of road network in Addis Ababa. The road network performance will be evaluated/expressed by several indicators like road availability, road performance, traffic load, road serviceability, safety and other indicators.

The specific objectives of the study are:

- To determine evaluation of 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.

1.3.1. Research questions

In order to work on the above research objectives, research questions have been formulated and specific answers need to be obtained. The table below shows the research objectives with the specific questions to address them.

No.	Research Objectives	Research Questions
1	To evaluate the Addis Ababa road network performance using indicators like Road availability/Road density, Road performance, Traffic load, Road serviceability, Road safety & Road connectivity	➢ Which methods have been used to analyze road transport network structure and how can they be used for road transport network performance? ➢ What is the meaning after the computation of the performance indicators? ➢ What is the spatial distribution of the current road transport networks and proposed new connections?
2	To make recommendations for improvement of road network performance	➢ Which road transport network indicators are suited for network structure analysis and traffic performance? ➢ What kind of effects is expected when additional transport connections are introduced in the network? ➢ What are the policy implications of such transport decisions regarding road network?

2. Literature review

2.1 History of Addis Ababa City Roads 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. ***(2)***

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. ***(2)***

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. ***(2)***

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 ***(19).*** 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). A high urbanization rate in combination with the intense desire for car ownership in developing countries causes a rapid growth of motorization ***(18).***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 ***(18 & 19).***

Improved mobility in urban areas in developing countries is possible by building new infrastructure. However, this is a long term and expensive solution also transport is a key requirement for economic and social development to take place. The lack of it causes isolation, backwardness and poverty. So, this improvement of constructing new roads and urbanization must be evaluated frequently.

2.2 Transport Infrastructure and Services in Addis Ababa

2.2.1 Transport Infrastructure

The Addis Ababa City has both international and local transport links which include the Bole International Air Port, the Ethio-Djibouti Railway (not functional now) and the road network. The Airport is within the city in a south-easterly direction outside the ring road. It is easily accessible by car or taxi and bus run nearby.

Addis Ababa has adequate roadway connections with most of the regional states and different parts of the country. The national network is being improved under the Road Sector development program (RSDP) according to City development Plan report.

Because of inadequate planning, there is a critical lack of hierarchical system in the road network. Moreover, there are bottlenecks of narrow bridges, poorly designed intersections, and alignments. Public transport facilities are inadequate. With linear developments adjacent to the arterial road network, there is no form of access control. On street parking and inadequate traffic management are significant factors which limit the capacity of the existing network. ***(3)***

2.2.2 Overall Planning of the Road Network in the city

The Addis Ababa City Road Network Report analyzed the nature and problems of the existing road network and addressed both freight and passenger terminals. It paid particular attention to the ring road and proposed a Conceptual Framework for the road network. The analysis was incorporated into the City Development Plan (2001-2010).

In the Project Proposal for Addis Ababa Transport Sector, October 2002, four components were identified:

- A transport planning system to integrate transport facilities with other aspects of the city development strategy, including evaluation and programming of all transport development programs;

• Transport management and control to improve traffic flow and use of streets and priorities for public and non-motorized transport;

• Traffic safety program to improve safety and reduce the very high levels of accidents and fatalities;

• A storm-water management project and transport infrastructure maintenance, to improve mobility, to reduce costs of maintenance, reduce damage to infrastructure including sidewalks and to reduce damage to adjacent urban areas.

The City Development Plan, in revising the 1986 Master Plan, included the following findings:

• Although right of ways have been generally respected, they are often substandard and there are many badly-designed or mismanaged squares and junctions;

• The ring road has not been properly integrated with the other parts of the network;

• There is a lack of alternative parallel routes and linkages and a failure to react to growth and changes in land use;

• Inappropriate road widths, poor mobility, poor pedestrian facilities and problems arising from informal trading;

• Concentration of passenger and goods terminals in the center of the city; and

• A radial national road network, with concomitant pressure on the central area.

A revised road network was proposed by consisting of:

- "High speed streets" typically with a width of 50-60 meters;
- "Boulevards" of widths "40 m and more"
- Collector streets (15 m wide) and local streets (I0 m wide). It was felt that there were insufficient collector roads and noted that most local streets were only 4-6 m wide.

In Addis Ababa City Road Network (AACRN) reference is made on the one hand to a hierarchy of expressways, arterial streets, collector streets and local streets and on the other hand to categories of radial and ring networks, iron-grid networks, organic networks and composite networks. In general, the CDP planning is confusing about the definition and role of roads.

The Addis Ababa Urban Transport Study (AAUTS) studied travel characteristics and the transport system, based inter alia on traffic surveys. The study found that the road network is limited, capacity is low and the prevailing level of service is low. Traffic volume coming from

Debre Zeit accounts for a large share of the total. Through-traffic in the core area accounts for a quarter of the total. There is a high level of accidents. According to the Urban Transport Study, the right of way of most roads ranges between 15 and 60 meters, but about 70 % of the network is with a right of way of up to 30 meters. Only 24 percent of the road length has divided carriageway. Despite high pedestrian traffic, facilities for pedestrians are not adequate and 63 percent of the road length has no sidewalks. Facilities such as drainage, street light, and traffic signs and pavement markings are inadequate on the existing road network. ***(3)***

At a regional level a regional grid, metropolitan motorway and Addis Ababa-Adama expressway are proposed. At the metropolitan level a hierarchy based arterial road network system comprising arterial, sub-arterial and collector roads is proposed. It is proposed to develop about 730 km of road as follows:

- an outer ring road (enables bypass traffic);
- an orbital road around the central business district ;
- city radial roads and connecting links, alternative corridors;
- all-purpose roads within the central business district orbital;
- a parking policy is to be formulated. ***(3)***

2.2.3 Addis Ababa City Roads Development Program

The CDP has critically evaluated the road network of the city and proposed upgrading the existing ones and opening new sections so that the city has adequate road infrastructure. AACRA has embarked on road development program to upgrade, rehabilitate, and expand the road network as per the City Development Plan (2001-2010) in 2005-2010.

The AACRA City Roads Development Program (CRDP) for 2005-2010 proposes to widen or construct 266 km of road. This includes improvement of junctions, squares, and interchanges.

The estimated cost of these projects was estimated at about birr 8.6 billion (954 million Euro at exchange rate of 9 .0), although there are some inconsistencies in the list of project costs. This might be US$ 1.3 Billion today. Of the total cost, it was proposed that the City Administration would cover design, right of way clearance and part of construction amounting to approximately

15% of this cost, the rest to come from foreign grants or loans. Over the period 2002-2005 AACRA undertook maintenance of 187 km of asphalt roads and 123 km of gravel roads. Maintenance of 159 km of storm water drains and painting of 390 km of road were also undertaken.

Assuming that the strategic plan for new and widened arterial, sub-arterial and collector streets is implemented, this will give rise to an additional 30% in maintenance needs. For both new construction and maintenance, there is likely to be a capacity bottleneck, on the part of local contractors and management. The US$ 1.3 billion proposed for new construction over five years is about 20% of the total ERA construction budget for the same period for the entire road network in the rest of the country. ***(3)***

Non-Motorized Transport

All the planning documents refer to the lack of and poor state of sidewalks, particularly at junctions. The Urban Transport Study points out that walking is the predominant mode of transport in AA, 60% of all trips. There is also an utter lack of respect for pedestrians on the part of drivers, and the issue or pedestrian crossings is critical. Over the period 2002 - 2005, *AACRA* designed and constructed about 50 km of pedestrian facilities, but many arterial, sub-arterial and collector roads remain without sidewalks or with sidewalks in poor condition. Planning of junctions and interchanges and new roads is said, however, to make provision for improved pedestrian facilities.

The Urban Transport Study proposes that sidewalks be developed on both sides of the above-mentioned roads, and on one side of local roads. It recommends that pedestrian facilities should aim at reducing traffic speed through traffic calming and other measures. It proposes exclusive budgets for pedestrian facilities.

In the process of widening or constructing new streets, pedestrian facilities are usually taken account of, although on the three categories of roads discussed above, traffic calming measure are likely to be limited and this topic may need to be revisited. ***(2)***

Mobility characteristics of cities in Sub Saharan Africa

"Within the group of developing countries, the subgroup of Sub Saharan African countries distinguishes themselves on a number of characteristics. While other regions in developing countries are industrializing rapidly as a result of the new global economy, the African cities remain economically marginalized. However, the population in African cities is growing despite poor macroeconomic performance and without significant foreign direct investment. Even more, Sub Saharan Africa has globally the highest urban population growth in percentages as cited by J.W Zwarteveen. By 2025, African society is expected to become predominantly urban (United Nations, 2004). The institutional weaknesses of political instability, corruption and chronic mismanagement of economic resources put extra stress on the level of services in cities. It can be concluded that world's challenges concerning urban mobility will be particularly significant in Sub Saharan Africa." ***(4)***

Mobility characteristics in Addis Ababa

By 2015, the Sub Sahara African region is expected to have five cities larger than 5 million inhabitants: Abidjan, Addis Ababa, Lagos, Luanda and Kinshasa ***(18).*** This thesis will focus on Addis Ababa, the capital city of Ethiopia, a city with numerous similarities with other Sub Saharan cities. The mobility problems in Addis Ababa are emergent, since the recent state of road traffic management is considerably poor (Kessides, 2007). Table 1 shows a benchmark of Addis Ababa with the average urban area in Africa, the developing world, Europe and the US. It can be seen that Addis Ababa has a relatively high population density and a high urban population growth; both facts combined with a low GDP per capita put high stress on the quality of mobility services. This stress is reflected by the very low supply of infrastructure: the current road density measured in kilometer of road per 1000 habitant in Addis Ababa is significantly lower than the average of developing countries; moreover, it is only one third of the African average. The public transport plays a dominant role in urban mobility in Ethiopia. The current average number of cars per 1000 habitants in whole Ethiopia is only one (The World Bank, 2011). In Addis Ababa, the car ownership has not gone up corresponding to the population growth. However, the number of trips per public transport is directly related to the urbanization.

In general, for every additional 1000 people in developing world cities, an increase of 350-400 public transport trips will be realized per day. ***(4)***

Table 1: Benchmarking Addis Ababa, Africa average, Developing countries average, Europe average and US average

City	Addis Ababa	Africa average	Developing average	Europe average	US average
Urban density habitants/km^2	12 400[1]	8 200[2]	9 200[2]	3 050[2]	1 150[2]
Annual national urbanization rate %	4.3[3]	3.6[4]	2.7[4]	0.3[4]	1.3[3]
National GDP per capita USD	700[5]	3700[5]	2 926[6]	28 700[5]	46 300[5]
Road density km/1000 habitants	0.13[7]	0.32[7]	1.0[7]	3.3[8]	6.4[8]

[1](Demographia, 2010) 2003 estimation, only urban areas included with >500 000 habitants
[2](Demographia, 2006) 2006 estimation, only urban areas included with >500 000 habitants
[3](CIA, 2010) 2005-2010 estimation
[4](United Nations, 2002) 2005-2010 estimation
[5](CIA, 2010) 2009 estimation, retrieved from (IndexMundi, 2010)
[6](The World Bank, 2010) 2009 estimation
[7](Kumar and Barret, 2008) The African average is based on 12 large Sub Saharan African cities
[8](Vivier and Mezghani, 2001) The US average is based on US and Canada

Source: (4)

Network Development Criteria

The study considers five criteria against which the road network development plans need to be vetted:

- the size of the city and its structure of production and population distribution;
- the cost to the economy of unreliable, deteriorated network;
- the fiscal implications of inefficient transport operations;
- road network's importance in creating regional balance (and connectivity);
- The importance of the road network in opening up new investments around the city

2.2.4 Need to Improve Internal Connectivity and Access

The first criteria, relating to the road network and the size of the city and its structure of production and population distribution, reflect the level of connectivity (or the lack of it). Indices are developed to measure the level of connectivity, but from the outset it can be concluded that Ethiopia which is about 1.1 million sq.km in area has a very low level of connectivity with 30 000 km of roads, part of them the federal network. About 30% of rural areas are presently connected with all-weather roads, and many of these are in poor condition. In this respect Addis Ababa is taken as a case study.

The Road Sector Development Program II (RSDPII) document (Second Draft, November 2001) gives an estimate that the country would need 2793 additional road links with a total length of 98,000 km in the future (at an unspecified date). Although this estimate is based on theoretical connectivity models and is well beyond present level of affordability and capacity to maintain, a road network of this size, about 125,000 km including existing roads, is not excessive for a country of this size including local roads.

Table 3 shows the road density for Ethiopia and a number of comparator African countries, for the main road network and for all roads and for COMESA (primarily East African countries, Ethiopia a member) and ECOWAS (members primarily West African countries). Due to different definitions of the main and total network, the figures are not directly comparable, but they are indicative.

Table 2 in the other hand puts the road network, mobility and accessibility in a broader, worldwide context, also based on World Bank database. Ethiopia is the lowest rank country of those listed in terms of: 1) road density per land area; 2) road density per population; 3) level of vehicle ownership; and 4) lack of accessibility to an all-weather road (60% of the population not connected). Road network planning cannot be based on network density considerations alone, as the need for transport is dependent on a large number of factors, such as spatial distribution of population, economic resources, location of ports and other terminals as well as the overall development level. However, density and accessibility parameters provide a useful framework for the analysis.

Table 2- Road Networks in Ethiopia and Selected African Countries (1997)

Country	**Land Area ('000 sq.km)**	**Popula-tion (million)**	**Road Network**		**Road Densities**			
			Main	**Total**	**Main**		**Total**	
					Km of road per 1000 population	**Km of road per 1000 sq.km of land area**	**Km of road per 1000 populati on**	**Km of road per 1000 km sq.km of land area**
Angola	1247	12.0	23570	72021	2.0	18.9	6.0	57.7
Cameroon	465	13.9	12736	50308	0.9	27.4	3.6	108.2
Chad	1260	7.1	4704	28704	0.7	3.7	4.0	22.7
DR Congo	2267	46.7	50000	132400	1.1	22.1	2.8	58.4
Ethiopia	**1100**	**59.8**	**15769**	**27112**	**0.3**	**14.3**	**0.5**	**24.6**
Kenya	569	28.6	6554	67181	0.3	11.5	2.4	118.1
Madagascar	582	14.1	8430	29905	0.6	14.5	2.1	51.4
Mali	1220	10.8	13004	16211	1.3	10.7	1.6	13.5
Mozambique	784	16.6	4371	25468	0.3	5.5	1.5	32.5

Nigeria	911	117.7	62800	193200	0.5	68.9	1.6	212.1
South Africa	1221	40.7	20000	525927	0.5	16.4	12.9	430.7
Sudan	2376	27.7	8322	23162	0.3	3.5	0.8	9.7
Tanzania	884	31.3	28000	63000	0.9	31.7	2.1	71.3
Zambia	743	9.4	17051	64551	0.5	22.9	6.9	86.9
ECOWAS	6139	208.0	173164	430390	0.8	28.3	2.4	70.1
COMESA	5244	161.0	243350	64094	0.4	12.2	1.5	46.4

Footnotes: Only larger countries selected. Data for SADC are not available. Road densities for the whole of Africa are higher than for ECOWAS and/or COMESA, mainly due to SADC (dominated by South Africa, but densities for other SADC countries also higher than for Africa in average). Source: World Bank, SSATP Data Base

2.3 World Bank road network overview *(6)*

2.3.1 Review of Road sector

- Road densities vary from a low of around 0.01 km per sq. km to a high of 4.90 km per sq. km (excluding exceptions), with a typical value of 0.20 km per sq. km.
- The proportion of the main road network that is paved varies from a low of around 2.5 percent to a high of 100 percent, with a typical value of 45.5 percent.
- The number of 4 plus wheel vehicles per 1,000 inhabitants varies from a low of around 0.20 to a high of 933.1, with a mid value of 45.8. At the lower end, about 50 percent of the vehicles are cars, while at the higher end over 90 percent are cars.
- The number of 4 plus wheel vehicles per km of road varies from a low of around 0.3 per km to a high of over 200, with a mid value of 13.0.
- Worldwide the stock of motor vehicles is growing at nearly 3 percent per year. The number of vehicle km traveled tends to grow somewhat faster than the stock of motor vehicles.

- Industrialized countries typically spend just over 1.0 percent of GDP on the road sector. Those with road funds typically spend over 1.5 percent of GDP.
- The largest industrialized economies typically spend about 0.4 percent of GDP on road maintenance and over 1.3 percent on new construction.
- Developing and transition countries typically spend about 0.75 percent of GDP on road maintenance, varying from an average of 0.78 percent in Africa, 0.49 percent in Latin America, 0.67 percent in Asia and 0.84 percent in Eastern Europe.
- Worldwide between 750,000 and 880,000 people are killed and between 23-34 million are injured in road crashes each year, costing the global economy about $500 billion per year.
- About 85 percent of these road accidents take place in developing and transition countries, with almost half of all estimated deaths occurring in the Asia-Pacific region.
- In industrialized countries, only about 15-20 percent of fatalities involve pedestrians, non-motorized vehicles and motorcycles. In developing and transition countries, the figure is closer to 50 percent and is as high as 70 percent in Asia.
- In developing and transition countries, road accident rates per 10,000 vehicles tend to be 10 to 20 times higher than in industrialized countries and cost between 1.0-1.5 percent of GNP. ***(6)***

2.3.2 General trends in road network

- Most national road agencies are still managed through a government department, although an increasing number are being restructured along commercial lines. They have been given more autonomy and some have been turned into not-for-profit joint stock companies, or have been incorporated under the Companies Act with their shares held in trust by the Minister.
- Steps are being taken to strengthen local government road agencies to ensure that all roads are brought under regular maintenance. The idea of setting up a central agency to manage these roads on behalf of local governments, is increasingly giving way to de-

centralized solutions, involving contracting out planning and management to firms of consultants, or combining local government road agencies into larger operating units to acquire greater scale (e.g., joint services committees).

- Roads carrying high volumes of traffic (generally over 10,000 to 15,000 vpd) are increasingly being tolled to generate additional revenues. Some are operated as free-standing toll roads, while others are operated as an integrated toll road network with high volume roads cross-subsidizing the lower volume ones. These roads may be managed by the national road agency, a public toll road authority, by a private concessionaire, or may be owned and managed by a private concessionaire.
- Tolled roads rarely account for more than 1-2 percent of the overall road network in a country, but may account for up to 20 percent of the national road network.
- Scarcity of government tax revenues is encouraging countries to seek alternative road financing mechanisms. Although toll roads generate some extra revenues, particularly on the national road network, they cannot meet the needs of the entire road network. A number of countries have therefore decided to put their roads on a fee-for-service basis. Under this arrangement, road users pay for any extra spending on roads (generally by way of a surcharge added to the price of fuel) and the proceeds from the surcharge are managed through an independent road fund administration under a board of directors made up primarily of road users and representatives of the business community.
- Planning and management of roads is increasingly being separated from the implementation of road works, either by contracting out all design and civil works to the private sector, or by moving them into two separate organizations that deal with each other under a formal contractual agreement.
- More attention is being paid to the views of road users, either through surveys, regular consultations with them, or by establishing a public-private oversight board. Such boards may advise the Minister on management of the road network, or may manage it in a non-executive capacity (usually the national network only).
- More attention is being paid to road accidents. In the case of road accidents, the trend is to establish a national coordinating agency (i.e., a directorate within a ministry), or a

national road safety council supported by an effective secretariat. Efforts are also underway to mobilize private finance for road safety interventions and to set up accident reporting systems to enable road safety interventions to be planned and implemented more effectively.

- There is continuing concern about the adverse environmental impacts of roads and road traffic. Environmental impact analysis is now obligatory for all projects with potentially significant adverse impacts (including resettlement) and the process is usually tied in to some form of public consultation.
- Efforts are underway in many countries to make better use of road building materials. Recent innovations include use of foamed bitumen and extensive use of recycled road surfacing materials.
- There is growing concern about the safe disposal of end-of-life vehicles. Within the EU, regulations are now in place that require almost total recycling of such vehicles. The recycling process includes residual fuel, oil and, coolant, as well as batteries and tires. Bodies are shredded and both ferrous and non-ferrous metals are recycled.
- There is a gradual move away from maintenance contracts based on procedural specifications towards use of performance (or end product) specifications. At the same time, different types of maintenance (e.g., routine and periodic) are being combined into one contract, which may apply to several roads (e.g., they may be area contracts covering a discrete part of the road network) and the contract may be let for an extended period of time (often 5-10 years). Such contractual arrangements have led to significant reductions in cost, combined with improved quality.
- Road agencies are becoming more business-like and are employing better management systems and procedures (road management systems, equipment management systems, etc.) and are improving their financial management and cost accounting systems (among other things, by explicitly accounting for capital items, rather than writing them off as a cash expense as soon as they are incurred).
- There is growing interest in Total Quality Management (TQM) and the standards that have been developed by the International Standards Organization (the ISO 9000 family of

standards). TQM seeks to place responsibility for quality assurance with the designers and implementers of works. This requires these persons to develop their own quality assurance procedures that are then certified by an independent third party. Implementation of the procedures is monitored by the client (the road agency) and supervising consultant. Partnering offers a slightly different approach to TQM and is more concerned with the quality of design and implementation, particularly when projects are expected to have adverse impacts on third parties. ***(6)***

2.3.3 Future consideration in road sector

- A number of road agencies still lack the capacity to plan and manage their road network effectively. The ideal is to create a small, white-collar agency, paying market-based wages and operating at arms-length from government. The reality is that few countries have managed to do this. Strong vested interests has stalled the reform process. Resistance typically comes from older members of staff, who have either set up parallel income streams to compensate for low salaries, or are delaying the reforms until after they have retired. Younger staff are more supportive of reform and one of the urgent challenges in the road sector is to find ways to give these younger staff more say in how the road agency is managed
- Many of the toll roads and maintenance concessions with tolls, are in serious financial difficulty. This seems to be largely due to unrealistic expectations on behalf of government regarding which costs can be reasonably financed through tolls when traffic volumes are below 15,000 vpd. The public-private partnerships, where government clearly accepts that some costs will have to be borne by government, appear to be working better.
- Some countries have a clear strategy and policy towards toll roads. They aim to develop a network of toll roads, revenues are partly or completely pooled to permit cross-subsidization, and toll levels are set to maximize revenues. The private sector participates in these networks within the framework are set by government. Other countries do not

have such a clear strategy and nor do they have a policy on toll levels. As a result, they are ending up with a fragmented toll road network, only covering roads with high volumes of traffic and with wide variations in toll levels.

- There is concern that long term, area wide maintenance concessions will lead to consolidation of the road construction industry. Small contractors may be put out of business and the industry may consolidate into a small number of large road operating companies. This may reduce competition and, in the long term, this could lead to an increase in costs.
- It is still unclear how the independent road fund administrations will evolve. A small number have been set up in the form of a public enterprise (i.e., the board has power to set its own road tariff subject only to a Ministerial "no objection"). However, this is a very new development and it is not clear how well it will work in practice. ***(6)***

2.4 An overview of Performance Measurement

“In the last two decades, interest has grown in the art and science of performance measurement, particularly as it applies to road and transportation systems. The topic is well documented in the literature with significant treatises from many organizations around the world, including the US Federal Highway Administration (FHWA) and the Transportation Research Board (TRB), the Organization for Economic Cooperation and Development (OECD), Austroads and the Transportation Association of Canada (TAC). In general, the available research and practice reports provide perspectives as to why performance measurement is important, how it should be undertaken, and what is typically measured. The following sections summarize information extracted from some key references on the theory of performance measurement." ***(7)***

2.4.1 Why Measure Performance?

The ultimate purpose of measuring performance is to improve transportation services for customers ***(7).*** Within that simple statement, two important emphases are contained: one regarding customers and the second regarding improving services. Both of these emphases underlie most of the reasons cited in the literature for the increasing importance of performance measurement to transportation agencies.

In an OECD review of performance indicators for the road sector (OECD, 2000), the authors observed that in the past, the expectations for public administrations were fairly straightforward. The dominant objective was to deliver services to the public at minimum cost. However, public administrations are now expected to meet service level targets at reduced costs and to develop mechanisms for customer feedback. In general, public administrations now operate in an environment in which there is a much greater emphasis on customers. Meeting customers' needs drives business for public sector as well as private sector agencies. That focus on customers has made the assessment of agencies' performance more complex and has been a trigger for the study and application of objective performance measurement.

Discussing the customer focus during the 2000 Transportation Research Board conference on performance measures, Pickrell and Neumann (2001) explained that publicly-funded agencies have come under increasing pressure to be accountable to the public – the owners and customers of the agencies and the transportation systems they deliver. In fact, the need to be accountable to the public is the reason most commonly offered in the literature for performance measurement. There is a growing expectation that the public should be advised on the performance of the transportation system upon which it depends. As well, there is a need to report how public funds are used to maintain the system and the effect of expenditures upon it. Performance measurement is essential to that process. It is interesting to note that the use of performance measurement is considered useful not only for reporting *to* the public but also for communicating *with* the public. It is seen as a tool that can help to educate the public as well as senior decision makers and legislators regarding the importance of transportation and the merits of making appropriate investments in the system (Federal Highway Administration, 2004).

A synthesis of highway practice on performance measurement, conducted for the National Cooperative Highway Research Program (Poister, 1997), drew attention to strategic planning as a driving force behind performance measurement. Government agencies are often mandated to have strategic plans with goals and objectives defined within those plans. Performance measurement provides important inputs to set priorities and it provides critical information that helps agencies detect potential problems and make corrections enroot to meeting goals and objectives. Performance measurement is a fundamental component of an effective management strategy as it allows process management and improvement.

A recurring theme in the literature on performance measurement relates to funding limitations and asset management. As agencies experience funding constraints while maintaining mature infrastructure systems, effective management of all assets is important to their success. The TAC framework for asset management (TAC, 2001) suggests performance measures be used for planning and programming. Performance measures are needed to evaluate the state of assets, which is a first step in developing priorities and allocating resources amongst competing priorities. Consequently, performance measures have been called the “backbone” of asset management systems and are considered to be a critical tool to report successes and opportunities (Bradbury, 2004).In the modern era of sustainability, performance measurement is also seen as key to measuring progress on that front. Transportation systems are recognized for the benefits they provide to the economy in terms of access and mobility but are also recognized for putting pressure on our environment. Widely held policy goals are to make progress towards sustainability while increasing economic prosperity and quality of life. In order to understand whether our systems are becoming more or less sustainable, measurement of performance against related indicators is necessary (Gudmundsson, 2001). While many good reasons exist to measure performance of the road network so that it can be monitored and improved, some caveats are also offered in the literature. In particular, Pickrell and Neumann (2001) noted that the use of performance measurement to benchmark performance of one agency against another can be problematic. Benchmarking may help an agency to initially define a reasonable or desirable level of performance but it may not be useful as an ongoing comparison. While there is some interest in obtaining a national ranking by performance measures, it will not be informative if agencies are operating in different circumstances or are not truly peers. Differences in measures may be the result of divergent objectives, differing resource availability or external factors and not the result of agencies' performance. ***(7)***

2.4.2 Developing Performance Measures

Transportation departments are fortunate to have a wealth of data available to them regarding the services they provide and the infrastructure they build, operate and maintain if they try to collect the data extensively. However, in a data-rich environment, the challenge is to determine how best to gather, analyze and present the data so that it is meaningful to stakeholders, and this is especially important for performance measures that are reported to or used by a broad range of audiences. In developing a performance measurement process and implementing it as a management system, the selection of the "right" performance measures is a critical step. When developing performance measures, the research emphasizes that the process should begin by defining an agency's vision, its mission and strategic objectives in our case AACRAs vision is "*Construct reliable, standardized and quality roads in Addis Ababa City. Besides to expand the road transport coverage of the city, strive to attain in 2020 the road network to 20% for the community to get interchangeable traffic flow*." And its mission is "*Building Asphalt roads, Gravel Access Roads, Coble Stone pavement Roads, Drainages, Bridges and concrete roads and making that for residents of Addis Ababa remarkably enhance the regular activities, there of using hi-tech and low cost being constructed by contractors and own force at improving level on time available for public service."* While these may be long-range in focus, performance measures used by an agency must be related to those broad goals. Long-term strategic goals can be translated into specific annual goals, against which performance is measured. Policy-makers and agency staff must be educated to understand the performance measures and to accept the link between them and the agency's goals (Poister, 1997).In the case of AACRA when we state its power and duties some of them are

- Initiate policies and laws with regard to road network, construction, protection and use of roads
- Determine design standards for road and implement same

- Prepare long term, medium and short term plans and programs with respect to the construction of roads and other related activities, and implement same upon approval
- Carry out or cause the carrying out of feasibility study and implement
- Prepare design for the construction of roads or cause its preparation through qualified consultants
- Construct roads on its own or have them construct through contractors
- Determine the criteria for the selection of consultants and contractors for roads to be constructed by other bodies
- Prepare and cause the preparation of work consultancy service contracts, conclude contracts and see to it that there is supervision with (a contractor an ensuring that works are executed as per contracts conclude and supervise same)
- Design or cause the designing of traffic signs with regard to roads, collect information from appropriate government offices and place traffic signs on roads, and inform to concerned offices of that they do follow up and implement accordingly
- Determine the size of land required for pedestrian roads and standards for the construction thereof, and it shall also construct, cause the construction of and protect pedestrian side walks'
- See to it that the personnel necessary for the authority are trained and establish training institutions

As we observe from the list of duties there are no duties regarding performance evaluation and measures. Performance measures should cover the full range of an agency's strategic objectives, but should nonetheless be few in number. In Japan, for example, the national ministry has established a core set of 17 performance measures (Federal Highway Administration, 2004). Limiting the selection of measures to those that reflect the issues that are important to an agency will simplify data collection and reporting. It will also increase the likelihood the measures will be understood by the public and used effectively by agencies.

In selecting a set of performance measures, it is important to recognize the distinction between input, output and outcome measures. Input measures reflect the resources that are dedicated to a program, output measures reflect the products of a program, and outcome measures look at the impact of the products on the goals of the agency (Dalton et al, 2005). Input- and output-based performance measurement was more common in the past, but current trends are to increase use of outcome-based performance measures, in conjunction with output-based measures.

Outcomes can be more difficult to measure but are considered important to measure because they directly relate to the activities an agency undertakes to its strategic goals. However, transportation agencies must consider the availability of data, the cost and time to collect the necessary data and the quality of the data in selecting performance measures. It must be possible to generate the measure with the technology and resources available to an agency if the performance measure is to be adopted.

Other issues that should be considered when selecting performance measures to evaluate a road network include the following (TRB, 2000):

- Forecastebility: is it possible to compare future alternative projects or strategies using this measure?
- Clarity: is it likely to be understood by transportation professionals, policy makers and the public?
- Usefulness: Does the measure reflect the issue or goal of concern? Is it an indicator of condition, which could be used as a trigger for action? Does it capture cause-and-effect between the agency's actions and conditions?
- Ability to diagnose problems: Is there a connection between the measure and the actions that affect it? Is the measure too aggregated to be helpful to agencies trying to improve performance?
- Temporal Effects: Is the measure comparable across time?
- Relevance: Is the measure relevant to planning and budgeting processes? Will changes in activities and budget levels affect a change in the measure that is apparent and meaningful? Can the measure be reported with a frequency that will be helpful to decision makers?

In summary, the list of performance measures that could be adopted by a transportation agency to evaluate its road network is essentially limitless. There is no one measure, or one set of measures, that could be identified as the "best" for all cases. Furthermore, although there are many common issues to be considered, there is not just one good way to develop a set of performance measures or establish a performance measurement system. In each case, the performance measures used must depend on the specific conditions of an agency, its goals, its resources, and its audience. So, for Addis Ababa case AACRA must consider the above issues and incorporate performance measures in its duties.

2.5. An overview of transport network indicator

In transport studies, different kinds of indicators may be used to measure the performance of the network. There are different categories that can be used to describe transport indicators. Some are grouped broadly as Economic, Social, Environmental and System indicators. Others are also grouped as Demand and Supply based indicators.

Demand based indicators are indicators that measure people's use of the transport network while Supply based indicators are indicators that measure the performance of transport networks. Conventional transport indicators measures mostly traffic conditions. These include Roadway level of service (LOS), average travel speeds, average congestion delay, system-wide travel time, unused capacity in the network and volume to capacity ratio.

There are no standardized indicator sets for comprehensive transport planning (Litman 2007). Each institution develops their own set of indicators based on the need and institutions abilities.

A great amount of research concerning networks has been based on topology, which mainly focuses on network structure. Many algorithms exist for analyzing transport networks. ***(8)***

2.5.1 Some network indicators and measurements

This section discusses some network measures and indices and how they are measured. Network measures and indices are used to evaluate the properties or performance of a transport network. Quantifiable indicators can abstract the properties of complex network structures and helps to explore structure from a spatial perspective (Xie and Levinson 2006). Indices are used to evaluate the properties of a network.

According to a study made in Turkey, about network based indicators for prioritizing the location of a new urban transport connection, some examples of network measures and indices are explained below.

Detour index

The detour index (DI) measures the efficiency of a connection in the transport network. The formula for the DI is expressed as the straight or airline distance divided by the network distance.

The closer the detour index gets to one, the more spatially efficient. It is however rare to have networks with detour index of one. This indicator is dimensionless and takes values from zero (0) to one (one). In terms of scale of operation, the detour index could be analyzed at the whole city level, but it makes more meaning when individual routes in a network are analyzed; say a particular bus route.

Network density/road density

Network density (ND) is the kilometer of network per square kilometer of surface. Network density measures transport network development depending on the scale of analysis. Cities with limited infrastructure score low (like less than 10%).

$ND = l/A$

Where ND denotes the network density

l is the total length of transport network in study area depending on scale

A represents the area of say the city, district or traffic analysis zone

The dimensions are normally in [km/km^2] depending on scale of network. A smaller area might be more meaningful to represent in m/m^2. This indicator can be measured at various degrees of aggregation at the city scale.

Beta index/connectivity

Connectivity – measures the number of segments (in this case links or arcs) to which a specific segment is directly connected. Connectivity reflects both the number and modality of joints along a route. 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 is obtained manually by counting from the master road network.

Beta index =Arc/Nodes

Where the nodes are the number of road junctions and arcs are connections (straight lines) between the nodes as straight lines.

2.6. Cases where performance evaluation indicators were used for urban road networks

2.6.1 An evaluation of road network performance in Indonesia cities

A study was made in Indonesia to assess the road network. In this research, there is a disparity of development achievement in East Region of Indonesia, which has been left behind from Western Region. To reach more optimum welfare development supported by high performance road, a good practice of fair evaluation is needed. The study evaluates the efficiency of road network in twelve provinces located in Sumatra, Kalimantan, and Sulawesi islands from 1999 to 2002. The study used four indicators, namely road performance, road availability, traffic load, and road services.

Analysis presents a significant difference for each road indicators among provinces, and the road index is just an average of the four indicators in each province and each year. The result shows there is a specific pattern of outputs (road index) and outcomes (Gross Regional Domestic Product, GRDP) for each island. As well expected that provinces with high road performance index correlate with high output and outcome, it is shown in the study that there are some provinces with high road index but produce either low outcome or low output and outcome. ***(15)***

2.6.2 Performance Measures for Road Networks: A case of Canadian cities

Encompassing 1.4 million kilometers, the road network in Canada is vital to the Canadian way of life. Roads form part of an extensive transportation system that enables much of what is important to Canadians. Managing the road network is becoming increasingly challenging as demands increase and resources are limited, but transportation departments must continue to deliver the services and facilities that are critical to the country's well-being.

In the face of growing challenges, performance measurement is attracting growing interest from transportation agencies. With the expectation that what is measured can be better managed, performance measurement is being implemented as a core component of management processes in public sector agencies. In transportation agencies, performance measurement has long been used as part of pavement management and bridge management systems. Now many agencies are extending the process to applications in construction and maintenance management systems, operations and safety programs, and administrative structures and processes.

In Canada, most provinces and territories use some form of performance measures to evaluate their road networks. However, the type of performance measures used and the implementation practices vary significantly between jurisdictions. The report summarizes the results of a survey, which was intended to share knowledge and experiences between jurisdictions on how transportation departments use performance measurement systems. The survey was conducted under the auspices of the Chief Engineers' Council of the Transportation Association of Canada for Transport Canada. The report provides a brief overview of the extensive literature available on the subject of performance measurement. Reasons to measure performance within transportation departments are cited, but it is noted that the use of performance measurement to benchmark performance of one agency against another can be problematic. Issues to consider when developing a performance measurement program are offered and it is observed that there is not one measure, or one set of measures, that can be considered the "best" for all cases. In each case, the performance measures used must depend on the specific conditions of an agency, its goals, its resources, and its audience.

When developing performance measurement programs, the literature emphasizes that outcome measures should be included, where these relate the activities an agency undertakes to its strategic goals. Output and input measures, which reflect the resources that are dedicated to, and the products of, a program, may also be included in a performance-based management program. The number of measures included in a performance-based program should be limited to those that reflect the issues that are important to an agency.

The primary focus of the project was to survey Canadian provincial and territorial jurisdictions regarding current practices for performance measurement of road networks. This report documents the results of the survey on agency use of specific performance measures related to six outcomes:

• Safety,

• Transportation system preservation,

• Sustainability and environmental quality,

• Cost effectiveness,

• Reliability, and

• Mobility/accessibility.

The survey revealed that all responding agencies track performance in the area of "system preservation," although a variety of measures and approaches are used. This appears to be the most highly developed and mature application of performance measures in Canadian highway agencies.

The survey also indicated that safety performance is a priority interest, with most agencies using accident rates per million vehicle kilometers as a key measure. The outcomes of cost effectiveness, reliability, and mobility/accessibility were subject to performance measurement in some Canadian provincial and territorial departments of transportation. There was little consistency in application and different measures tend to be used in different agencies.

According to the survey, measures to assess performance on sustainability and environmental quality are used to a limited extent by Canadian agencies. The report also highlights performance measurement applications in the United States, Europe and Australia to provide an international perspective on trends in performance measurement of road networks. It is noted that there is considerable commonality amongst the categories of performance measures that are used internationally. ***(7)***

3. Research Approach and Methodology

3.1 Scope of research

This research tries to evaluate road network performance using selected evaluation tools listed in research objective in Addis Ababa city administration with the current condition and give some suggestions for concerned bodies

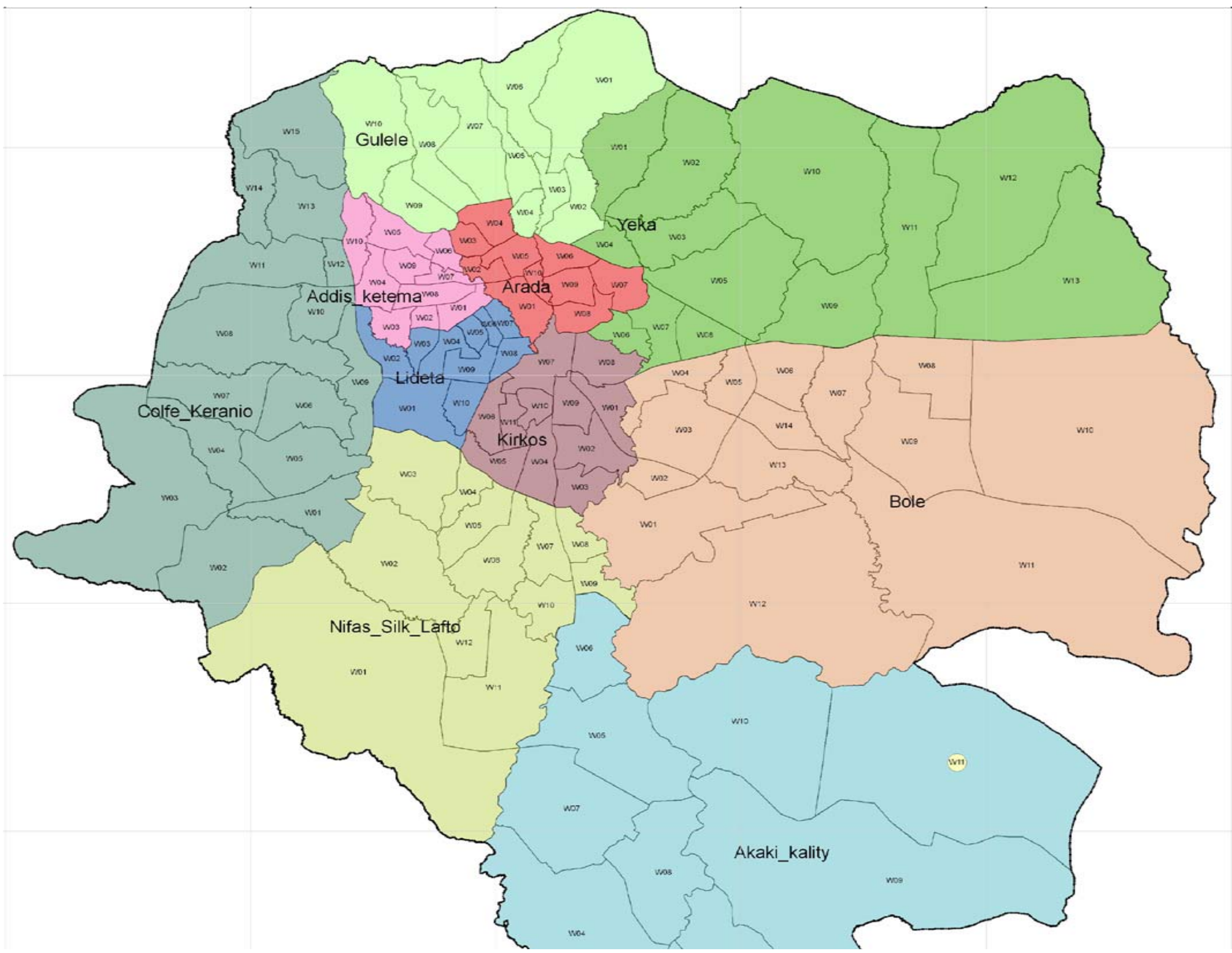


Fig 1 Layout of Addis Ababa City Administration *Source: City development plan (2001)*

The current road network of Addis Ababa as it is incorporated into the City Development Plan (2001-2010) construction is going in the city with the guidance of the master road network. But, the road network of Addis Ababa has not enough quality in both density and quality. Much of the city is still not served by paved roads. As municipal data show, the total road length of the city was 2,146 kilometers in 2004. Obviously, this is not an impressive figure when compared to the total built-up area of some 290 square kilometers. Overall, roads accounted for only about 6.1 percent of the total built area in Addis Ababa in 2004. Even more disheartening, asphalted roads accounted for only 36.25 percent of the total road length that same year. Principal arterial roads comprise the largest proportion of the asphalted roads (about 42 percent of the total) (UN-Habitat, 2007).

In addition to this, where roads are asphalted, sidewalks are for the most part either absent or in disrepair, irrespective of the fact that walking is the predominant mode of travel. Overall, the length of side-walked ways is only 252 kilometers – which means that over two thirds of asphalted roads are simply without any sidewalks. As a result, it often happens that vehicular traffic mingles with pedestrians and animals all over the city.

Another consequence is that Addis Ababa today is experiencing one of the world's highest rates of car accidents involving pedestrians. Even more worrying, the physical damage caused by these accidents is fast increasing. From 3.6 per cent of traffic accidents in 1998, deaths and heavy injuries rose to 6.3 percent per annum in 2003. Given the poor condition of public thoroughfares in Addis Ababa, obviously a large amount of work is required in order to upgrade Addis Ababa's road network to acceptable levels. Still, according to a 1996 PADCO study (1997), some 65 percent of residential units in Addis Ababa are accessible by car (UN-Habitat, 2007) so all this are assessed by this research first by selecting road network performance evaluation tools.

In general the scope of this research covers performance evaluation using indicators in Addis Ababa with macro level just by considering the city as a whole due to shortage of data in micro level by classifying in sub cities.

3.2 *Methodology*

The research methodology employed in this thesis outlines the steps used to answer research questions as described in section 1.3.1 above. A key data source used for the entire study is the transport network layer for the whole city and related study concerned the road network. The research relied mainly on secondary data sources, however some data was derived from primary sources, key among them was through unstructured interviews.

The main aim of this research is to find out the truth which is hidden and which has not been discovered as yet. Though the study has its own specific purpose, in this research some of the methodologies used are:

- To gain familiarity with a phenomenon or to achieve new insights into it (studies with this object in view are termed as exploratory or formulative research studies); ***this research tries to see the view of performance evaluation in road networks.***
- To portray accurately the characteristics of a particular individual, situation or a group (studies with this object in view are known as descriptive research studies); in which the descriptive research attempts to describe, explain and interpret conditions of the present i.e. "what is'. The purpose of a descriptive research is to examine a phenomenon that is occurring at a specific place and time. ***So, this research tries to evaluate the current performance of road network in Addis Ababa using indicators listed below.***
- To determine the frequency with which something occurs or with which it is associated with something else (studies with this object in view are known as diagnostic research studies); ***in this research it tries to see the trend in change of the road performance indicators for some years***.
- To test a hypothesis of a causal relationship between variables (such studies are known as hypothesis-testing research studies). ***Likewise it will try to see a relationship between population and area with road network.***

Following are some specific methods in this research.

- First of all analysis regarding the study area is made in which socio economic and transport related documents reviewed
- Research objective and research questions identified
- Literatures which discuses about performance evaluation of road networks assessed deeply to understand what is performance measure and also how this performance evaluation done using some performance indicators.

For this research the selected performance evaluation indicators are

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..

b. **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.

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.

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 of road constructed in the city and total number of population of the city.

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 is found from Addis Ababa Police Commission office.

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.

As connectivity increases, travel distances decrease and route options increase, allowing more direct travel between destinations, creating a more Accessible and reachable system so this indicator shows this.

In general,

- This research tries to use analytical research approach which means it uses facts or information already available in the concerned bodies related to Addis Ababa road network from like AACRA, Transport office and Traffic police office and analyze these to make a critical evaluation using some evaluation tools.

- Regarding application this research use a method of applied research methodology in which it tries to find a solution or recommendation for the current problem in transport regarding the established road network of the city
- Regarding data the collected data from concerned body's analyzed using quantitative research methodology method to get some relation between them.
- The research tries to compare the result of the analysis with given standards in other countries for some results.

The evaluation has a goal to value the level of service of existing road network. The evaluation result will be used to estimate and build the strategy of road network rehabilitation and development.

4. Data Collection and Analysis

4.1 Data Collection Techniques

Multiple data sources were used for the purpose of investigating the different dimensions of the research objective. Therefore data used can be categorized as primary and secondary data. These different data were collected using different techniques at various stages as presented in the coming subsections.

Sources of data and Data Collection Method

Most of the data collected from government offices like AACRA, Transport office and Traffic police commission.

A combination of the following techniques was employed in the study.

1. Annals Study /historical record study/ –By looking through the existing relevant documents or literatures tried to analyze the issues related with the performance evaluation and road network also how the current master road network of the city developed.

2. Observations- as a resident and researcher in the city, it was convenient to use the technique of participant-observation by observing the current traffic movement in the city and the assessment of transport planning for the city. In which it has an advantage of Directness, Diversity, Flexibility, and Provision of a permanent record and Applicability.

3. Discussion –This is conducted by applying the method of dramaturgy. This has helped to create conversation with persons found in concerned governmental bodies without creating the feeling that they are being interviewed. This method has helped to understand how relevance is this issue i.e. performance evaluation.

4.2 Collected Data

For this research data collected directly from the concerned bodies the AACRA(Addis Ababa City Road Authority)

- Financial progress for the road sector in addis ababa
- The progress of constructed roads according to the master road network plan
- The progress of maintenance of the roads

From Addis Ababa Transport Office about

- The number of vehicles in the city
- The master road network study and

From Addis Ababa Traffic police commision research documents about

- The number of accidents and their relation with road

From Addis Ababa City Adminstration Buletin about

- Area and poulation of the city

Most of the data are secondary data which were acquired through reviews in the institutions.However, some data was derived from primary sources and among them was through unstructured interviews. This collected datas used directly or indirevctly for the results and analysis part of the research.

Fig 2 Road network map as planned in the CDP (2001-2010)

Source : City development plan (2001)

4.3 Data analysis

After the datas collected they are aranged in the way that they used in the results and calculations part.

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	

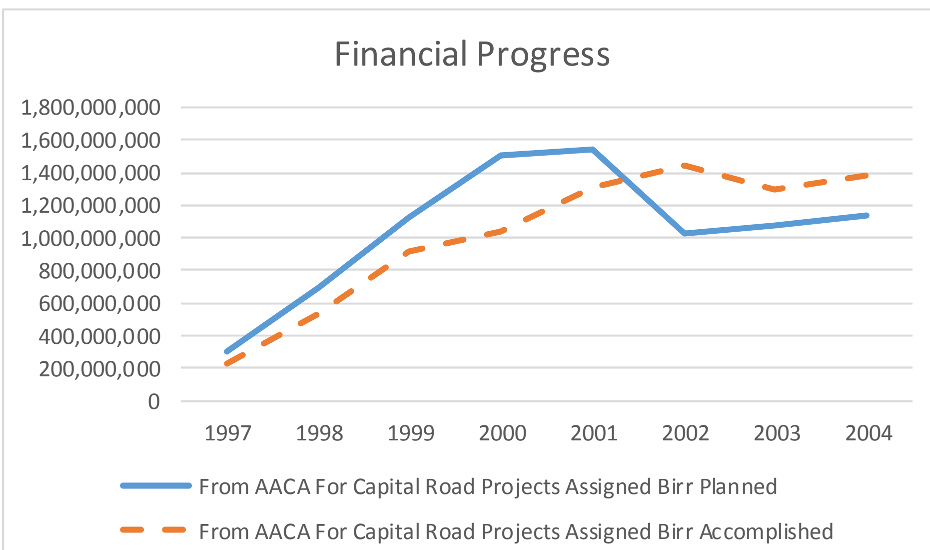
Table 3- Addis Ababa Population and Area

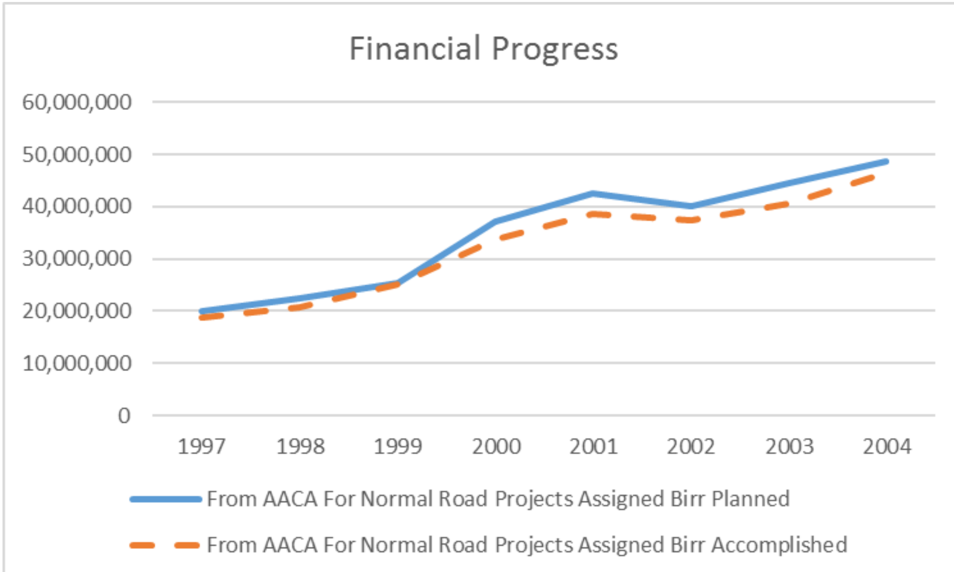
Note all years specified below in the data analysis are in Ethiopian Calendar.

AACRA Financial progress For Road Projects

Year in Ethiopian Calander	*From AACA For Capital Road Projects Assigned Birr*		*From AACA For Normal Road Projects Assigned Birr*		*From Federal Road Fund For Maintenance Projects*	
	Planned	*Accomplished*	*Planned*	*Accomplished*	*Planned*	*Accomplished*
1997	303,620,000	227,802,584	20,095,082	18,857,848	19,922,867	16,911,361
1998	700,071,638	532,933,329	22,436,443	20,753,431	24,150,000	25,020,000
1999	1,121,427,638	921,587,928	25,460,226	25,242,089	32,500,000	33,261,981
2000	1,507,915,880	1,039,274,356	37,043,614	33,758,970	37,500,000	36,638,445
2001	1,545,050,568	1,307,392,599	42,572,091	38,699,758	37,500,000	37,600,000
2002	1,027,414,794	1,443,615,649	40,187,310	37,476,522	35,000,000	38,900,000
2003	1,077,870,000	1,295,062,249	44,403,884	40,493,845	41,630,000	41,200,000
2004	1,134,878,400	1,381,031,651	48,564,890	46,359,200	45,793,013	46,547,195
Total	***8,418,248,918***	***8,148,700,345***	***280,763,540***	***261,641,663***	***273,995,880***	***276,078,982***

Tabel 4 – Addis Ababa Road Financial progress





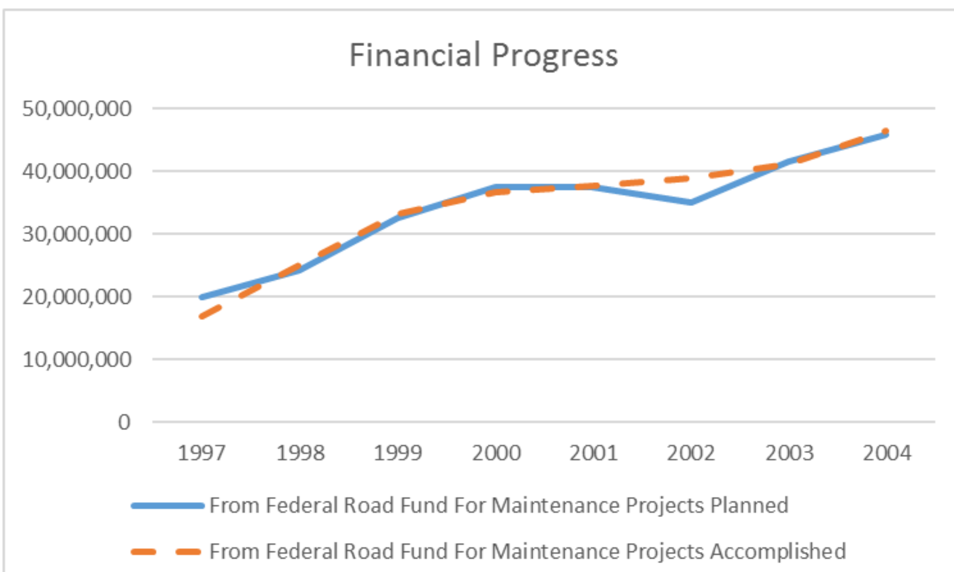


Chart 1 – AACRA Financial progress (1997 -2004)

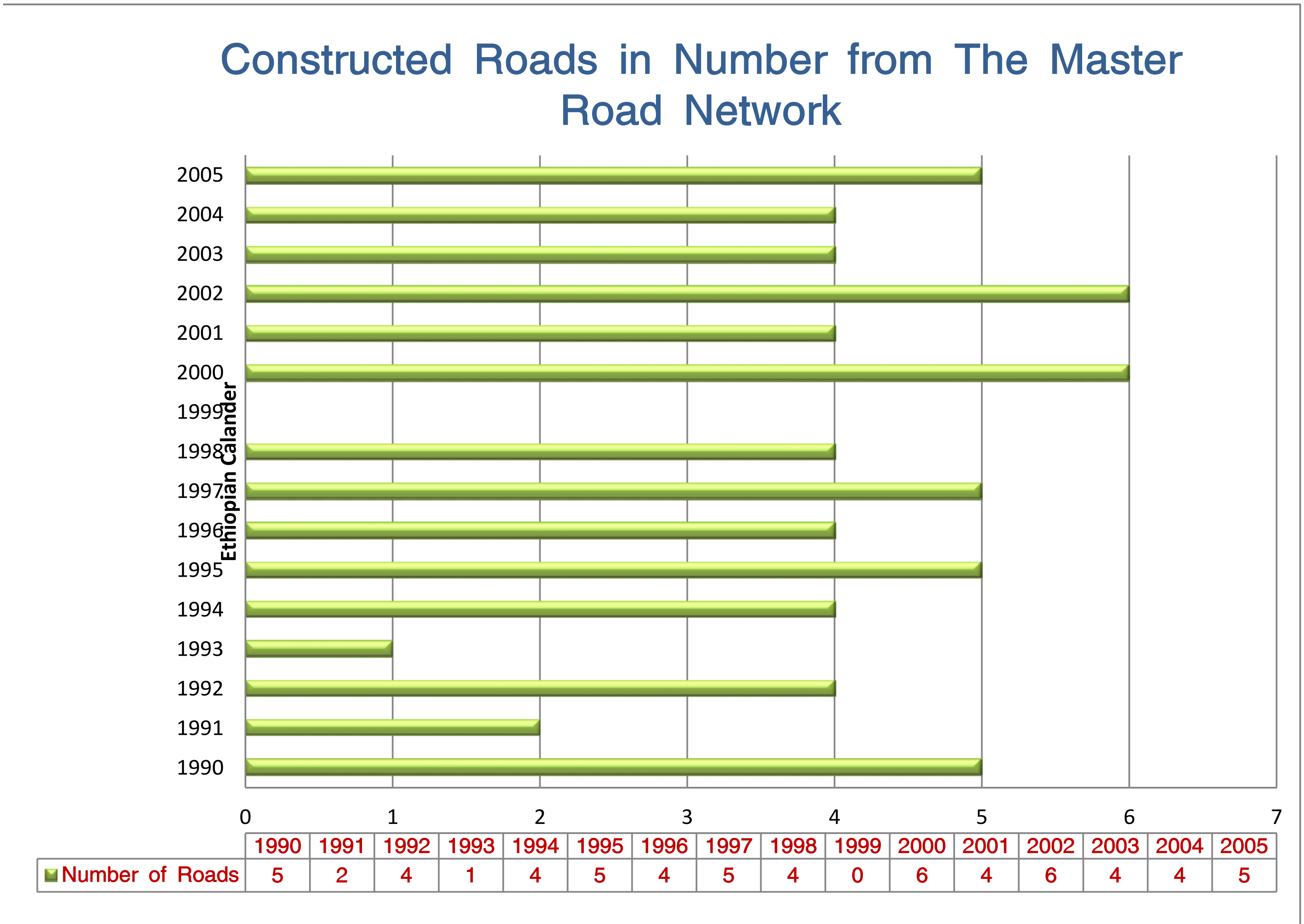
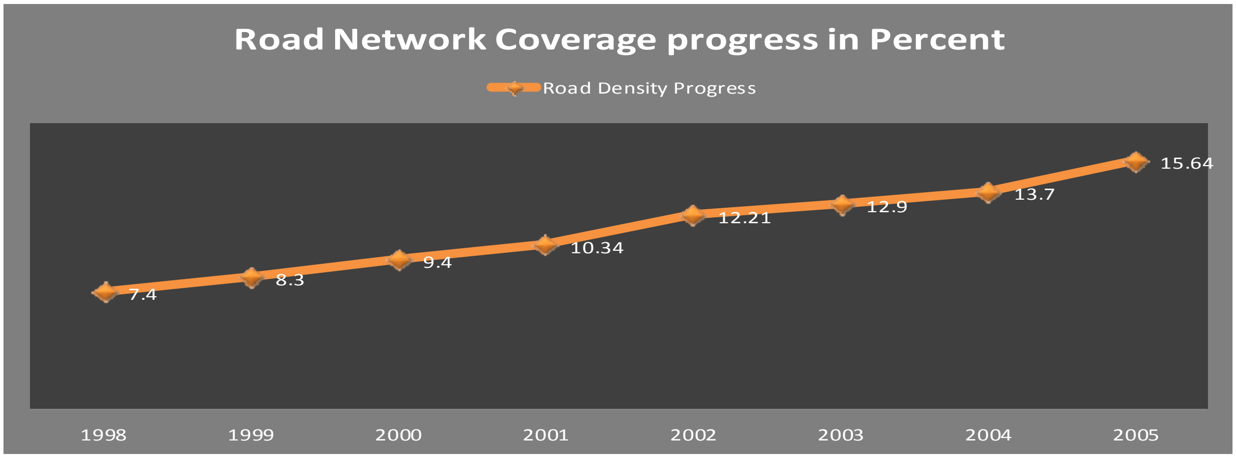


Chart 2 – Constructed roads in Addis Ababa from the master plan (1990 -2005)



Ethiopian calendar

Chart 3 – Road network coverage progress in Addis Ababa (1998 -2005)

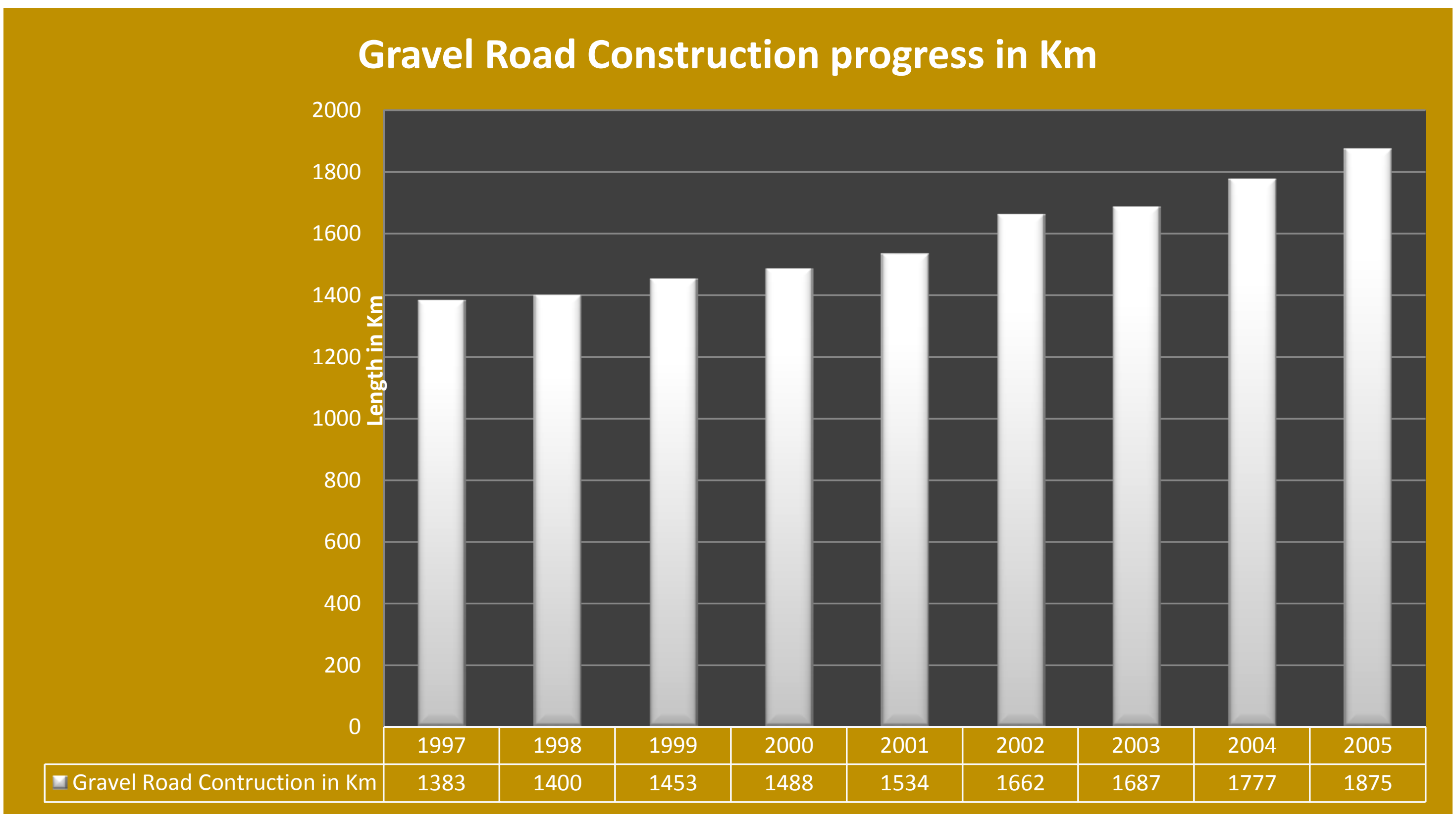


Chart 4 – Gravel Road Construction Progress (1997 -2005)

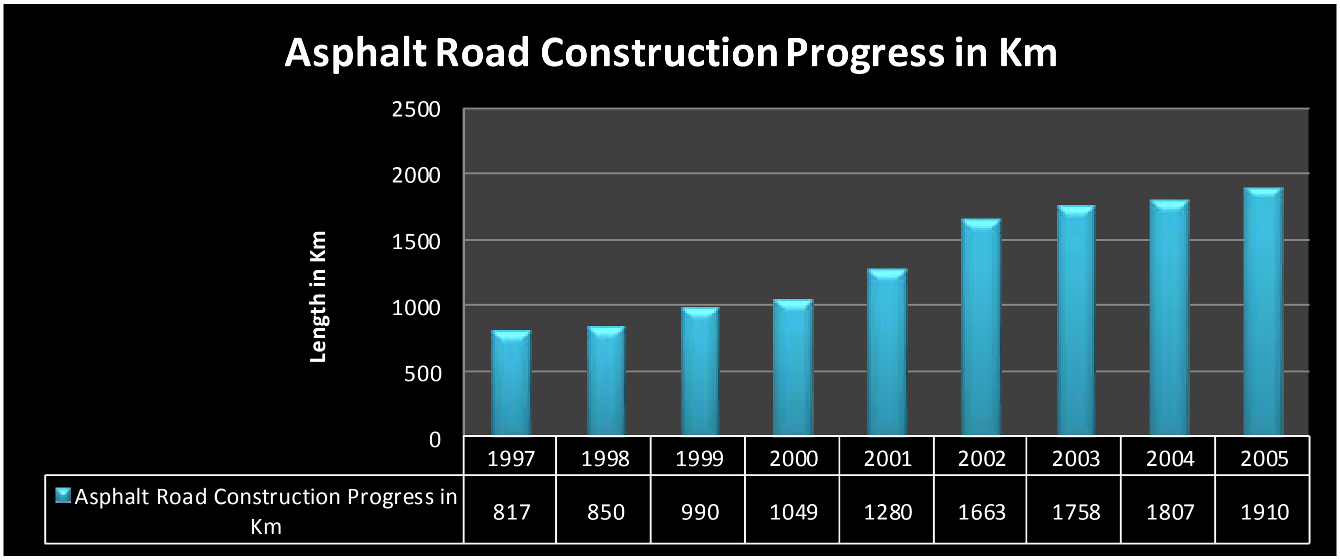


Chart 5 – Asphalt Road Construction progress (1997 -2005)

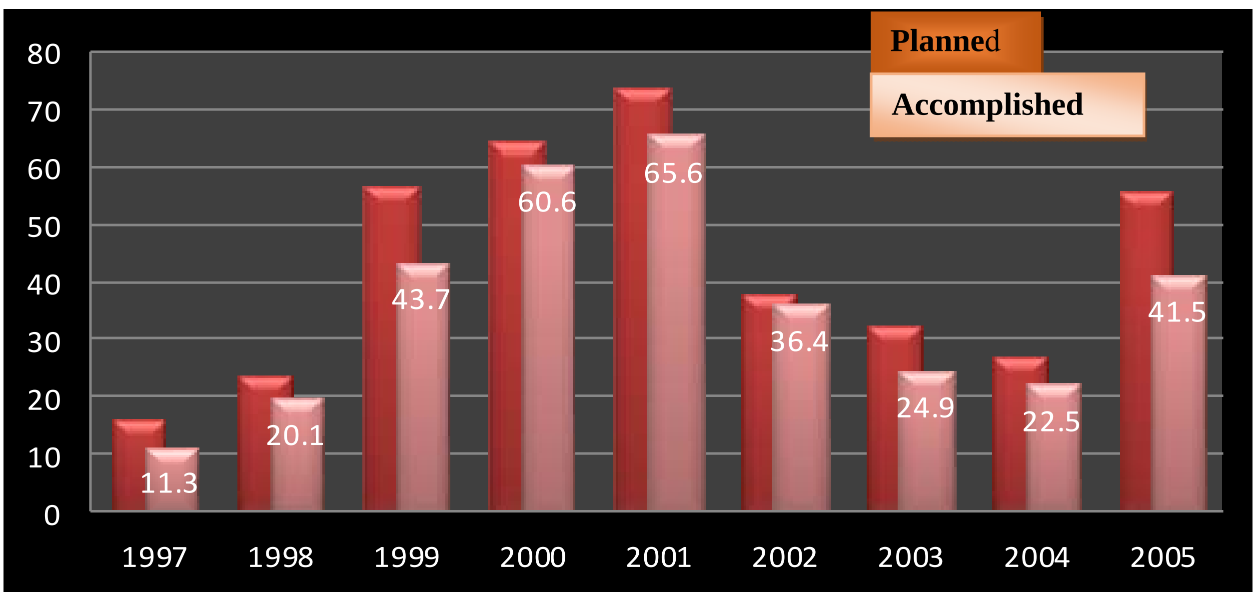


Chart 6 - New Asphalt Road Construction Progress in Km planned vs Accomplished

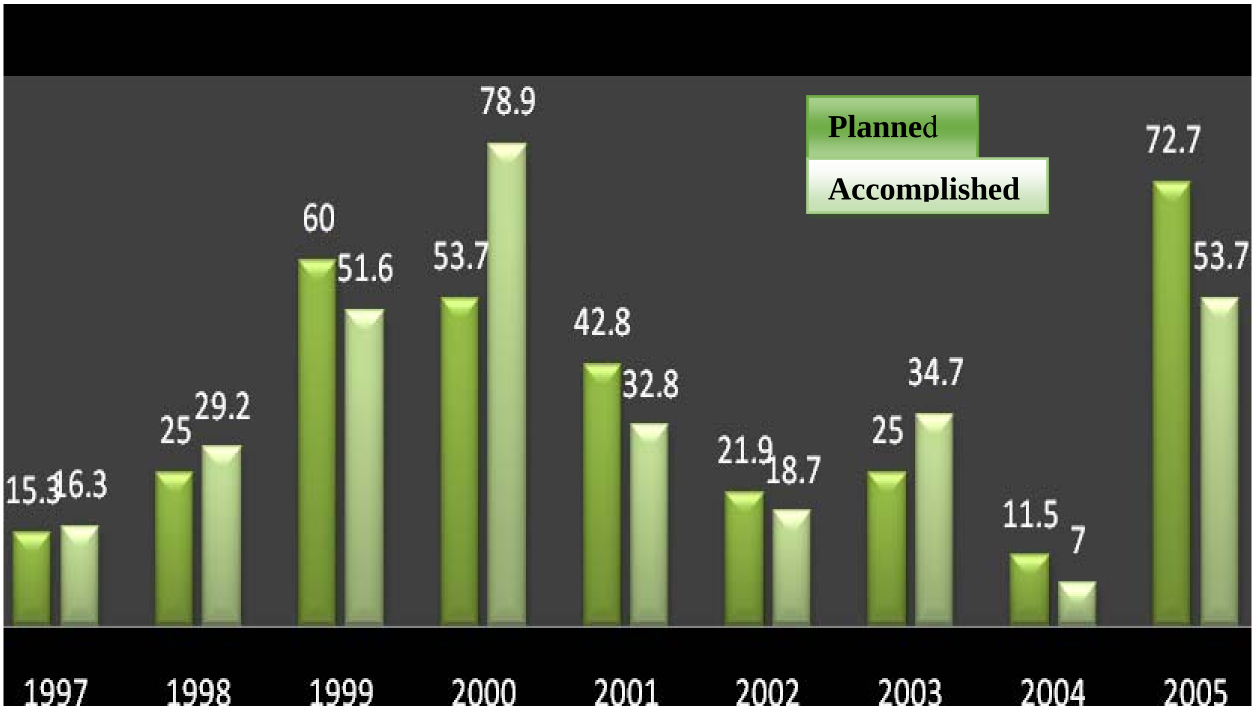


Chart 7 - New Gravel Road Construction Progress in Km planned vs Accomplished

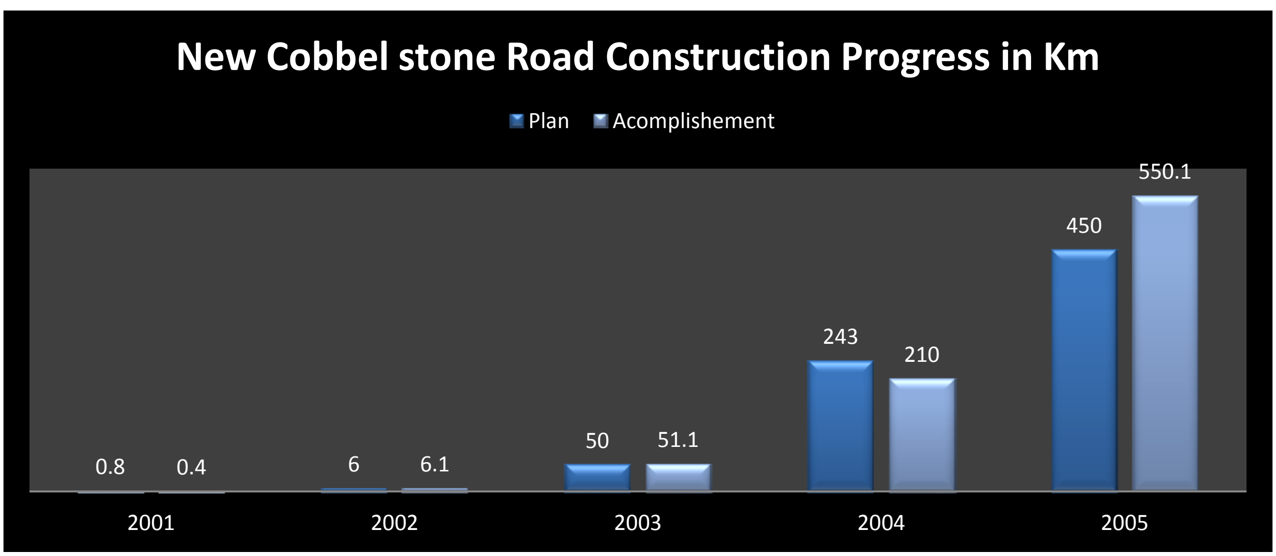


Chart 8 – Cobbel stone road Construction progress (2001 -2005)

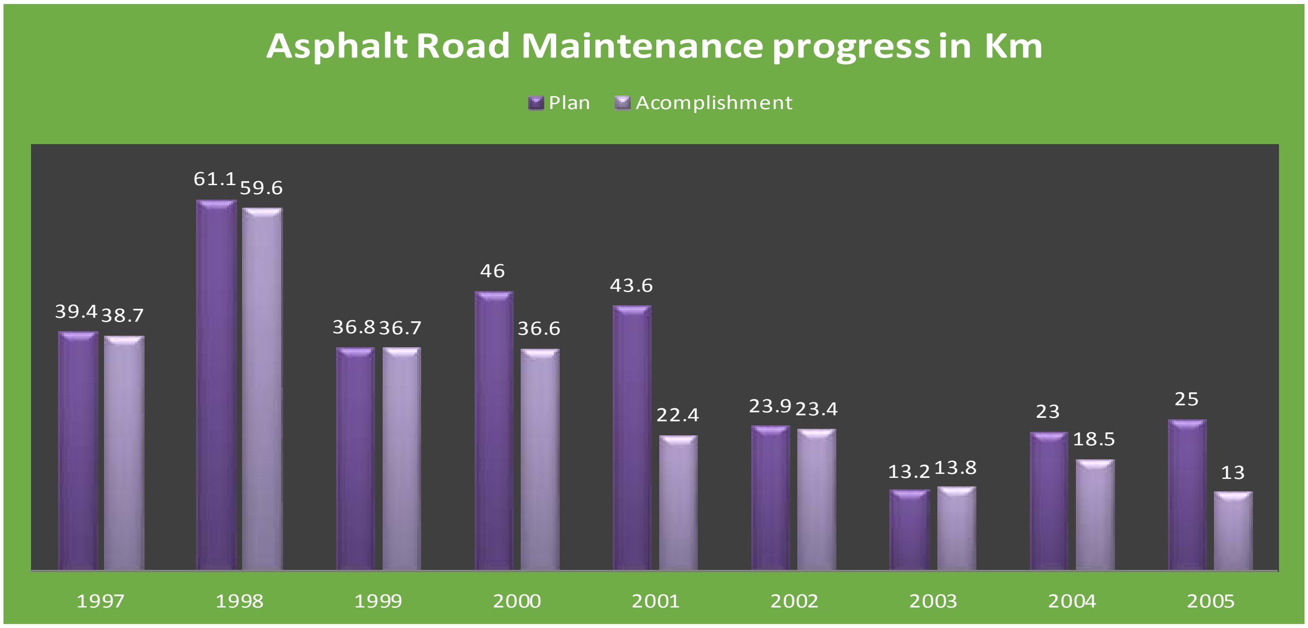


Chart 9 – Asphalt road maintenance progress (1997 -2005)

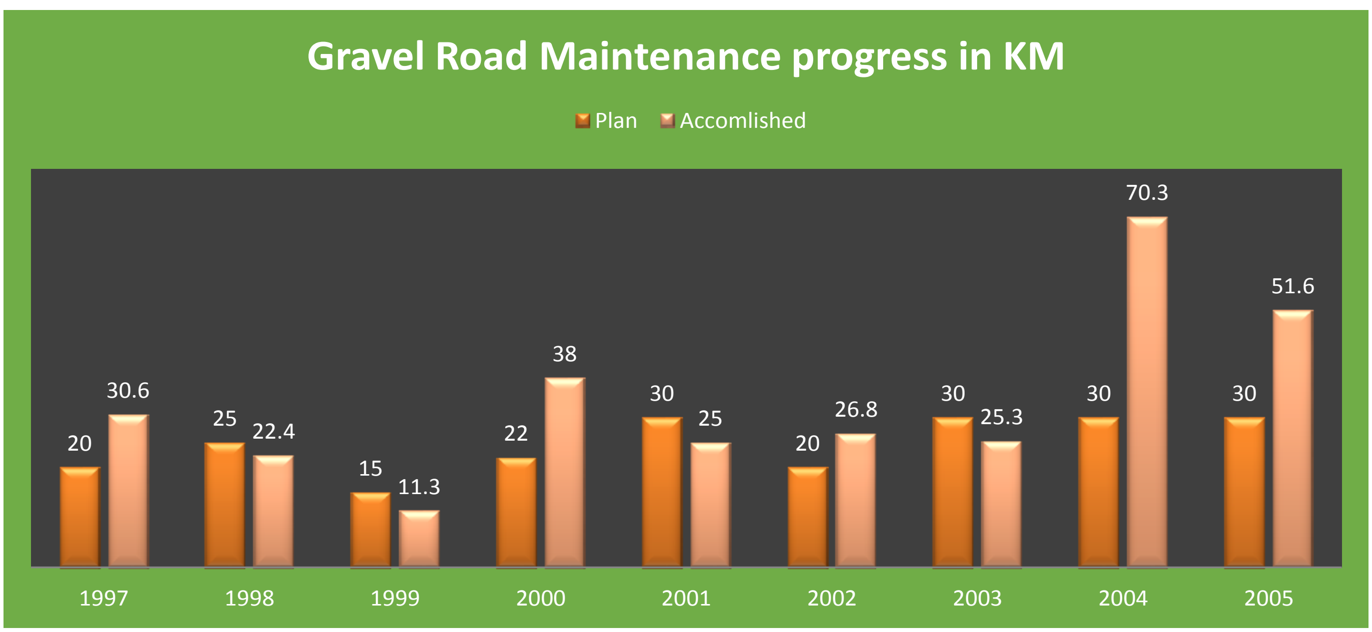


Chart 10 – Gravel Road Maintenance progress (1997 -2005)

Number of Vehicles registered in Addis Ababa

Code	1999	2000	2001	2002	2003
1	17156	17536	18845	19179	19372
2	66911	55996	56636	72244	72621
3	71265	90019	80196	81939	83464
4	10565	13433	11324	11623	12070
5	1995	2044	2224	2327	2482
AO	5793	6372	6246	6685	7348
AU	187	208	231	249	290
CD	842	1110	1050	1366	1631
UN	980	1127	1191	1344	1544
Total	*175694*	*187845*	*177943*	*196956*	*200822*

Avarage annual growth rate= 3.4%

Table 5 – Number of vehicles in Addis Ababa

Number of Traffic Accident in Addis Ababa Related to Road Junction

No	Junction Type	Year					Total
		2000	2001	2002	2003	2004	
1	In No Junction Road	5,942	3,695	5,372	5,499	7,093	*27,601*
2	In Junction road	1218	1069	1139	1624	1540	*6590*
4	In Round About	374	416	245	940	1,316	*3291*
5	In Four leg Cross junction	611	1,092	766	861	1,286	*4,616*
	In Five leg Junction	8	12	1	205	265	*491*
6	Others	16	1	-	5	29	*51*
	TOTAL	*8,169*	*6,285*	*7,523*	*9,134*	*11,529*	*42,640*

Table 6 – Number of Traffic Accident in Addis Ababa Related to Road Junction

Number of Traffic Accidents in Addis Ababa according to Road condition

No	Road	Year					Total
		2000	2001	2002	2003	2004	
1	Straight and flat	7,775	5,659	7,125	7,619	10219	*38,397*
2	Straight with gentl slope	139	173	153	385	302	*1152*
3	Straight with steep slope	5	36	20	118	70	*249*
4	Straight with ups and downs	-	25	1	71	106	*203*
5	A little bit curved	58	106	51	139	94	*448*
6	Highly curved	6	7	20	15	37	*85*
7	steep upgrade slope	79	72	55	330	303	*839*
8	Downgrade slope	105	204	97	430	291	*1127*
9	Others	2	3	1	27	107	*140*
	TOTAL	*8,169*	*6,285*	*7,523*	*9,134*	*11,529*	*42,640*

Table 7 – Number of Traffic Accident in Addis Ababa According to Road Junction

Number of Traffic Accidents in Addis Ababa according to road Pavement condition

No	Pavement Condition	Year					Total
		2000	2001	2002	2003	2004	
1	Good Asphalt Road	7,851	6,108	7,261	8,888	10,952	*41,060*
2	Deteriorated Asphalt Road	62	57	77	79	348	*623*
3	Gravel Road	129	91	134	153	207	*714*
4	Earth Road	127	29	51	14	22	*243*
	TOTAL	*8,169*	*6,285*	*7,523*	*9,134*	*11,529*	*42,640*

Table 8 – Number of Traffic Accident in Addis Ababa Related to Road Junction

5. Results and Discussion

In this research the main objective is based on the above collected date. It needs to evaluate the road network performance considering some of road indicators.

Indicators are results of measurements and analysis used to evaluate progresses towards goals and objectives. In order to provide useful information to policy makers, decision makers and athe general public there is the need to carefully select indicators. More so there is the need to understand what they measure and also their limitations (Litman 2007). Litman (2007) recommends asking the following questions about potential indicators:

- Is it relevant to the community?
- Is it understandable to the community at large? It further explains that if it is only understood by experts, it is only these experts who will use it.
- Does it provide a long term view of the community?
- Is it based on information that is reliable, accessible, timely and accurate?

These checklist of questions helps to pre-consider which indicators will be used and also ensures that the indicators chosen are relevant. This is to ensure its usage by decision makers and also beneficial for transport goals set by municipal authorities, in this case, the AACRA and Transport Office. Aside these questions that should be asked, Hart (1997) and Marsden et al (2006) as cited by Litman (2007) also mention some principles that should be applied when selecting transportation network performance indicators. Litman mentions that the indicators should take these aspects of the data into cognition,

High standards in terms of data quality, data sets should be comparable, indicators should be useful to decision makers and understandable to the general public, indicators should be cost effective to collect and lastly indicators selected should reflect set objectives.

These guidelines are general issues to consider in selecting indicators. They are helpful as they keep the researcher focused on what to collect and also at which scale the analysis is going to be made. It is good also to be realistic when selecting indicators, taking into consideration data availability, understandability and usefulness in decision-making. It is also important that users understand the perspectives, assumptions and limitations in different types of indicators and indicator data.

In this research we relied on information that was readily available considering the time availability and resources availability. The indicators used are understandable and will make meaning to both the AACRA, Transport Office and the general public.

A. Determination of the road density

As we discussed above to calculate the road density first we have to know the total road length and the total area. From the above data, the total area of Addis Ababa is 526.99 km^2 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

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

Avarage annual growth rate of the road density is 8.9 percent

Table 9 – Addis Ababa City Road Density Trend

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.

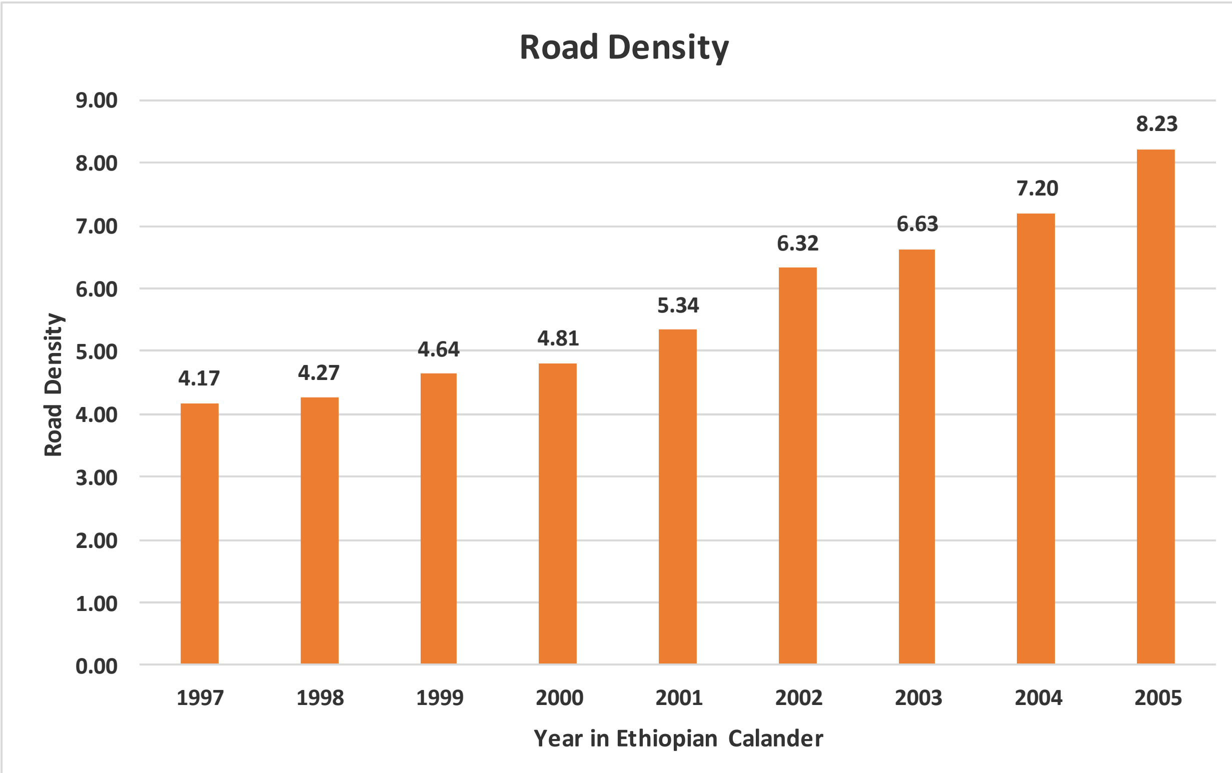
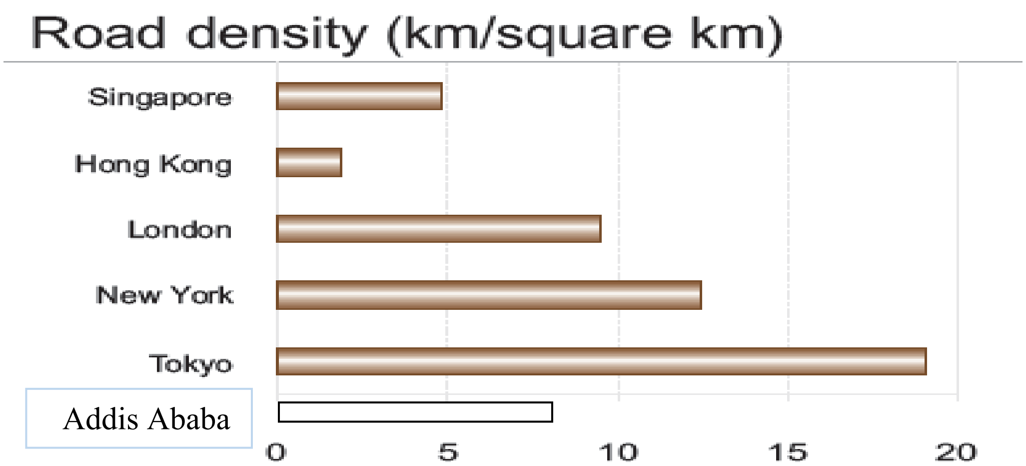


Chart 11 – Addis Ababa City Road Density progress (1997 -2005)

In their simplest form, road networks are primarily designed to connect local resources and people to distant markets and population centers. Roads provide access and allow land use to occur, but changes in land use also induce new travel demands and create new transportation needs. Land-use changes and the response to travel demands are mediated by political, social, and economic institutions that direct development to certain areas based on short and long-term goals .However, development may be constrained by environmental factors such as topography. Advances in technology may decrease the relevance of constraints and initiate new phases of land-use change. Understanding the variation in road density is no trivial task given the variety of factors involved in shaping the transportation network, their complicated interactions among factors, and their changing significance over time.

So from the above result the trend in change of road density from 1997 E.C up to 2005 E.C. is increasing. 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 but compared with other cities like shown below, road density this values for Addis Ababa city must be changed in a better way to enhance the economic growth and land use pattern so we have to work on the road network more. Chart 12 shows road density of specific cities in developing countries



***Source**: Singapore land transport report*

Chart 12- Road densities of other countries

Here it seems Addis Ababa has a better road density than Singapore and Hong Kong also almost equal with London but road density is related with the area of the city so this cities attain this much road density with a smaller area than Addis Ababa.

B. Determination of road performance

To calculate the road performance we have to know the total road length in stable condition and this is determined by deducting total gravel road length and total asphalt road with maintenance from the total road length because this type of roads are not comfortable to ride.

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

Table 10 shows road density and chart 12 graphically illustrates the same

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

Table 10 – Road performance Trend

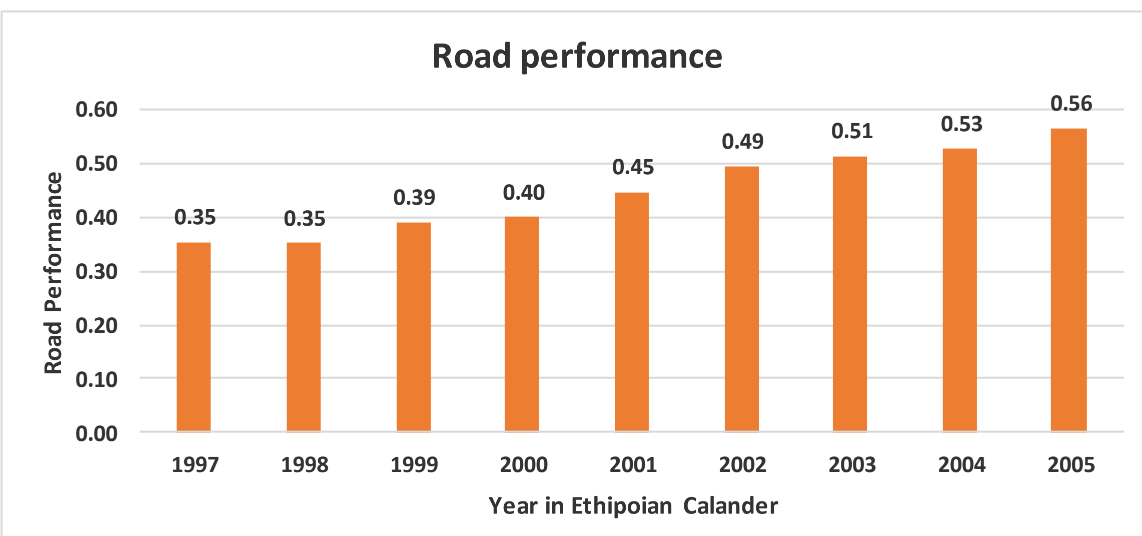


Chart 12 – Road performance progress (1997 -2005)

Motorized vehicles are the dominant mode of transport in Addis Ababa. The road system in Addis Ababa, which totals just above 4335 kilometers, is mostly in poor condition. At present, less than 60 percent of this total network is paved as we observe from the above analysis. This percent of road performance in the city has many effects like it increases in road maintenance cost because gravel roads has grater maintenance cost than paved roads also it increases the user operating cost due to poor quality of roads. In the consequence of this, even if government allocate a large amount of budget for road construction (as we observe from Chart 1 in the data analysis for road construction budget which is increasing on average by 10% yearly) the quality of road network will decrease.

Additionally, as we observe 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 increase 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 is a ratio between total lengths of road with number of vehicle. This indicator has a unit km/no of vehicle. Which tells us how the number of vehicles affects the total road network and we can calculate using the above data as

Traffic load= Total length/Total number of vehicles

Table 11 shows the trend in change of traffic density

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

Table 11 – Traffic load Trend (1999 -2003)

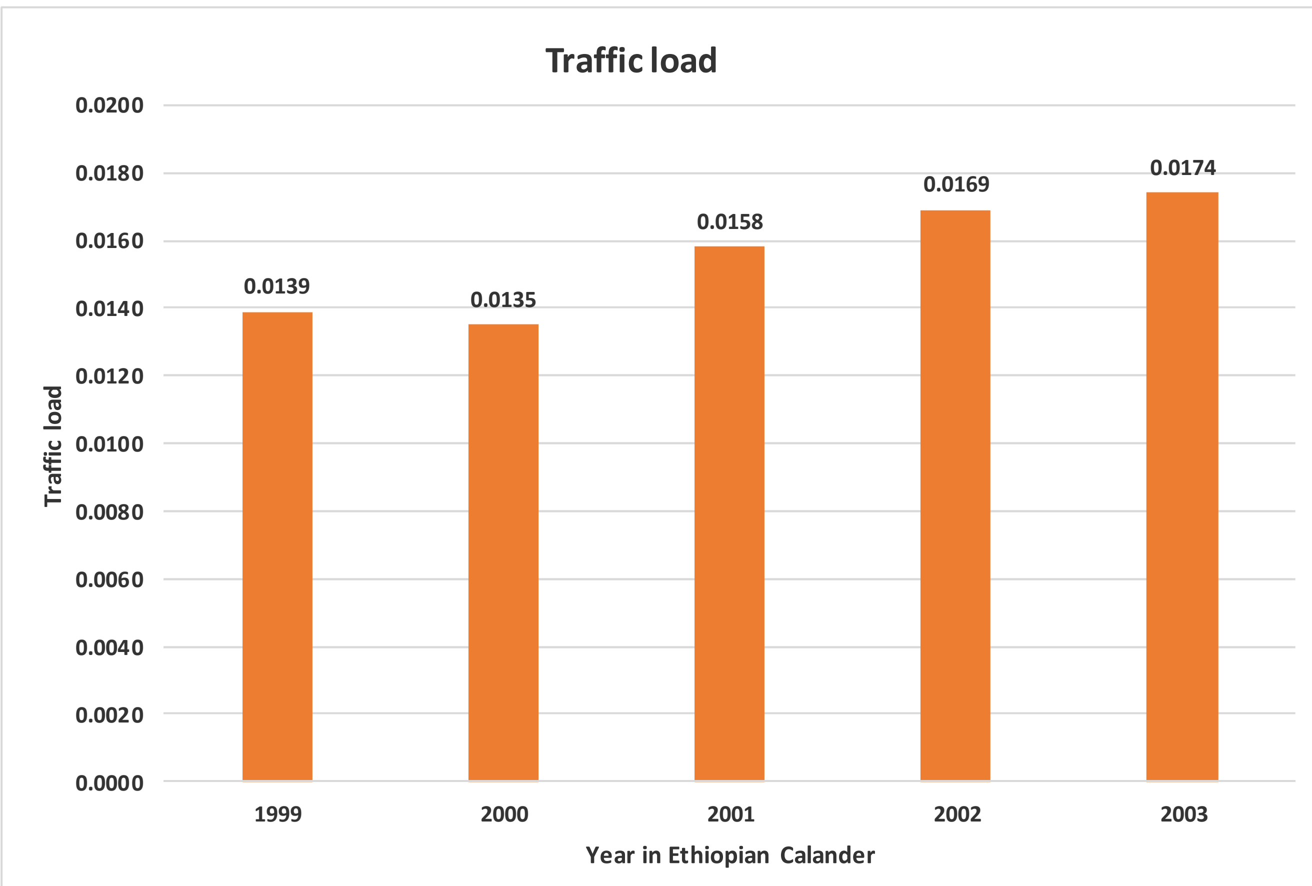


Chart 13 – Traffic density progress (1999 -2003)

The number of cars also grows in line with road network growth. Consequently, as more roads are built, more cars will be acquired to use them as shown in Table 12. Experience in the developed world shows that no road infrastructures are able to cope with the private car demand in the long term, undermining the outmoded traditional approach to transport planning and infrastructure construction of 'predict and provide'.

In Africa, more than elsewhere, the road network suffers from a lack of regular, planned expansion and from a lack of long-term maintenance plans. It is therefore even more critical to provide mobility options other than just encouraging the use of the private car. This illustrates moreover the limited availability of road infrastructures and especially of quality paved roads. It is therefore necessary to seek adapted transport solutions which optimize the use of road infrastructures currently available. Therefore, we can see that encouraging the development of private cars or even failing to address the issue of implementing affordable, cost-efficient public transport systems in Africa, clearly means marginalizing and hampering the mobility of the vast majority of its people.

Table 12 – Road network and traffic data in Addis Ababa and some African countries

INDICATORS	ABIDJAN	ACCRA	ADDIS ABABA	DAKAR	DAR ES SALAAM	DOUALA	JOHANN ESBURG	LAGOS	NAIROBI	WIND HOEK
GDP per capita (euros)	1,800	1,562	700	1,700	1,100	2,300	10,600	2,200	1,600	5,200
Population (inhab.)	4,252,986	3,832,680	2,973,004	2,482,294	3,296,203	2,500,000	3,800,000	17,552,942	4,736,000	230,000
Area (km^2)	1,183	1,994	530	549	1,800	923	1,645	3,569	4,200	645
Urbanised area (km^2)	120	1,994	530	214	572	210	1,645	2,831	3,900	645
Human density ($inhab/km^2$)	3,593.7	2,682.0	5,608.0	4,519.0	1,831.2	2,708.6	1,962.0	4,918.7	1,127.6	356.6
Human density with urbanised area (inhab/km2)	35,441.6	1,922.1	5,608.0	11,583.3	5,762.6	11,904.8	2,310.0	6,200.3	1,214.4	356.6

Total number of cars	201,134	270,026	116,297	159,982	240,483	150,665	917,042	405,430	519,185	26,209
Car density per km^2 of	170.0	135.4	219.4	291.2	133.6	163.2	557.5	113.6	123.6	40.6
Car/1,000 hab	47.3	70.5	39.1	64.4	73.0	60.3	241.3	23.1	109.6	114.0

***Source** - International Association of Public Transport report on statistical Indicators of public transport performance in Africa, April 2010*

INDICATORS	Abidjan	Accra	Addis Ababa	Dakar	Dar es Salaam	Douala	Johannes burg	Lagos	Nairobi
Length of road network (kms)	2,042	2,355	640	804	1,140	1,800	10,000	5,180	2,385
Length of paved roads (kms)	1,205	1,437	400	520	445	450	8,500	4,818	1,153
Percentage	59%	61%	63%	65%	39%	25%	85%	93%	48%

Source - International Association of Public Transport report on statistical indicators of public transport performance in Africa, April 2010

From table 12 comparing Addis Ababa with the other nine cities in Africa Addis Ababa

- Has smallest land area
- Is the largest in population density
- Has the second lowest number of vehicles
- Is the second in car density next to Johannesburg
- Is the second lowest in the ratio of the number of vehicles by population
- Has the smallest length of road network both in total and paved roads and
- The fourth highest in percentage of length of paved roads as compared with the total

D. Determination of Road serviceability

Road serviceability is a ratio between total lengths of road with number of population in that region. The unit of this index is km/people using the above data we can calculate this as

Road serviceability = Total road length/population

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

Table 13 – Road serviceability Trend (1999 -2005)

Chart 14 – Road Serviceability progress (1997 -2004)

Many literatures pointed out that the transportation-land use relationship is reciprocal and dynamic in nature. As our cities have grown, both in terms of their population size and functions, the relative advantage of locations and accessibility/serviceability within them has changed through time because of the development of new roads in response to the current pressure for development. Inevitably, these developments provide different level of accessibility/serviceability to new locations. This in turn will ease the movements or reduce the travel costs between locations, which open up new opportunities and contribute to the economic vitality of specific economic and social activities as well as residential locations.

Recent development in highway development in Addis Ababa especially ring road highways have produced some significant effects in term of accessibility to certain locations resulting in land use changes in certain localities along these highways this also affects the road network performance .

Accessibility measures the ease of reaching destinations. The higher the travel cost, the lower the accessibility. It also measures the value of destinations: the more activities there are at the destination, the more valuable it is for the peoples.

An accessibility increase does two things. First it increases total wealth. Agglomeration economies caused by new infrastructure enlarge aggregate output. Second, it redistributes wealth, as the locations where the accessibility gains are larger gain more of the aggregate wealth. Places which do not increase accessibility by at least the average amount may find themselves losing economic opportunities, since these opportunities will relocate to take advantage of the accessibility benefits.

As it is observed 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.

From the stand-point of road safety, road modernization is not an easy task. This is mainly due to the level of current scientific knowledge, which does not allow for an exact explanation of the process leading to a road accident. It is even more difficult to specify the effects of road modernization on changes in this process and how it happens. In this context, scientific evaluation of road safety aspects in the process of road design seems to be a complicated task, because:

I We don't have a clear view on the criteria for evaluating the elements of the road accident process and we also lack demographic data on its participants. Basically, apart from the sex and age of the casualties, we know little about their professions, employment, educational background, income, family, reason for journey, transportation means, consumption structure (including alcohol), ways of spending leisure time, etc. And it is these data that can tell us what the relation between a road feature and the behavior of road user is in the critical moment,

II There is doubts about the usefulness of typical measures to evaluate risks in road traffic in general, and especially the risks generated by construction elements or road environment. Currently, we know and apply various road accidents indicators and each of them represents a certain point of view (global, local, individual, collective, drivers' and pedestrians' views, etc.) whereas often they should be seen as parallel. The doubts we are having as to the adequacy and usefulness of road safety evaluation indicators are a sufficient justification of the question: "What road safety aspects in road design are we supposed to discuss?" In spite of commonly recognized importance of safety as a criterion in the process of planning, designing and road operating, neither science nor engineering practice have so far provided sufficiently clear answers to the questions on the relations between road geometries and road safety.

From the stand-point of road safety, a proper design has a crucial significance in preventing road users' errors. When the numbers and significance of these accidents are decreased, the number of deaths and injuries and material losses also decreases. The obvious truth can be supported by three main principles, which say that a well-planned road should:

- Prevent unintended ways of its usage (type of road vs. traffic structure, type of road environment vs. vehicle speed; road function vs. type of traffic),
- Prevent conflicts by unification of vehicle flows from the stand-point of their speed, driving direction, or mass of vehicles,
- Prevent insecurity in the road user's behavior, at the same time making it possible to foresee the user's reaction. Fulfillment of the three principles in the design process should be a great help in adapting the road to modem traffic and securing a higher level of its safety. But as we see from the results, there is a clear relation between road geometric elements with road safety. ***(9)***

F. Determination of 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. As connectivity increases, travel distances decrease and route options increase, allowing more direct travel between destinations, creating a more accessible and reachable system.

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.

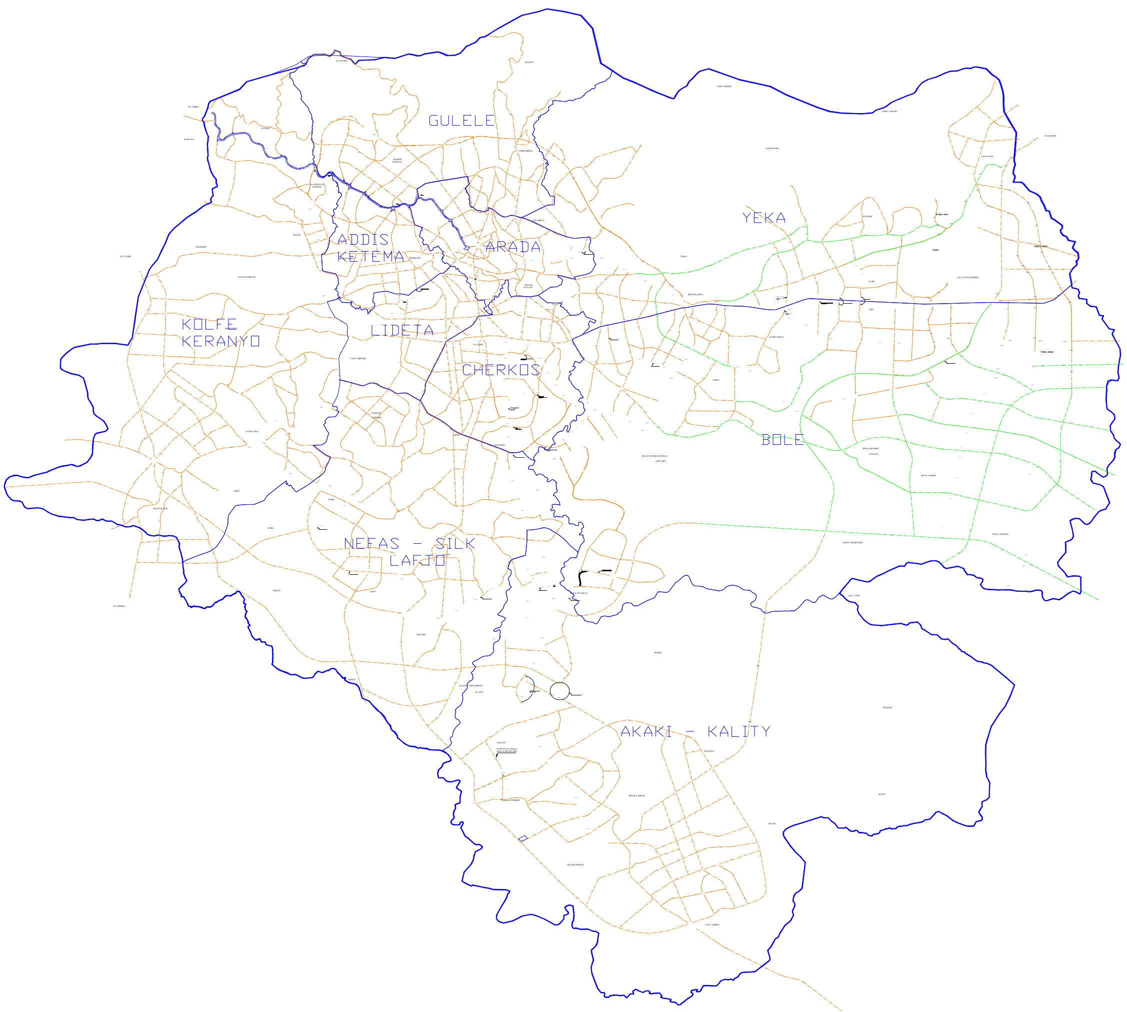


Fig 3- Road network nodes and straight lines by sub city

From the master road network, the number of nodes and the straight lines with the beta index for each sub city is shown below

Beta index =Arc/Nodes

Where the nodes are the number of road junctions and arcs are connections (straight lines) between the nodes as straight lines

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***

Table 14 - Road connectivity beta index value for sub cities

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

In accordance with future land use policy and consistent with the master road network, the City shall combine the mobility of the traditional interconnected street pattern with the safety, security, and topographic sensitivity of the conventional or contemporary network. Such a hybrid network features short, curved stretches that follow the lay of the land or

contribute to good urban design, as well as short loops and streets designed to be permanently closed at one end, so long as the higher-order street network is left intact.
"Higher-order" means arterials, collectors, and sub-collectors that carry through traffic. An acceptable individual project master plan may feature interrupted grids of short streets ending at T or Y intersections, traffic circles or squares/parks. By design, local streets may carry some through traffic, but the truncated nature of local streets means that traffic moves more slowly and the heaviest volumes are diverted to higher-order streets.

A simple measure of connectivity is the number of street links divided by the number of nodes or link ends. The more links relative to nodes, the more connectivity. A connectivity index of 1.4 to 1.8 represents an acceptable street network in the area. The optimal connectivity index for a perfect grid network is 2.5 and from the above results the connectivity index of the city is not perfect grid but it is in acceptable range. ***(8)***

Increased street connectivity can reduce vehicle travel by reducing travel distances between origins and destinations and by supporting alternative modes. Increased Connectivity tends to Improve Walking and cycling conditions, particularly where paths provide shortcuts, so walking and cycling are relatively faster than driving. This also supports transit use.

How to improve?

- Simple changes in design, such as removing dead ends and connecting the street-ends to other streets, can bring about significant changes in connectivity index scoring. The City shall utilize the connectivity index mechanism, in addition to other qualitative measures, to determine whether transportation impact fees can be reduced within the city.
- Connectivity can be increased during roadway and pathway planning, when subdivisions are Designed, by adopting street connectivity standards or goals, by requiring midblock pedestrian shortcuts, by constructing new roads and paths connecting destinations, by using shorter streets and smaller blocks, and by applying Traffic Calming rather than closing off streets to control excessive vehicle traffic. New Urbanism development practices emphasize a high degree of street connectivity.

6. Conclusion and Recommendations

6.1. Conclusion

As it is discussed above the current performance of the road network in Addis Ababa is evaluated using some evaluation tools. From the results and discussions we can conclude the following points.

- Network indicators explored in this research provided quantitative information for urban transport analysis.
- Currently the construction of new roads and maintaining the existing ones is increasing throughout years as we observed from the result but it needs more effort to gain a good road network in the city.
- To attain an increasing road serviceability, we have to construct new roads conceding with increasing number of population of the city but now, it seems constant throughout years as we observed above in the result, it grows from 0.0009 to 0.0013 from1999 up to 2005 E. C.
- The road network connectivity of the city is with a range of 1.25 up to 1.96 beta index where the mean BI is 1.76 which is short by 0.74 from the perfect grid network of 2.5 BI. In this regard, the concerned body has to work on the connectivity of the nodes in roads.
- Constructing new roads only will not improve road network when we evaluate using road safety evaluation tool so there must be a work harder on engineering solutions on road designs and construction to improve road network performance..
- The increase in the construction of new road only will not assure the safety of users rather the number and complexity of accidents increase which also has effect on road network performance as we see the percentage of accidents occurred in the road with good asphalt condition which is equal to around 96.3%. This shows that connecting the city with new asphalt roads may not reduce the performance of the road when we evaluate according to safety.

- Population, number of cars, total length of roads, area and safety have direct and indirect relation among themselves related to road network.
- When the current road network of the City is compared with other countries and standards it is generally less than the optimum value, so more effort is required to improve the road network of the city.

6.2. Recommendations

Based on the outcomes of this research, the following are recommended

- The master road network has to be modified frequently because the population, the way of living and socio economic activity of the city is changing dynamically.
- AACRA must always evaluate the performance of the road network to take timely corrective measures regarding the road network.
- The total length of paved and good condition roads in the city must be increase to attain a optimum road network
- The concerned government offices for transport infrastructure have to work together using monolithic data which helps to improve the road network.
- Transport and infrastructure related offices especially AACRA has to work on performance evaluation
- Researches on performance evaluation must be conducted by the concerned governmental offices since it is useful for efficient budget allocation and efficient resource management.

Limitations of the research

The following factors restrict the extent to which findings in this research may not be conclusive enough in choosing the best option for road network improvements.

- One of the limitations of this work was that economic, social, environmental indicators were not considered as data required for such comprehensive analysis are huge and not possible to obtain considering the time and resources available to do this research. The idea is that an approach had to be developed which utilized data already available and hence easy to collect, and develop it into a framework.

- This study also excluded other network improvements for the city including but not limited to public transport, rail improvements and sea transportation. The focus was only on road transportation and its impacts on traffic re-distribution and also accessibility as a result of improvements. Information on such network improvements by the modes not considered can be made available by AACRA and Transport Office for a holistic analysis of accessibility and traffic mitigation measures.

Limitations encountered in this research can be interesting areas to overcome and to consider for future work.

Future research direction

Findings from this research work can be used as a stepping stone to analyze other network based indicators that were not explored in this research work. The problem of congestion is a growing concern in most cities and government efforts to improve network performance by additional connections to ease congestion will always be with us. Provided in the paragraphs below are some directions for future research work. This can enhance the understanding of network based indicators in these kinds of decision problems. More so, the limitations outlined in this research are all potential areas to consider in subsequent work to improve on the concept.

In further research it would be interesting to consider exploring inter-relationships that might exist between performance evaluation indicators, volume-to-capacity (v/c) ratio and system wide travel time at various levels of aggregation. For example it was realized that with the addition of a new connection over one route, the accessibility measure (sum and mean of global and local integration) increased, volume-to-capacity ratio decreased as well as system wide travel time reduced. Although indicator values for each option gave similar results, this can be explored further to find correlations.

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