# Analysing Public Transport Performance Using Efficiency Measures and Spatial Analysis; the case of Addis Ababa, Ethiopia

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**March, 2007**

# Analysing Public Transport Performance Using Efficiency Measures and Spatial Analysis: The case of Addis Ababa, Ethiopia

By

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Thesis Report submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Urban Planning and Land Administration

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**ENSCHEDE, THE NETHERLANDS**

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# Abstract

Public transport is one of the social facilities which are provided with the aim of improving social welfare. However providing equitable and efficient public transport for the ever increasing demand with the limited resource available is a challenge in the developing world. Thus the need to evaluate current public transport efficiency to identify opportunities and deficiencies as the cost of maintaining, expanding and extending public transport service is very high and mostly unaffordable for developing countries. Efficiency measures compare realized and optimal levels of outputs and inputs. In public transport, efficiency measures can be used to monitor resource and service distributions, identify deficiencies and opportunities.

This research investigates Anbessa city bus transport service efficiency and bus route network deficiencies, aiming for equitable bus service to all groups of society in Addis Ababa, the capital city of Ethiopia. In Addis Ababa city bus service is run by a sole company called 'Anbessa'. Addis Ababa is a home city for more than 3.5million inhabitants.

The research uses GIS techniques and Statistical analysis to evaluate the cross-sectional efficiency of the system and 'radar-visualization' techniques to identify the overall efficiency. It has identified that the current efficiency of Anbessa organization is poor. There are service deficiencies in some place though the system is over-stretched for the current fiscal and financial capacity at the cost of quality. Moreover, the bus route network has deficiencies that make equal spatial accessibility of the service difficult. The research has also identified areas with inadequate level of service due to missing links, based on deterrence of the existing route. It therefore has recommended upgrading routes, encouraging private participation, increasing frequency of service and bus priority measures in order to improve the system for the benefit of the society.

*(Key words: Public Transport, efficiency, deficiency, spatial analysis)*

# Acknowledgements

I would like to express my sincere appreciation to my supervisors Ir. M.J.G. Brussel and Dr. Ir. M.H.P. Zuidgeest for their unlimited and continuous support, critical comments and guidance from the inception to the success of the research. I am very much grateful for their encouragement, advice and friendship during my study and hardships.

I also would like to thank the program director Drs. E.J.M. Emile Dopheide for all his help during my study and hardships. I am also grateful for Ing. F.H.M. Frans van den Bosch for all his technical help, friendship and idea shearing. I thank very much all the staff members of UPLA who have contributed in one way or another to the success of my study and the research in particular.

I would also like to thank all UPLA 2005 group for their friendships, advice, help and encouragement. Without their friendship, I would have been lost in desert in day light. At this end, I would like to thank Denis Tugume and Emmanuel Midheme in Particular.

I am also very much grateful to Fikirte Arega (ERA) for helping me during my field work. Besides, I would like to thank Ato Fikreyehoannes(ACRA), Ato Tadesse Tafese(AATA general manager),Fikirya Sabit(Service design and control department head, Anbessa), Ato Melaku Kassaye(Service design and control expert, Anbessa),Ato Shewarega(public relations ,Anbessa), Tsion (municipality), and Eyob(AAU MSc Student) for their kind help and reception during my field work. I am very much grateful to all Anbessa Staffs who have contributed and helped me during the field work.

Bedilu Abayneh,Yeshitlaw Bayou,Getachew Genete, Sintayehu Fiseha, Manahilot, Komminist sisay , Birhanu Mulu, Getachew Abebe and Migbar Assefa thank you very much for staying in touch, encouragement and help during my study, field work and hardship.

Of course, all my academic success counts back on the help, support and encouragement that I got from my family. They have always trusted on me and stood by my side when I needed them. So I would like to dedicate this work to my mother Elfinesh Ahmed in particular. I am very much grateful to my sisters and brothers; Almaz, Hirut, Fitsum, Meron, Bethelhem, Tsegaab, Petros, Asfaw and my grand mother Aselefech.

Last but not least, I would like to thank my beloved Freweini Gebru for loving, encouraging and sharing all the difficulties with me. This work is also dedicated to her with lots lots… of love.

# Table of contents

# List of figures

# List of tables

# 1. Introduction

## 1.1. General Introduction

The spatial structure of cities, in developing countries particularly, is highly variegated. In some areas services and facilities are adequately provided while there are inadequate or no services provided in others. Similarly, there is variation in socio-economic characteristics of the dwellers from place to place. Moreover, the urban vulnerable groups are located mostly either at the city centre, economic heart, or at the fringes, where no one else wants to live. Theses variations ooze the challenge of getting equal and efficient urban services for the disadvantaged and vulnerable groups. As a consequence the quality of life in most developing countries is poor. Pred (1977) in (Pacione 1989) notes that quality of life is closely related to people accessibility to alternative employment, educational and medical facilities, essential public services, and nature or extensive recreational open space.

The essence of urban planning is to provide adequate and equitable services to all groups. One of the important urban services is transport services. It has influence and impact on regional patterns of development, economic viability, environmental impacts, and on maintaining socially acceptable levels of quality of life (Murray et al. 1998). Hanson (1995) states, transport is an absolutely necessary means to an end and allow people to carry out the diverse range of activities that make up daily life. It is a means to access business activities, education, employment and recreational opportunities (Murray et al. 1998). It contributes to pro-poor policy by providing access to opportunities, and enhancements to security (through reduced isolation), as well as providing job opportunities in the sector (World Bank 2002). There are many reasons why people take trips in urban areas, but trips to work (40±50 per cent of urban trips in developing countries) and school (20±35 per cent) are major components of travel (Mohan 1994) in (Ingram 1998).In general, transportation systems form the basis by which economic development can occur and the means by which society interact (Murray et al. 1998).

The urban transport sector, however, has many problems in most developing countries. Inadequate and poor quality infrastructures, mismatch between demand and supply, and increased rate of accidents are some of the problems. These problems are triggered by interrelated trends such as urban population growth and (rapid, unplanned, and uncoordinated) growth of cities (TranSafety 1998). Transport planners must consider influences of these trends and trip purpose, temporal and spatial distributions of trips, modal splits of travel, and costs on mobility which fits into a more general interpretation of sustainability that includes social, economic and environmental factors(Murray et al. 1998).

The inherent characteristics of developing countries like high population density, low income, spatially separated land uses and lack of resources force these countries to depend on public transport/transit systems, which can transport large numbers of people at low cost. Generally in less developed countries, more than three-quarters of peak travel public transport are required for work trips (Ingram 1998). As cities expand to the size where walking alone can not satisfy the travel demand of the population, transit system becomes major mode of transportation. The study of (De Jong et al. 2002) in Dar Es Salaam shows for longer distance clinics, patients increasingly use public transport over walking. Public transport in most developing countries is run under subsidies and low revenue. However as (Murray et al. 1998) observes, transport planning has to ensure that certain modes of public transport are available for use.

White (2002) defines 'public transport' as all modes available to the public irrespective of ownership. The importance of public transport services in a successful transport system is widely recognized (Nash 1982; May and Roberts, 1995) cited by (Murray et al. 1998).It provides mobility for those who can not drive their own car, helps in creating and maintaining liveable communities, relieves highway congestion, and assures long term sustainability in terms of resource consumption and the environment (David et al. ) cited by(Paul 2001). It can also provide a very efficient means of moving large numbers of people with considerable flexibility, in order to meet demand throughout the city (Armstrong-Wright et al. 1987). However, existing public transport capacities (in developing countries) do not satisfy the demand. The quality of travel on public transport is poor, roads are badly maintained and managed; cost of travel is high for the poor to make regular use of public transport (Armstrong-Wright et al. 1987). Thus, transport planners should provide a framework within which the poor and the less poor use the public transport with more confidence and comfort (World Bank 2002b).

The dominant mode of public transport in developing countries in road based transport is the 'conventional' bus. It has wider social and environmental benefits. It is the only one affordable to the urban poor (Armstrong-Wright et al. 1987). It is the most flexible as it satisfies high short distance mobility demands. It needs less investment on infrastructure. It is feasible economically to all groups and environment friendly system. Vikash (2003) reckons how people can trade off between owning a vehicle and good quality public transport as: "Most people in a city are better off if they access vehicles rather than own them."

However, in line with the general discussion above, the demand of this service (particularly during peak hours) is beyond its capacity and the quality of service is poor. Moreover, the general prevailing traffic congestion and inadequate street networks constrain the level of service. To illustrate how severe the problem of traffic congestions is in some cities Vikash (2003) reckons that: "… the traffic speed in most urban areas has been dramatically similar to what existed at the times when horse and carriage was the fastest means of travel (Vikash 2003)". Armstrong-Wright et al.(1987) describe the poor performances of existing bus service in many developing countries by saying "…[public bus service] in many places fall short of demand; systems are frequently severely overstretched, uncomfortable, and unreliable(Armstrong-Wright et al. 1987).". Only 52.25% of the total population gets suitable service in South East Queensland's, despite the policy goal for public transport in the region of at least 90% total population coverage within 400 meters of a bus stop(Murray et al. 1998). In Dar Es Salaam 94% of the roof area are within a walking distance of 1km (Girmay 1998).

Public bus transport service in most developing countries is provided by the government. In most cases it is subsidized and the return is very low. This inhibits investment and expansion, resulting in reduced standards and systems fall short of demand (Armstrong-Wright et al. 1987). However, it should be encouraged and improved to spread its wider social and environmental benefits. There are numerous details to be sorted out in providing or overseeing this form of public assistance such as the best placement of stops and routes, the frequency of operation, and the connectivity of the transport network for regional service delivery (Murray et al. 1998). The suggested improvements to achieve the policy goals in the South East Queensland's region are: first adjust the notion of service coverage to reflect the spatial, socioeconomic and demographic characteristics of potential patronage rather than attempting to set public transport goals for the entire region assess cost of recovery and give priority to the most disadvantaged ones. Second strengthen and extend the coverage of the transport system. This includes addition of separate bus lanes, providing new public transport corridor, improving the efficiency of transport stops and travel routes in terms of redundancy and suitability (Murray et al. 1998). These solutions focus on improving ease of access and efficiency to overcome resistance to travel by public transport and ensure the system will get people from where they are to where they need to go in a reasonable amount of time (Murray 2001).

Gauging or measuring the effectiveness of public transportation performance is critical in assessing policy goals as well as planning for future improvements (Murray et al. 1998). Access and accessibility can be used to measure its performance. Murray (2001) reckons; "access provision and system efficiency are both important elements of public transport service". Access is opportunity to use system based on proximity and cost while accessibility is suitability of system to use. Access and accessibility of public transport improves accessibility of other basic services which have larger influence area due to limited finance and some other reasons. With the help of geographic information systems (GIS) better understanding on access and accessibility can be achieved however "caution should be used when employing GIS technology." (Albert et al. 1995) cited by (Perry et al. 2000).

## 1.2. Justifications And Research Problem

This study is carried out for Addis Ababa city, which is the capital city of Ethiopia, with population over 3.5million. It is situated on mountainous landscape at an altitude of about 2500meters above mean sea level and extends over 540km$^2$. As a metropolitan city, it has been divided into 10 sub-metropolitan divisions of average capacity 400000 inhabitants. The sub metropolitans are further subdivided into 10 lower administrative blocks called "kebele" for better administrative management. 'Students' and service are the main occupations. The people of Addis Ababa are poor. According to the UN-Habitat report over 90% of the population live in slum areas.

The vision of transport plan in Addis Ababa is 'affordable transport, enhanced access and mobility'. Pubic transport in Addis Ababa consists of conventional bus services provided by the publicly owned Anbessa city bus enterprise, mini buses operated by the private sector, conventional taxis, and buses exclusively for employees of large organizations (World Bank 2002). Anbessa city bus, formerly under the central government but now under city municipality, charges a range of flat fare depending on distance and it is subsidized by the government. The minimum cost is 0.25cents per trip (the current currency exchange rate is 1 Euro for 11.15 Ethiopian birr, Jan/30/ 2007) compared to minibuses and taxis this is only one-third. According to the scoping study carried out by World Bank (2002) , it provides services affordable to the poor. In contrary, students and the poor can not afford this cost on regular basis as I have observed during my field work.

According to the scoping study by World Bank (2002), Anbessa city bus enterprise gives service only to 27% of the public transport users, which might have risen to 30-35% currently, while more than one-third of the total population is pedestrian. The remaining 30% of the population use taxi provided by private sectors. This is not because the society can afford the other means or prefer to walk, but the level of service of the bus is very poor. Uncontrolled and rapid horizontal expansion, increasing population and poor road infrastructure of the city (narrow road, limited network extent, no pedestrian facility and lack of adequate traffic signs, etc.) dictate the level of service.

When we consider proximity of the service; in some areas people walk long distance to reach the service and have to disembark far from their destination. In newly developing parts of the city, western part of the city where there is affordable real state housing development, and other areas due to limited network extent the service is not available. Suitability of the system to provide low cost service (accessible to all groups) is constrained by many factors. There is no separate bus lane in the city, so it has to compete for space with other traffic in the busy and narrow road network. The distance between stops is longer which makes the travel time large and the system less flexible. It takes longer time in loading and unloading commuters at stops. Due to congested traffic on one hand and poor performance of the operators on the other hand the headway is long hence people wait longer at the stops.

The city is densely populated and the population is young. Moreover, the main occupations,' students' and service, in the city increase the demand during peak hours. At this time of the day, the buses are over crowded and operate without closing their doors, which exposes the people to accident, suffocations, pick pocketing and air borne diseases. The system is not suitable for the weak in particular and the public in general and needs proper extending and expanding to the disadvantaged areas.

### Specific Research Problem

Due to the limited extent of Anbessa, insufficiency of public bus route network and deficiency of Anbessa service people spend more time and money on travel. Therefore, network and service deficiencies under current physical, financial and institutional constraints have to be investigated to improve the service to comply with the transport vision of the city 'affordable transport, enhanced access and mobility'.

## 1.3. Research Objective And Questions

### 1.3.1. Main Objective

The main objective is to investigate Anbessa city bus transport service efficiency and bus route network deficiencies which prevent equal spatial accessibility of the bus service to all groups of society and make recommendations on possible improvements on the network and operations.

### 1.3.2. Sub Objectives

1. To define parameters of an efficient public bus transport system
2. To assess the level of service of the exiting public bus service and to analyze the coverage of the current bus service in space and time

3. to identify the bus route network deficiencies
4. to suggest improvements to the bus service

### 1.3.3. Research Questions

1. to define parameters of an efficient public bus transport system
    - What parameters can be used in measuring efficiency of public transport system?
    - Which parameters are used by Anbessa city bus?
    - How can these parameters be combined to measure overall efficiency?
    - How does the Addis Ababa transport policy address these parameters?

2. To assess the level of service of the existing public bus transport system and analyze the current coverage of public transport service in space and time.
    - How is Anbessa performing under the current situation?
    - How is the service spatially distributed?
    - Is it equally accessible by all economic groups?
    - What are the spatial variability and problems of the service?
    - Are there capacity constraints?

3. to identify the deficient network elements
    - Which areas are missing network links?
    - Can we identify major public transport corridors?
    - Can we identify existing road elements which can be used for bus route?

4. to suggest improvement to the bus service
    - How much capacity is needed to satisfy the demand?
    - What policy options can improve the quality of service in terms of capacity, bus stops, bus lanes and transfer points?

## 1.4. Conceptual framework

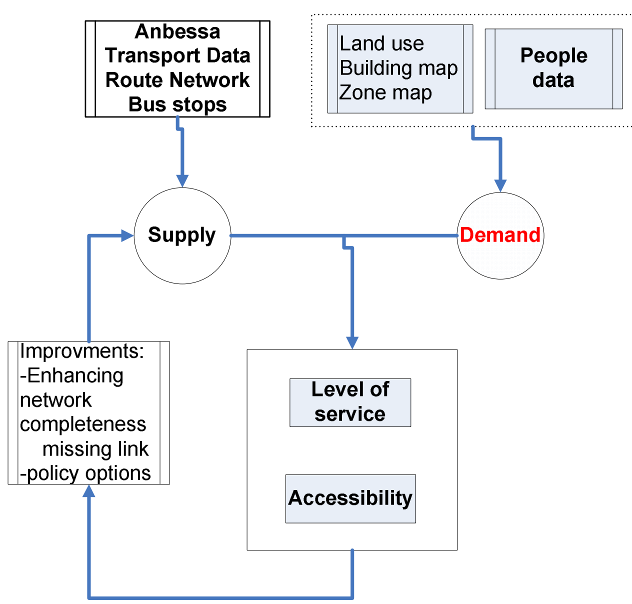



**Figure 1-1 Conceptual Framework**

## 1.5. Research Design

The figure below shows the procedures followed in carrying out the research. The research problem was identified through literature review and investigation of the real world problem. To solve the problem, appropriate research objectives and questions were defined. Next, key concepts were conceptualized and operationalized based on literature survey. Then, the necessary data were collected during the field work and prepared to make suitable for the analysis. Finally, analyses at different levels were carried out. Existing Situation analysis was done to evaluate the performance of the existing system which led to modelling of the public transport system to identify deficient network elements. Based on analysis result conclusions and recommendation for future were drawn.

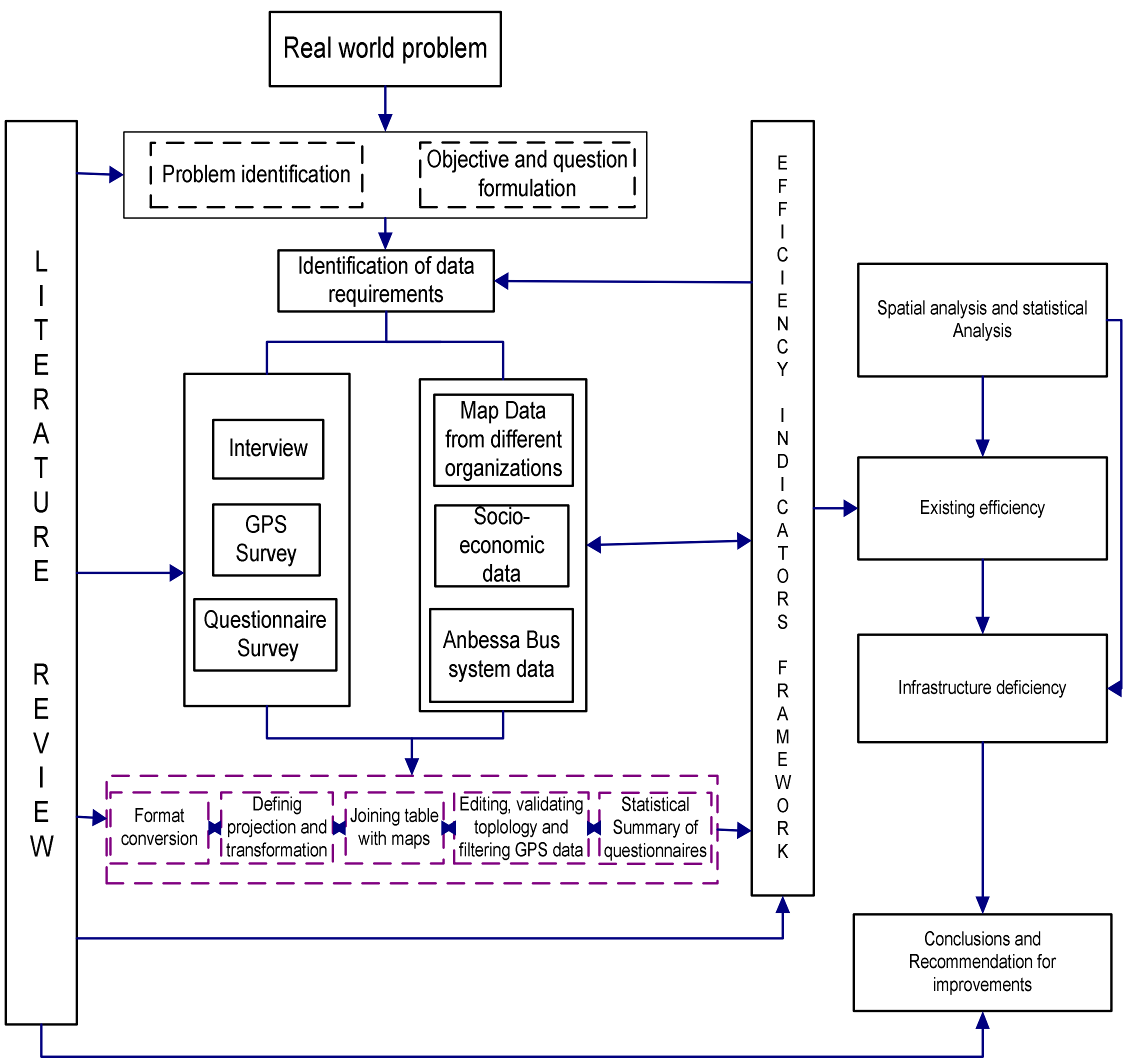



**Figure 1-2 Research Design**

The table below shows the research matrix, which shows the data required, methodology and source of the data for each specific research objective.

**Table 1-1 Research Matrix**

| No. | Specific research objectives | methodology | Data required | Data sources |
|---|---|---|---|---|
| 1. | To define parameters of an efficient public bus transport system | Literature review<br>policy document review<br>interview | Policy documents and literatures | Internet, Secondary source, primary source and policy documents |
| 2. | to assess the level of service of the existing public bus transport system | -GIS analysis<br>-Secondary and primary data statistical analysis | Road network<br>Routes<br>Bus stops<br>Zone map<br>Land use<br>-Field data on travel characteristics<br>-socio-economic data | -secondary source<br>-primary sources |
| 3. | To identify deficient network elements | -transport modelling<br>-GIS analysis | -In put data for gravity model based on UTS 2004/05<br>-maps mentioned above<br>-Socio-economic characteristics | -secondary sources |
| 4. | To suggest improvements | -literature review | -results from previous analysis and literature | |

## 1.6. Limitations of the research

The main limitations of this research are that it assumes Anbessa as the only public transport system; and analyses and recommends based on this assumption. It does not consider the competition, contribution and effect of the service provided by taxi or private sector. Data available were either aggregated at zone or sub-city level, which calls for a simplified assumption of homogeneous behaviour either at zone level or sub-city level. The data collection has also encountered problems. It was very difficult to receive proper signal for the GPS's due to the over-crowded bus load and fogy weather condition. Moreover due to lack of awareness by the local people about the instrument it was considered as a threat and was questioned many times, which of course consumed the working times.

## 1.7. Beneficiaries

Different organizations can benefit directly or indirectly from the results of this research. To mention some;

- Anbessa organization can develop better awareness about the spatial distribution, strength and weakness of their service. Besides they can get ideas on how and where to improve the service.
- AATA will have the awareness about Anbessa service in particular and can identify where feeder services are required to alleviate the problems of spatial equity

- City municipality, as the owners of the Anbessa organization, they will get insight into the operational characteristics of the service.
- AACRA can have an opportunity to investigate the possibility of providing separate bus lanes
- It gives an opportunity for further research by individuals and organizations.

### 1.8. Thesis Structure

Chapter-1 briefly presents the background for the research, identifies the research problem, defines the research objectives and questions and shows the general overview how the research aims to achieve the objective.
Chapter-2 Defines efficiency, and identifies and defines the parameters used for measuring the efficiency of public transport based on literature survey.
Chapter-3 gives general description of the study area based on topography, demography, socio-economic characteristics and land use.
Chapter-4 presents the material and methodology used. It out lines and discusses the methodology used from pre-field work stage to post-field work stage and shows the overall data analysis procedure followed.
Chapter-5 Describes the current situation of Anbessa bus service through cross sectional analysis of the data collected for the parameters defined mainly using statistical summaries and simple GIS techniques and summarizes the overall performance qualitatively evaluating the cross-sectional analysis results.
Chapter-6 identifies missing links based on methodological insight from method called 'cycle through' using Flowmap and ARC GIS as platforms for analysis and gives discussion of the results.
Chapter-7 presents conclusion based on the analysis results and recommends possible improvements.

# 2. Defining Indicators of Public Transport Efficiency

## 2.1. Introduction

Transport is the back bone of urban life. It is one of the factors which determines the form and socio-economic development of a city. Mobility and accessibility provided by the transport system have been playing a major role in shaping countries, influencing the location of social and economic activity, the form and size of cities, and the style and pace of life by facilitating trade, permitting access to people and resources, and enabling greater economies of scale, worldwide and throughout history (Zuidgeest 2005).

However, urban transportation systems are wilting under the pressure of ever growing demands on an inadequate street network (Santhakumar et al. 2003)**.** Increased urbanization and population growth, urban expansion, dispersal of amenity and activity have increased the demand for and dependence on motorized transportation. Consequently, urban transportation problems like congestion, accidents, environmental degradation and urban sprawl have increased. Sustainable transport development plans are thus replacing the routine approach of building more roads to alleviate congestion with an integrated transport system (Davison et al. 2006) which is affordable, space- and resource-efficient, and minimizes environmental impacts and transport nuisances. As a consequence, encouraging and improving public transport system in developing and the developed world has got wider attention and has become a central issue in transport planning.

Public transport is a collection of modes of transport which are available to the public irrespective of ownership(White 2002). It includes road-based modes like conventional buses, Para-transit vehicles, human and animal powered vehicles, cycles and walking; rail-based models like heavy rail system, light rail transit, street tramway; and rapid transit systems (Iles 2005). Among these modes, the conventional bus is the most common public transport mode in developing countries mainly due to its low running and initial cost, route flexibility and permeability into town and city centres (Davison et al. 2006). As the research studies the bus transport system of Addis Ababa the focus is on conventional bus transport system.

Some people believe public transport is the ‘panacea’ for some of urban transport problems (Black 1995). And its importance has been widely acknowledged. It helps to overcome some of the social and environmental impacts of transport system which includes mobility problem for the disadvantaged groups (e.g. poor, handicapped and elderly), congestion, accident, environmental impact, land consumption, urban sprawl and energy consumptions. It also provides mobility for those who cannot drive their own cars; helps in creating and maintaining liveable communities; relieves highway congestion; assures long-term sustainability in terms of resource consumption and the environment (David et al, )cited by (Paul 2001).

Although the primary objectives may be different, there is an increasing demand to improve the performance of public transport both in developing and developed countries to make transport systems sustainable. In the developed world, the primary objective of improving the performance of this system is to shift modal share away from private car to reduce the negative side effects of transportation on quality of life as proposed by actors such as European Commission (Geerlings et al. 2006) . In the UK for example, encouraging modal transfer from the car to another more sustainable form of transport is a key aim of the Ten Year Plan for Transport (DTLR 2002a,b) cited by (Davison et al.  2006).

In the developing countries however, the primary importance of public transport is to move large numbers of people with considerable flexibility in order to meet mobility demand, particularly access for employment throughout the city (Armstrong-Wright et al.1987)). However, existing public transport capacities in developing countries do not satisfy the demand for a number of reasons: the quality of travel on public transport is poor; roads are badly maintained and managed; and costs of travel are high for the poor to make regular use of the public transport system (Armstrong-Wright et al. 1987).

Driver's bad treatment, long and undisciplined queues at bus stops, badly maintained and unreliable old vehicles and crowdedness are common problems in developing countries which frustrate the customers. Besides, public transport services have deteriorated despite the rapidly increasing demand due to rapid growth in population and urbanization; low standards of efficiency, reliability and safety; poor enforcement of regulations; and shortage of money (Iles 2005). In most cases, there is hardly any improvement on this system. Vasconcellos (2001)reckons the conflict between demand and public transport problems in developing countries as: "Public transport in developing countries is at the center of a conflict between its nature as a matter of vital importance for many people, and the difficulties inherent in an often poor economic environment(Vasconcellos 2001)."

Governments in developing countries subsidize the service to reach the demand. 'Anbessa' city bus of Addis Ababa and Kenya Bus Service (KBS) are typical examples (The World Bank 2002 ). However, the cost of maintaining, expanding and extending service is very high and mostly unaffordable by local government. Thus, the existing system has to be utilized effectively and efficiently (The World Bank 2002b). The minimum required for the success as observed by Murray (2001) are, a more effective price structure, enhanced travel comfort, better suitability and convenience of service quality. from less capital intensive improvement alternatives like better management, bus priority, separate lanes and better scheduling of the service to more capital intensive alternatives like constructing and buying new infrastructures and vehicles can be adopted to achieve this. However, it needs proper evaluation of performance and systematic approach to improve the service. Thus efficiency measures, which compare realized and optimal levels of outputs and inputs, have to be carried out to evaluate and compare the success, to identify problems and to come up with alternatives (Costa et al. 1997).

The objective of this research is to identify network and service deficiency of 'Anbessa' bus transport system in Addis. The literature review is organized in such a way that; it first gives a brief overview of efficiency categories and their hierarchy and interrelation ship; then it identifies and discusses the indicators which show system and network efficiency with respect to urban poor mainly from spatial equity point of view.

## 2.2. Public Transport Efficiency Indicators

Similar to any social service, efficiency and performance measures in public transport are necessary to monitor progress toward a result or goal. Efficiency measures compare realized and optimal levels of outputs and inputs. It is also important in terms of identifying and measuring sources of successful performance and therefore can be used in policy planning and allocation of resource. Efficiency measures can be used as means of evaluating recently realized or proposed extensive changes towards increased deregulation, reorganization and privatization of public transport (Costa et al. 1997).

The performance measure criteria's should thus be tools to evaluate system condition, level of service, and safety provided to customers based on economic, environmental and community policy goals. They should also evaluate the day-to-day performances for strategic management, analysis of options and trade-offs. Performance measures also provide information for decision on how to allocate resources and help to prioritize improvements to the neediest areas. In general performance measure indicators should be policy driven, which can be used in analysis of options and trade-offs, decision making on resource allocation, and monitoring to provide clear accountability and feedback (NCHRP 2005). Furthermore, they can show trends, or warn problems, and will influence immediate action or long term plans. In general, performance indicators of sustainable transport system will address the following questions;

*Is the performance of the transport sector improving in respect of its adverse impacts on environment and health?*

*Is transport activity changing in directions consistent with positive answers to the other questions?*

*Are land use, urban form, and transportation systems changing so as to reduce transportation effort?*

*Are we increasing the efficiency of use of current infrastructure and changing the infrastructure supply in sustainable ways?*

*Are the patterns of expenditure by governments, businesses, and households, and the associated pricing systems, consistent with moving towards sustainability?*

*Is technology being used more in ways that make vehicle transport systems and their utilization more sustainable?*

*How effectively are environmental management and monitoring tools being used to support policy- and decision-making towards sustainability?*(The Centre for Sustainable Transportation 2002)

The efficiency of public transport system has been reported in terms of operational indicators, engineering indicators, labor indicators, social indicators, resource indicators and financial indicators on literatures as shown below. The NCHRP (2005) report categorizes performance measures for general transport assets under Preservation of assets, Mobility and accessibility, Operations and maintenance, and Safety. Public Transport Authority of Western Australia (2004) in their annual report used five categories of performance measure with indicators. This includes; Use of public transport measured by passenger per service km and Total passenger place kilometres, Service reliability, Level of overall customer satisfaction, Customer perception of safety and Level of notifiable safety incidents. In the context of developing countries Armstrong-Wright et al. (1987) listed passenger volume, fleet utilization, vehicle-km, break-down in service, fuel consumption, staff ratio, accidents and cost of bus services as operation performance indicators in addition to quality indicators. Iles (2005) grouped efficiency indicators under labor, operational, engineering, personnel and financial indicators. The relevance and appropriateness of each measure depends on the context of analysis. Thus as Iles (2005) reckons indicators have to be clearly and unambiguously defined. In this research the different efficiency measures from literatures are grouped into five main categories based on the main operational components of public transport (i.e. network, vehicle, labor, finance and operational/system). These are; service efficiency, network operating efficiency, utilization efficiency, labor efficiency and finance efficiency as shown in the table below.

| **Efficiency category** | **Description** | **Indicators** | |
|---|---|---|---|
| System efficiency | System efficiency is the ratio of output to the input consumed in the transportation process. It depends on labor, financial, network and utilization efficiency. | accessibility | |
| | | mobility | |
| | | equity | |
| | | productivity | Passenger volume |
| | | | Vehicle-km |
| | | Infrastructure availability | |
| | | safety | |
| | | Quality, comfort, conveniences | |
| Network operating efficiency | Network efficiency measures the ability of the network to support direct services between areas, short distance flexibility and coverage. | Continuity and balancing of lines | |
| | | Operating flexibility | |
| | | Integration with other modes | |
| | | Cost of the system | |
| Labor efficiency | Labor efficiency refers to the amount of labor required to produce unit system out put. | Operating employee per vehicle-km | |
| | | Passenger carried per day per total number of employee | |
| | | Number of workers employed in maintenance shop per vehicle serviced in it | |
| | | Administrative staff employed per operating bus | |
| Utilization efficiency | This compares the rate of resource (vehicle, labor, line) utilization to the available capacity. | Vehicle utilization | |
| | | Vehicle break down in service | |
| | | Fuel consumption per km | |
| | | Vehicle capacity utilization | |
| | | Line capacity utilization | |
| | | Labor utilization | |
| Finance efficiency | Finance efficiency refers to the amount of investment required and/or gained to/from produce unit system out put. | Operating cost per vehicle-km<br>Operating cost per passenger trip<br>Revenue per vehicle-km<br>Revenue per vehicle-hr<br>Total revenue per total operating cost | |

**Table 2-1 Summary of Efficiency Indicators**

Anbessa organization performs monthly efficiency study. The organization conducts route and service efficiency studies. Since the company is subsidized by the municipality, and have very limited resource, gets vehicles on loan and gets vehicles from donors the concern and the need for proper assessments of efficiency is an arguable. As described from the interview, the vision of providing modern and fast service to satisfy the need of customers can not be achieved without efficient performance. The company measures and evaluates service efficiency and route performance based on vehicle-km, passenger volume and revenue. The next section describes some of the system efficiency indicators.

## 2.3. System Efficiency Indicators

### 2.3.1. Public Transport Infrastructure Availability

The first determining factor of quality and level of service is the availability of adequate infrastructure. Infrastructure refers to road and vehicle infrastructure. The road surface, total road area, road width and symbols have direct effect on the speed of the service, quality of ride, reliability and accident rate (Vasconcellos 2001). In most developing countries, bus road infrastructures are very limited in extent and width. The shortage of bus route supply is attributed to the general low supply of road infrastructure. The table below compares the road supply rate of the developed world with developing countries. Buses compete for space in congested traffic system. As a result the speed of service is very low and rate of accidents are high.

**Table 2-2 Road supply as percentage of urbanized area**

| city | Road space |
|---|---|
| Developing countries | |
| Kolkata(India) | 6.4 |
| Shanghai(China) | 7.4 |
| Bangkok(Thiland) | 11.4 |
| Seoul(South Korea) | 20.0 |
| Delhi(India) | 21 |
| Sao Paulo(Brazil) | 21 |
| Developed countries | |
| New york | 22 |
| London | 23 |
| Tokyo | 24 |
| Paris | 25 |

(Source; Vasconcellos, 2001)

Some of the statistical data which describe the bus route network are; number of lane, length of the route in km and network length in km. other features; influencing operating characteristics and service offered are the stop location and densities.

Average spacing between stops and routes

The average spacing between stops needs a trade-off between cost and journey time. Usually simple roadside stops incur very low cost for bus. The spacing for such case should emphasize on minimizing passenger journey time which includes; walking time, waiting time, boarding time, in vehicle time, alighting time and walking to destinations time. It should be noted that for very small spacing, total trip time would be high, since each passengers journey on the major mode would be interrupted by numerous intermediate stops. On the other hand, if the stops spacing are very wide, feeder trip times would lengthen, outweighing the benefits of a faster 'line-haul' section. In conditions of fairly uniform population density along the whole route, with some concentration around stops , the feeder trip length is equal to about one-quarter of the average spacing between stops(White 2002).

Area coverage

Area coverage which can be computed as the area within a certain distance, for e.g.400m, or five minute walk circles from bus stops. Network area coverage is the total area within these distances from stops, excluding overlapping areas. Percent of area covered is the area covered divided by the total bus service areas expressed as percent. Percent of population served is the population in the covered area as percent of the population in the bus service area.

Vehicle availability

The vehicle infrastructure determines the capacity and speed of the bus and operating and maintenance costs. Number of spaces/ vehicles offered on the line at a given time, such as peak-or off-peak hours, represents service offered at any one time, and it may be given for peak- and off-peak hours, or on different days. Vehicle availability, which shows the extent to which the vehicle fleet is available, indicates the effectiveness of maintenance. With effective preventive maintenance it should be possible to obtain average availability figures of 90% of fleet; 85% is reasonably good figure in most circumstances, although 75%is more typical in developing countries(Iles 2005).

### 2.3.2. Quality of Service

The quality of service refers to the level of comfort the service offer during travel/ ride. Some of the performance indicators are: Average network speed, waiting time, walking distance to bus stop, journey times and reliability.

a) **Average network speed** $\vec{v}_{av}$ (km/h) must be computed as a weighted average by the volume of service provided on different lines.

$$\vec{V}av = \frac{\sum_i Wi.Vi}{\sum_i Wi} \left|\frac{V}{km/h}\right| \left|\frac{w}{veh-km}\right| \quad \text{(Vuchic 2005)}$$

**b) Waiting time** is the time passengers have to wait at bus stops for busses. Longer waiting times indicate poor adequacy. In developing countries to achieve a reasonable level of service, the average waiting time should be in the range of 5 to 10min, with a maximum waiting time of 10 to 20min under the prevailing conditions(Armstrong-Wright et al.1987).

**c) Walking distance to bus stops** is the distance that passengers have to walk to and from bus stops. It is an indicator of the coverage. For well-served urban areas it should be in the range of 300 to 500m from home or work place. Distance in excess of 500m may be acceptable in low-density area but the maximum should not exceed 1000m(Armstrong-Wright et al.1987).

**d) Journey time**: is the total time spent to reach a destination from a given origin. It includes the walking time, waiting time, on vehicle time and walking to the destination. It should not be more than two to three hours per day. Excessive journey time reflects inadequate bus supply or poor scheduling or routing(Armstrong-Wright et al.1987).

**e) Headways** on lines represent another important element of service quality.

**f) The reliability** depends heavily on the actual conditions of buses while they are circulating. Indicators: average speed, volume-capacity ratio, number of signals per kilometre and number of bus stops per kilometre. Bus stop spacing needs trade off between travel time and walking distance. Too

closely spaced stops will increase the delay and thereby the total travel time. Widely spaced stops increase the walking distance and the inconvenience.
Schedule reliability can be computed as the percent of TU arrivals with 0-4 minute delays:

$$R = \frac{number\ of\ arrivals\ 0-4\min\ late}{total\ arrivals}$$ (Vuchic 2005)

The punctuality is affected by level of congestion. In a very congested city a greater variance from schedule may be tolerated than in a city where traffic congestion is not a problem. A reasonable target in most operation is for 90% of journey to operate on time, where this may be defined up to five minutes late for service with frequencies up to fifteen minute, up to ten minutes late for services with frequencies between fifteen minutes and two hours, up to thirty minutes late for services with frequencies of more than two hours (Iles 2005).

### 2.3.3. Productivity

The productivity of an economic unit is typically defined as the ratio of its output to its input and is a function of many factors such as technology, environment, efficiency, etc. The output of public transport is usually indicated as passenger-kilometres or daily passengers. Standard inputs used in analyzing public transit production function include number of workers and vehicles and network length. In economic terms the productivity is reflected as revenue earned under the given costs. As a public service, the efficiency is more related to the level of achieving the objectives, enhanced mobility and equity, than profit maximization. Some of the indicators of productivity are given below.

**a) Passengers carried Per Vehicle Per Day(PPVPD);** is computed as total number of passengers carried divided by total number of vehicles, and then divided by the number of days in the period (Iles, 2005). It is an indicator of the level of patronage of a bus service. It is influenced by vehicle capacity, length of operating day, length of route, average distance travelled per passenger, total demand and the extent to which the demand varies between peak and off-peak periods, and the kilometres operated per bus per day (Iles 2005). Assuming 85% of the fleet is operational, the normal range for a bus with a capacity of 80-100 passengers on city services is between 1000 and 2000PPVPD (Iles 2005). Addis Ababa, 2500 passenger per day, and Paris, 715 passengers per day, are the over and under utilized extremes (Armstrong-Wright et al.1987).
A reasonably well- managed bus company should produce results in the following range:

**Table 2-3 passengers Per Bus per Day**

| Type of bus | Crush capacity | Passengers per bus per day |
|---|---|---|
| Single-deck bus | 80 | 1000-1200 |
| Single-deck bus | 100 | 1200-1500 |
| Single- or double-deck bus | 120 | 1500-1800 |
| Articulated or double-deck bus | 160 | 2000-2400 |

(Source; Armstrong-Wright, 1987)

**b) Passenger-km**

Work performed or "production" of transit system is expressed by passenger-km transported. It is computed when the passenger volume is multiplied by average trip length. The passenger volume can either be taken from the maximum load section or average volume along the line.

The passengers travelling during a specified period of time, usually one hour, past a fixed point in one direction assuming boarding and alighting only at transit stops or stations can be computed as:

$$passenger\ volume = B - A = \sum_{i=1}^{k} b_i - \sum_{i=1}^{k} a_i$$ (Vuchic 2005)

Where; $a_i$ = alighting at any station i , i=1…k

$b_i$=boarding at any station i , i=1…k

$A_i$=cumulative alighting along a line

$B_i$= cumulative alighting along a line

**c) Vehicle productivity**-the work done by vehicles is given by vehicle-km. **Vehicle-kilometres** are the total distance travelled by buses in service. A vehicle should be used as intensively as possible, provided that sufficient traffic is available to cover the direct costs of operation. A high KPVPD figure indicates intensive use though it does not indicate the viability of the kilometres operated. Kilometres per vehicle are influenced by operating speeds, proportion of idle to operating time, hours of operation each day. Urban buses on all day service will normally operate between 150 and 300 kilometres per day (Iles 2005). For a reasonably run bus service the average should be in the range of 210 to 260 (Armstrong-Wright et al.1987).

### 2.3.4. Equity, Mobility and Accessibility

**a) Mobility**

Mobility is simply the ability to move, a function of physical and economic resources. This means, in a city with equal physical access to transport means, poor and elderly people with disabilities would be placed at the lower extreme of a mobility scale (Vasconcellos 2001). It is measured by the number of trips made per person per day. Mobility measures include the time and cost of making a trip and the relative ease or difficulty with which a trip is made, especially congestion and the trip measures related to congestion. Some of these are: volume capacity ratio, capacity related level of service, speed, travel time, delay, trip reliability and user cost (NCHRP 1997). Mobility measures indicate the quality of movement and the quantity being moved(Zuidgeest 2005).

Due to lack of adequate infrastructure and transport modes Zuidgeest (2005), mobility of people in the developing world is low. This is a direct consequence of the inherent transport and socio-economic problems like: poverty, traffic congestion and safety.

In 1992, about 40 to 50 percent of the population in SSA (Sub-Saharan Africa) were living below the poverty thresholds and the condition was the same even in 2002. However transport expenditures were increasing, for example the increase in Abidjan was about 20% in 1994. The increasing transport expenditures produced exacerbating phenomena such as: (a) an increasing number of trips made by walk, (b) fewer days on which people travel, and (c) a reduction in the average number of trips, especially in the larger cities (Africa Region and World Bank 2005).

Due to inadequate road capacities and increased street vendors in Africa traffic congestion and rate of accidents are very high. Traffic congestion is the main cause for impeding commerce, increasing noise and air pollution, and frustrates city travel. Moreover, accidents between vehicles and pedestrians are all too common and their frequency is growing rapidly. Between 1968 and 1998, road fatalities in Africa increased by 400 percent, pedestrians and public transport passengers making up the largest group of accident victims (Africa Region and World Bank 2005).

In addition to the aforementioned problems, partly due to the failure of the mass transit companies in the 1980s and their high fare levels, more than 50% of urban trips in developing counties are by walk. As a consequence the mobility rate of most Sub-Saharan African countries is less than 4trips per person per day (Africa Region and World Bank 2005). The table below shows mobility in different African countries and the share of public transport. In addition to the socio-economic reasons the low share of public transport is attributed to the urban morphology and structural organization; the more dispersed and less structured the development, the lower its level of efficiency and competitiveness and consequently its share of the mobility market (Camagni et al. 2002).

**Table 2-4 Mobility rate In African Countries**

| City | Country | Mobility (trips/person/day) | % of Total Trips Public Transport* |
|---|---|---|---|
| Morogoro | Tanzania | 1.7 | 12 |
| Dar es Salaam | Tanzania | 1.9 | 43 |
| Nairobi | Kenya | 2.2 | 42 |
| Eldoret | Kenya | 2.7 | 24 |
| Kinshasa | Congo | 2.2 | 20 |
| Addis Ababa | Ethiopia | 4.9 | 26 |
| Bamako | Mali | 3.1 | 17 |
| Ouagadougou | Burkina Faso | 3.8 | 3 |
| Harare | Zimbabwe | N/A | 16 |
| Niamey | Niger | N/A | 9 |
| Dakar | Senegal | 3.2 | 17 |

Mobility alone is just technical computation and very limited concept for transport policy analysis. Hence, it has to be combined with other concepts which show why and how mobility is exercised(Vasconcellos 2001).

b) Accessibility

Unlike private sector enterprises, which seek to maximize private benefits, social facilities are provided with the aim of improving social welfare. In measuring the performance, quality and level of service of urban services the concept of accessibility has been employed in different forms as an indicator of the guiding principles equity, efficiency Hodgart (1978) and effectiveness Sherif (2005). Planners and politicians make use of Accessibility indices to bolster their everyday propositions (Baradaran et al. 2001).

However there are no universally acknowledged definitions De Jong et al. (1996) of accessibility and various indicators have been used to quantify it. Baradaran et al.(2001) quotes "accessibility . . . is a slippery notion . . . one of those common terms which everyone uses until faced with the problem of defining and measuring it Gould (1969, 64)." to show the flexibility of the term.

Accessibility is 'mobility for opportunities'. Accessibility is a much broader concept than mobility and the only one capable of capturing the travel pattern in its entirety; hence, it is an important tool for analyzing transport and traffic policies. Being primarily a social measure, accessibility analysis considers social, economic and political difference (Vasconcellos 2001). He defines accessibility as the degree of ease with which people get to desired destinations. Geurs et al. (2001) define accessibility of transport system as the extent to which the system facilitates people's participation in activities, which is modelled as Figure **2-**1 below. Thus, its components are transport system, people (individuals), activities (land use and time). Mobility, proximity and connectivity have been incorporated in accessibility by arguing that it is a function of land use configuration(which gives the idea of proximity), transportation networks and services(issue of connectivity between activities) and system performance, or quality of movement( notion of mobility). Accessibility can be pictured as in fig2-1, which shows the interaction of people with land use along certain transport mode, for e.g. public transport at certain period of time for e.g. peak hour.

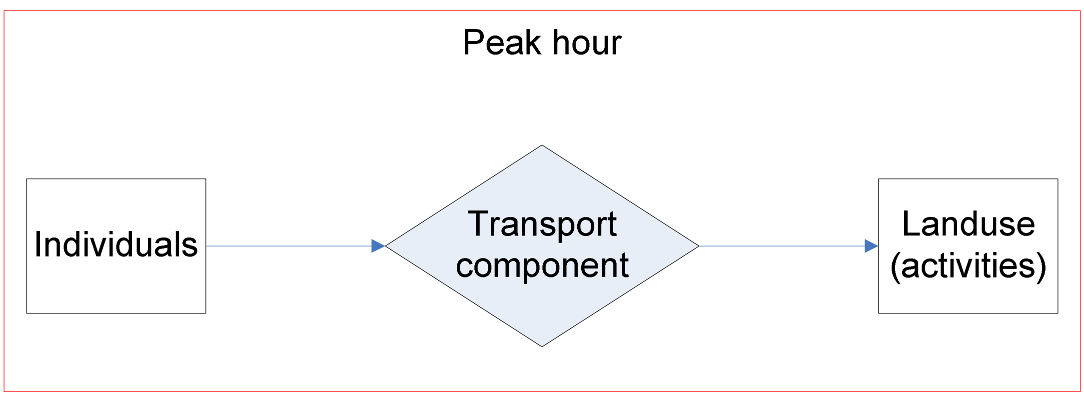



Figure **2-**1 Accessibility Model

Accessibility measures include a "density" of opportunities enabled by transportation services (e.g. number of households within a 30-minute derive of key regional centres or number of employment opportunities within a 10-minute walk of transit stops) or the ability of a facility to serve a particular user group (e.g. a particular segment of population or type of freight). Availability of modes and modal choice can also be treated as an accessibility measure (NCHRP 1997).

c) Equity

The term equity is used to refer the fairness in the distribution of goods and services among (group of individuals) and to the corresponding injustice caused by substantial uncompensated losses ( Lichfield et al., 1975, Friedman, 1984) cited by (Geurs et al. 2001). The two basic concepts of equity are:

I. Horizontal equity which has the notion 'every body gets what he or she pays for and they pay for what they get'. In this approach there is no special consideration for the weak, disadvantaged and poor group in particular. Simply it means if one can not afford to pay public transport fares then he can not get service. Its main focus is on fairness among competitive groups.

II. Vertical equity- opposed to the previous one, this approach focuses on allocation of cost and benefits between groups in society. It considers spatial equity (distribution of activities in space), social equity (considers age, sex, educational level, household structure, disability or handicap) and Economic equity (poor and non-poor).

The main objective of public transport is to facilitate participation of less mobile people (disadvantaged group) in economic activities and improve mobility of all groups. Although there are no recognized and acceptable methods for analyzing equity impacts of transport (Banister 1998) cited by (Geurs et al. 2001), social, spatial and economic aspects have to be considered in public transport service provision. Thus, public transport provision should stratify its customers into different group based on their socio-economic behaviour and adjust the service accordingly. i.e. for example special fare structure( subsidy) can be considered for students and the poor to avoid financial exclusion of this group, special service should be allocated to those areas where the private sector is not willing to give service due to market and infrastructure reasons to overcome spatial exclusion, during the peak hour they should arrange additional service to accommodate the needs of the labor group on time and overcome problems of temporal exclusion and also they should have appropriate facilities to help the weak, disabled and handicap group to overcome the problem of personal exclusion (Zuidgeest 2005).

## 2.4. Summary

This chapter has identified and discussed the parameters that should be considered in measuring the efficiency of public transport based on literature. The indicators which measure service efficiency are further detailed and discussed to meet the objective of measuring service efficiency of Anbessa. Formulas to quantify the sub-indicators under the main indicators infrastructure availability, proximity, quality, equity, productivity and customer satisfaction are also discussed. In the study area policy goal for public transport is not available, which makes difficult to measure performance of Anbessa. Thus, threshold values recommended for the indicators by Armstrong-Wright et al. (1987) for well-performing public bus service in developing countries are used as a reference in evaluating the performance of Anbessa service. The current performance and efficiency of Anbessa service will be evaluated based on the parameters identified in this section in chapter five. So first the socio-economic characteristics, topographic characteristics, road and organizational structure of Addis Ababa will be discussed in chapter three to show the working environment of Anbessa.

# 3. Study Area Description

## 3.1. Introduction

Addis Ababa is the capital city of Ethiopia. It is the diplomatic centre of Africa and the seat for many international organizations. Being the centre of the country it has a wider role in economic, social political and administrative perspectives. The topography of Addis Ababa is hilly to rolling with steep gradients and deep valleys. It is located at a height of 2000 to 2500m above mean sea level (MSL). Addis Ababa city Administration extends over 540 sq. km. For Administrative purpose it is divided into 10 sub-cities which are further subdivided into 99kebeles.

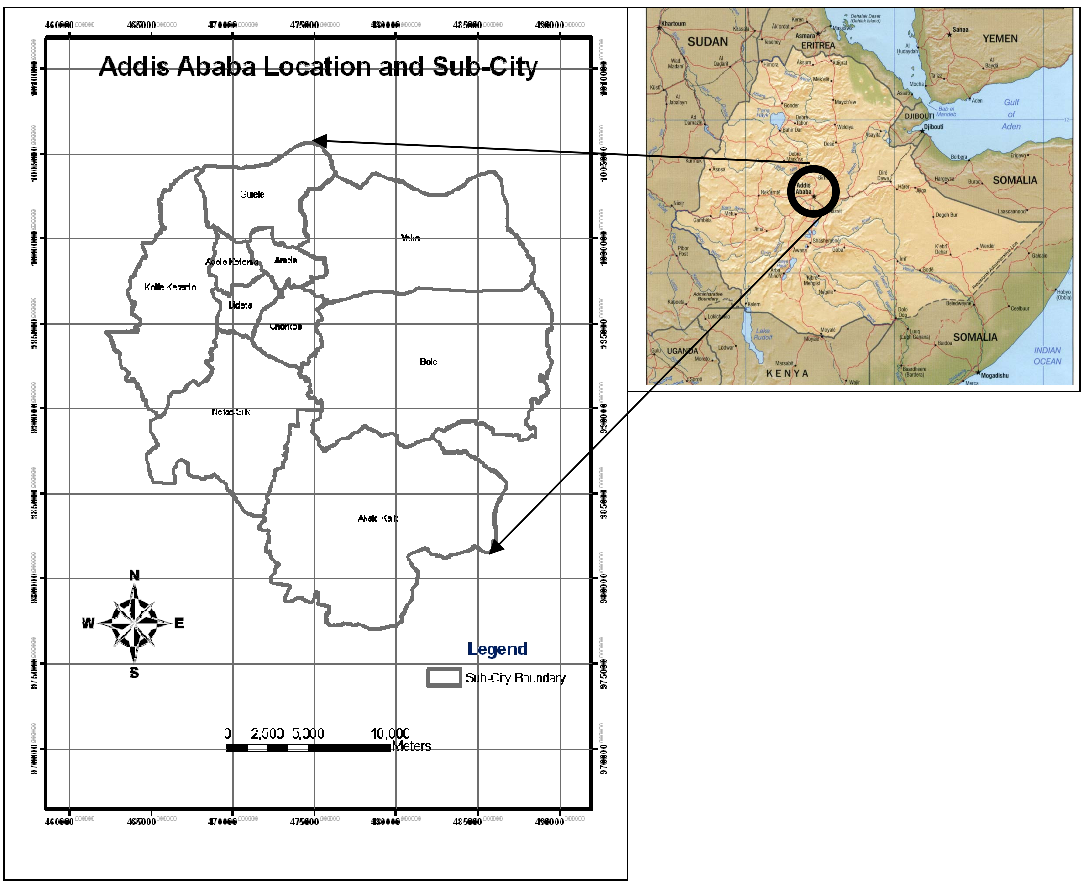



**Figure 3-1 Study Area Location**

### 3.2. Demography

Addis Ababa is one of the fast growing cities in the World. Between 1961 and 1994, its population size has increased from about less than half a million to 2.11 million. Between the 1984 and 1994, the population registered an annual growth rate (AGR) of 3.8%. Of this natural increase accounted for 1.82% and migration for 1.98%.

According to the projection of the 1994 population and housing census result, the total population of Addis Ababa for the year 2005 is 2.969 million. However for this same period the population was estimated as 3.1 million. According to the 1994 census, 52% of the total population are female and 48% are male. The average annual growth rate of the population of the city is 2.9%. The demographic indicators as found in the 1994 census are listed in the table below.

**Table 3-1 Demographic Indicator**

| No | Demographic Indicator | Indicator Values |
|---|---|---|
| 1 | Total fertility rate (children per women) | 1.9 |
| 2 | Life Expectancy at Birth | |
| | Male<br>Female | 62.8<br>66.5 |
| 3 | Annual population growth rate (in %)<br>Rate of natural increase<br>Net migration rate | 2.9<br>1.21<br>1.69 |
| 4 | Economic dependency ratio | 130.5 |
| 5 | Sex Ration (number of male per 100 female) | 92 |
| 6 | Infant mortality rate (the number of deaths of infants under age one per 1000 live births) | 50 |
| 7 | Under five mortality rate ( The number of deaths of infants under age give per 1000 live births) | 66 |
| 8 | Crude death rate (the number of deaths per 1000 population) | 6.7 |
| 9 | Crude birth rate (the number of live births per 1000 population) | 27.6 |
| 10 | Female literacy rate | 68 |
| 11 | Female employment rate | 36.8 |

(Source: CSA 1994 population and housing census & report on urban bi-annual employment-unemployment survey April 2004 cited by Eyob).

### 3.3. Socio-economic characteristics

According to the household survey of the Urban Transport Study (2004/2005), the average house hold size is 5.08. The people in Addis are in average in the age range from 18-40 years. The income level is low and the average house hold monthly income is 725 Birr. Nearly 50% are below poverty line(less than 500 birr per household per month) and about 23% are in absolute poverty (less than 300 Birr per household per month). The mobility is normal at 1.07 per capita trip rates with walk being the predominant mode (60.5%). Vehicular ownership is low. Vehicular trip rate is also low at 0.47 per capita. Some of the socio-economic characteristics indicators aggregated at sub-city level are shown in the table below.

**Table 3-2 Socio-economic characteristics of Sub-cities**

| Sub-city | Population('02) | Population('04) | Population density | Average HH size | Average monthly HH Income |
|---|---|---|---|---|---|
| Kirkos | 335330 | 353889 | 236.54 | 5.09 | 860.62 |
| Lideta | 296083 | 312470 | 278.3 | 4.97 | 778.66 |
| Arada | 303810 | 320625 | 324.35 | 4.47 | 778.66 |
| Addis ketema | 320389 | 338120 | 448 | 5.65 | 578.54 |
| Bole | 290170 | 306231 | 24.74 | 4.45 | 1067.84 |
| Yeka | 299050 | 315601 | 39.07 | 4.82 | 646.82 |
| Gulela | 318508 | 336137 | 107.3 | 4.87 | 595.55 |
| Kolfe keranio | 261235 | 275691 | 42.89 | 5.59 | 643.3 |
| Nefas Silk | 330427 | 348716 | 56.96 | 5.54 | 980.74 |
| Akaki Kaliti | 192447 | 201951 | 14.48 | 5.42 | 443.69 |

(Source: Urban transport study 2004/05)

According to the UN-Habitat definition of slum, about 90% of the population in Addis lives in Slums. In line with this the 1994 census shows 24.9% of housing unit have no toilet and 48.94% use shared toilets; 70.9% use shared tap water meter and 50.49% use shared electric meter. The person per room ratio is 2.1.

### 3.4. Land Use

As the data from the Spatial planning department of the city government indicates, the land use is dominated by mixed use (Which is 44.7% of the total area). Transport and road network account only for 5.7%. Nearly one fourth (23%) of the city area is under mountains with steep slopes and forests and hence is not developable (Urban transport study 2004/5).

**Table 3-3 Land Use**

| Major components of the structure plan | Area(ha) | Percentage |
|---|---|---|
| Mixed use(Housing) Built up | 16274 | 31.30 |
| Mixed Use (housing) Expansion area | 6974 | 13.40 |
| Existing Industry | 1244 | 2.44 |
| Proposed industry | 1777 | 3.4 |
| Centers( CBD and Sub CBD's) | 1276 | 2.4 |
| Exsisting social service | 495 | 1.00 |
| Proposed social services | 600 | 1.2 |
| Road network | 1975 | 3.80 |
| transportation | 989 | 1.90 |
| Forest open space | 12176 | 23.40 |
| Agricultures | 7175 | 13.80 |
| Reserved area | 1045 | 2.00 |
| Total | 52000 | 100.00 |

(Source: Spatial planning Department, City Government Addis Ababa)

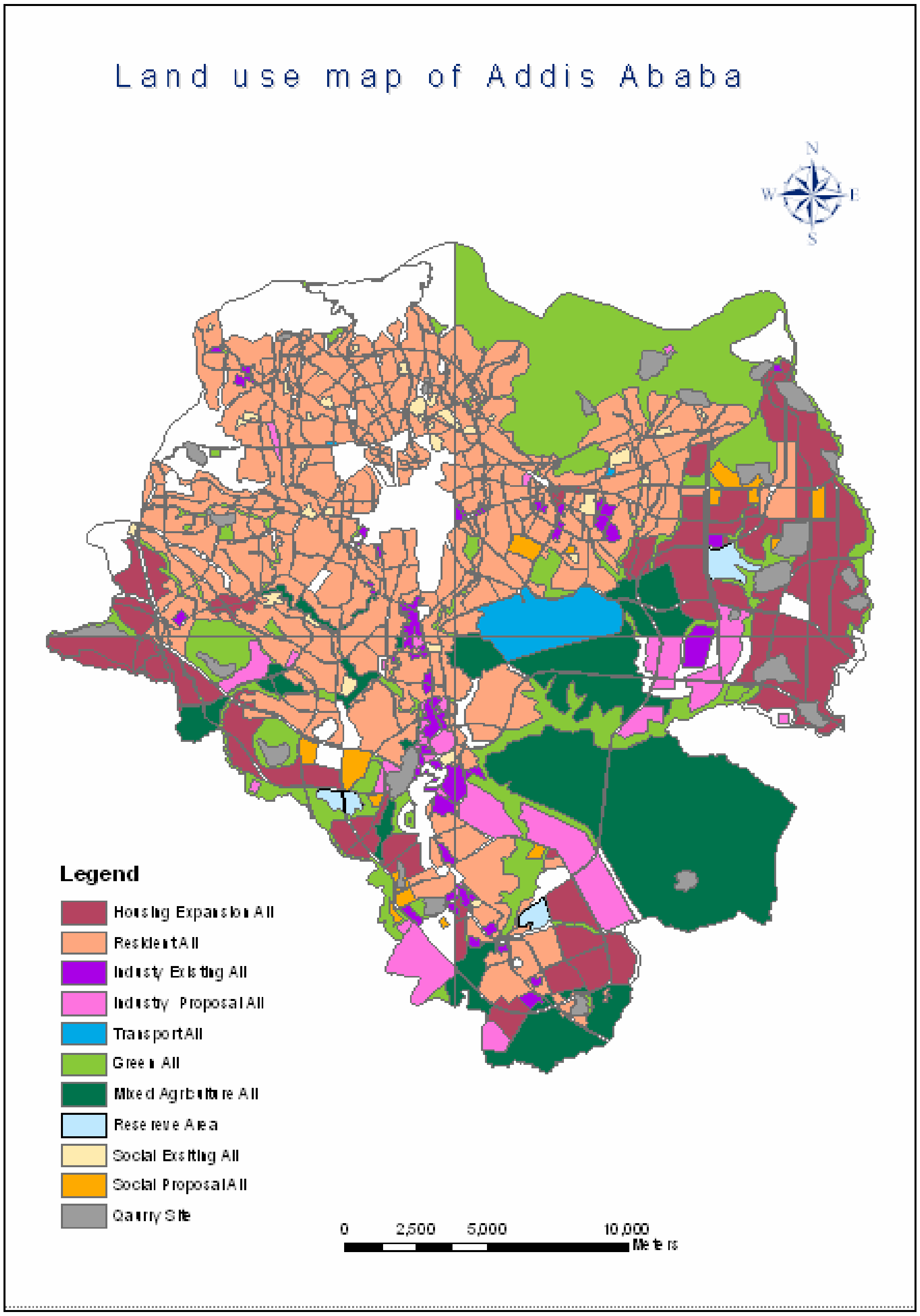



**Figure 3-2 Land use map**

## 3.5. Road network

ORAAMP (Office for Reviewing Addis Ababa Master Plan) describes the road network and capacity as badly constrained by poor quality and standards, shortage of pedestrian walkways, misuse and encroachment on the available road space. According to Urban Transport study 2004/5 study report the share of roads in the land use is about 7% and the total length of roads is about 13,795 km of which only about 395 km is asphalt paved. On discussion with senior officials of AATA, it was revealed that the share of the road in the land use is far below standard which is about 20 to 25 %. So there is a policy to increase this share to 15%.

The road network of Addis Ababa has developed in a radial form shaped by the five regional roads, from Dessie, Debre Zeit, Jima, Ambo, and Gojam converging into Addis Ababa. There is no well defined hierarchical system. However, SMEC International (during the development of a pavement management system) recently divided the road system in Addis Ababa into the following road classes:

**Arterial**: Roads of continuous flow of through traffic, including intra-urban and inter-urban public transport lines. Road reserve widths from 30 to 120 m.

**Sub-Arterial**: Streets that serve a lower level of intra-urban mobility than the main arterial streets and connect adjoining areas. Road reserve widths from 25 to 30 m.

**Collector**: Minor public streets used to collect and distribute the through traffic to and from local streets and provide access to arterial streets.

**Local**: Streets that provide access to residential, business or other abutting properties.

As per this classification, the arterials and sub-arterials are composed of the radial and ring roads while the local and collector roads are developed as a grid system within the major road system.
The table below shows the trend of development of the different hierarchical roads as described and given by AACRA.

**Table 3-4 hierarchical road distribution**

| No. | Road category/ indicator | Unit of measure | Annual Trend | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
| A | Total asphalt road length | km | 681 | 684 | 688 | 698 | 716 | 756 | 778 |
| | Principal arterial road | | | | | | | 308 | 327 |
| | sub arterial road | | | | | | | 118 | 119 |
| | Collector road | | | | | | | 178 | 180 |
| | Local road | | | | | | | 152 | 152 |
| B | Gravel Road | km | 1184 | 1223 | 1235 | 1266 | 1286 | 1300 | 1368 |
| C | Total Road length | | | | | | | | |

(Source: AACRA)

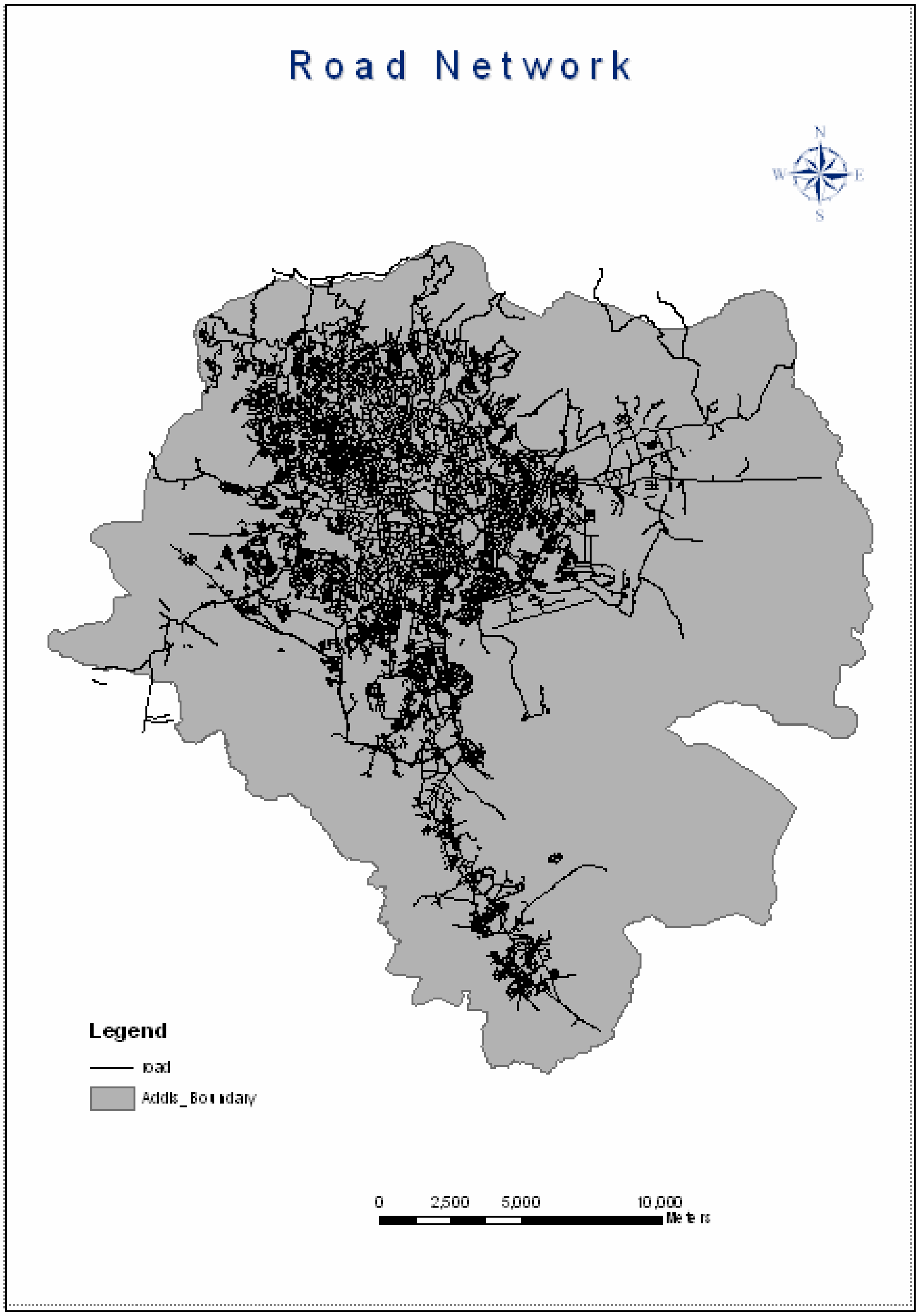



**Figure 3-3 Road Network of Addis Ababa**

## 3.6. Transport

The role of transport in economic development of a nation has been acknowledged and definite framework for the development of the city transportation system is provided by the City Development plan 2001-2010, which has extended to 2020. As revealed during discussions with an AATA manager, a holistic policy framework for passenger services for the City of Addis Ababa is absent currently and it is under development. The transport vision of the structural plan is **"**affordable transport, enhanced access and mobility**"**. However, the upgrading of road infrastructure and facilities and the provision of public transport services in the City has not kept pace with the rapid growth and influx of people into the city. Consequently, the City suffers from traffic congestion and excessive vehicle friction resulting in low throughput on the road network, unnecessary long travel times (at slow operating speeds) and hazardous traffic conditions.

### 3.6.1. Modal share

The main mode of transport is walking. Despite the fact that the pedestrian facilities are poor, the share of walking is between 60% and 70%. From the total patronage by vehicles the share by private vehicles is 2%, while 72% is by taxi and 26% is by city buses. The ratio between the city bus and taxi is 33:66.

### 3.6.2. Institutional organisation

The private and public transport in Addis Ababa comes under the responsibility of the Transport Authority. The roads (construction maintenance and repairs) are under the responsibility of Addis Ababa City Road Authority (AACRA). The city bus is run by a sole organization called Anbessa city bus. It is one of the service giving organizations and it is under the Addis Ababa City Municipal services. Anbessa is governed by a public sector Board appointed by the Federal Government's Public Enterprises Supervisory Authority. The City Manager serves as the Chairman and the General Manager of the Transport Authority is a member of the Board. The organizational structure is shown below.

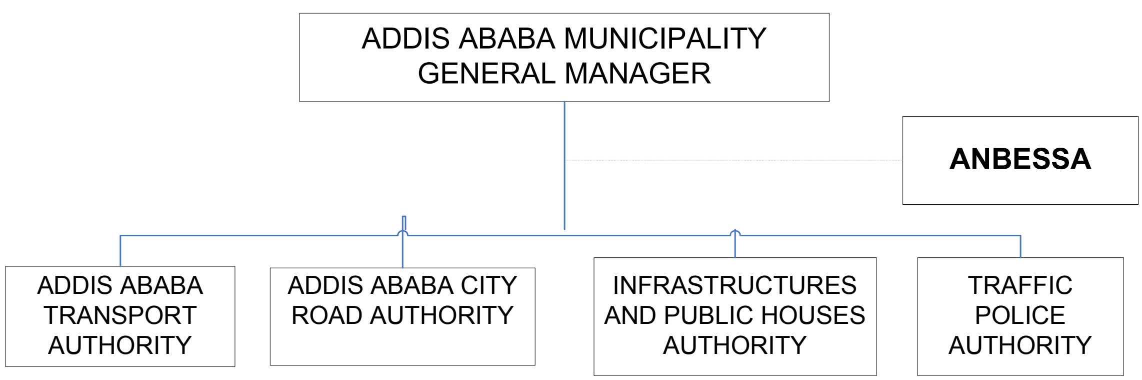



**Figure 3-4 Institutional Organization**

# 4. Methdology and Materials

A key component in the emerging methods and techniques for better understanding transportation processes is geographical information systems (GIS). Whether it is the assessment of broad scale regional policies or link specific capacity, GIS are proving to be valuable transportation management and modelling platforms (Nyerges, 1995) cited by (Murray et al. 1998). Moreover its application in infrastructure planning is getting wider attention due to query operation (attribute and spatial query) and spatial operation capabilities. In relation to public transport, Researchers have used GIS technology to measure accessibility of public transport, creating public transport routes, identifying optimum routes, optimizing bus stops and spatial analysis of service level, measuring spatial equity and public transport management. Generally, at present its application in public transport planning and management has increased. Its query, spatial analysis and network analysis capabilities make it attractive tool for this research. Hence, GIS has been used as the main tool of analysis together with some statistical techniques.

The research has three consecutive stages. The pre-field work stage, field-work stage and post field work stage. The methodology and material used are grouped under these stages as discussed below. The general methods followed to achieve the objective were literature review, interview with Addis Ababa transport authority manager and planning and design and public relations official of Anbessa organization, questionnaire survey for 500 Anbessa transport customers, data collection from secondary and primary sources, data maintenance and preparations and data analysis using statistical and GIS techniques. The state-of-art software's like Arc GIS9.1 and Flow map7.2 and SPSS12 are used. The research also used the results of Addis Ababa transport model generated by World Bank, 2004 for Addis Ababa and some methodological insight for potential cycle route identifying , 'Cycle through' Rouwette et al. (2006) as background materials.

## 4.1. Pre-field work study:

In this stage three main tasks were accomplished. First, the parameters and data required were identified through intensive literature review and also potential sources of data and key contact persons were identified. These ultimately led to the development of the conceptual framework and research design. The parameters identified to assess the efficiency of public transport were categorized as service efficiency, network efficiency, vehicle efficiency, labour efficiency and financial efficiency. The data required identified during this stage are classed under data on people, map data and Anbessa transport data.

**Table 4-1 Data required Identified during pre-field study**

| People data | Map data | Anbessa transport Data |
|---|---|---|
| Demographic data | land use | Passenger volume |
| Socio-economic data | road network | Vehicle-km |
| | Route map | Speed per route |
| | Bus stop | Passenger count per trip |
| | Building foot prints | Vehicle characteristics |
| | Sub-city | Labour utilization |
| | Zone | |

The second task was preparing the questioners and interview questions. Semi- structured interview questions were prepared for Transport Authority with the assumption that they might not have the time to give the required information through interview. The questions for Anbessa organization were structured. Different questions were prepared for the different departments. The questionnaire for the customer survey was prepared to conduct at bus stops. So it was made as short as possible to obtain the required information in the waiting time. It mainly included questions on socio-economic characteristics of the customer, travel characteristics and convenience of the service.
The last part of the pre-field work is to collect the field work material and train with them. The material used on the field work is GPS.

## 4.2. Field work

### 4.2.1. Primary data collection

The data identified during the pre-field work were collected from primary and secondary sources during the field work. The primary data collection included interview, questioner survey and a GPS survey on Anbessa route.

Interviews were conducted with AATA officials to get information about the city-bus in the context of the public transport systems policy and compare its performance with other alternatives in the city. However, due to lack of public transport policy sufficient information was not obtained, though the officials were willing to cooperate. Moreover, the authority has no mandate to control Anbessa organization. Also planning and design and public relation officials of Anbessa were interviewed to obtain information on operational characteristics of the city bus. In addition data on passenger volume, vehicle-km, trip frequency and other operational characteristics were collected from the organization records.

In Addition, questionnaire survey was conducted on customers to identify their opinion about the service offered. A total of 500 questioners were administered at bus stops with the help of field assistants. Since prior information about the spatial distribution of the bus stops was lacking, the sampling technique used is random sampling. As a result, most of the survey was conducted at the three main terminals namely Legehar, Merkato and Piyassa terminals where 63 routes start.

Since most of the bus-routes pass over the major north-south axis road and East-west Axis road, it was assumed surveying some of the routes can give the representative value about the operational speed of the bus within the short period of the field work time. So, fifty-three bus routes were navigated with GPS. Track points were recorded and the bus stops were marked as way points. The main purpose of the GPS survey is to identify the operational speed of the vehicles and the location of the bus stops. The GPS data were then converted into shape files as way points and tracks. However, during the data transfer the speed was not transferred as one attribute so the tracks were also saved as text files. Along the GPS survey traffic count was conducted for the administered routes. The numbers of people boarding and alighting at the stops were recorded.

Some problems were encountered during the field work. As mentioned above, lack of transport policy is one of the problems. Others include logistic shortage, GPS to PC connector cables, weak signal strength, some times totally lost signals, lack of proper knowledge and experience on GPS setting, suspicions by the people.

### 4.2.2. Secondary data collection

Demographic data, socio-economic data and Maps were collected from secondary sources. The data collected, source and format are shown in the table below.

**Table 4-2 Data collected from Secondary source**

| No. | Data | Format | Source | Remark |
|---|---|---|---|---|
| 1 | Demographic data | Excel table | ERA,<br>Urban Transport Study(2004/05)<br>AACRA | Aggregated at Sub-city and traffic zone level |
| 2 | Socio-economic data | Excel | Anbessa<br>Urban Transport study(2004/05) | Aggregated at sub-city level |
| 3 | Land use map<br>Road network<br>Building foot print<br>Traffic zone<br>Sub-city | Auto-Cad | ORAAMP<br>AACRA<br>ERA | UTM-Zone 37N |
| 4 | Route | JPEG | Anbessa | Some changes were corrected using sketches |
| 5 | Bus stops | Table | Anbessa | Distance between consecutive stops |

## 4.3. Post-Field work

The post field work includes both data preparation and maintenance and data analysis.

### 4.3.1. Data preparation

The first task in the post-field work was preparing the data collected for analysis. The major tasks were converting data format, constructing the bus route network, joining the alpha-numeric data collected on demography and socio-economic data with map data, converting the questionnaire survey into statistical environment, defining projection and co-ordinate transformation and filtering the GPS data.

Most map data were collected in AutoCAD format and for analysis in Arc GIS these data were converted into ESRI shape file. The method used is export data in Arc GIS 9.1. Topology rules were defined and validated. The attribute data collected from different source as excel sheets were converted to DBASE file format and joined with the appropriate shape file in Arc GIS. Since the maps were obtained from different sources, the co-ordinates were different. So, in some cases projections were defined and the coordinate systems of others were transformed into the working coordinate system. The working co-ordinate system used is WGS1984 zone 37 N.

The data for the bus route were obtained in JPG format without co-ordinate system and scale. So visually the lines which make up the route were selected from the general road network and topology rules were checked and validated. Finally, the routes were constructed in ARCGIS using the route create wizards.

During transfer from one bus to other in GPS navigation, the GPS was active and has recorded the intermediate points in the track log. So, the GPS data was overlaid with the route map and the intermediate points were identified and filtered. The instantaneous speed recorded for the points on the routes were converted into average speed per route.

Information about bus stops were collected in excel table i.e. for each route the spacing between consecutive stops were given in table. So the bus stops were digitized from the routes using these tables and hatches on the route complemented by the bus stop data marked during GPS navigation.

Finally since part of the analysis was carried out in Flowmap 7.2 the map data were converted from ESRI shape file format to BNA and from BNA to flowmap format.

### 4.3.2. Data Analysis

The data collected and prepared are analyzed in two stages. The first analysis evaluates Anbessa transport system based on the indicators defined under system efficiency. It employs descriptive statistics and GIS-techniques. It shows and measures the performance qualitatively.

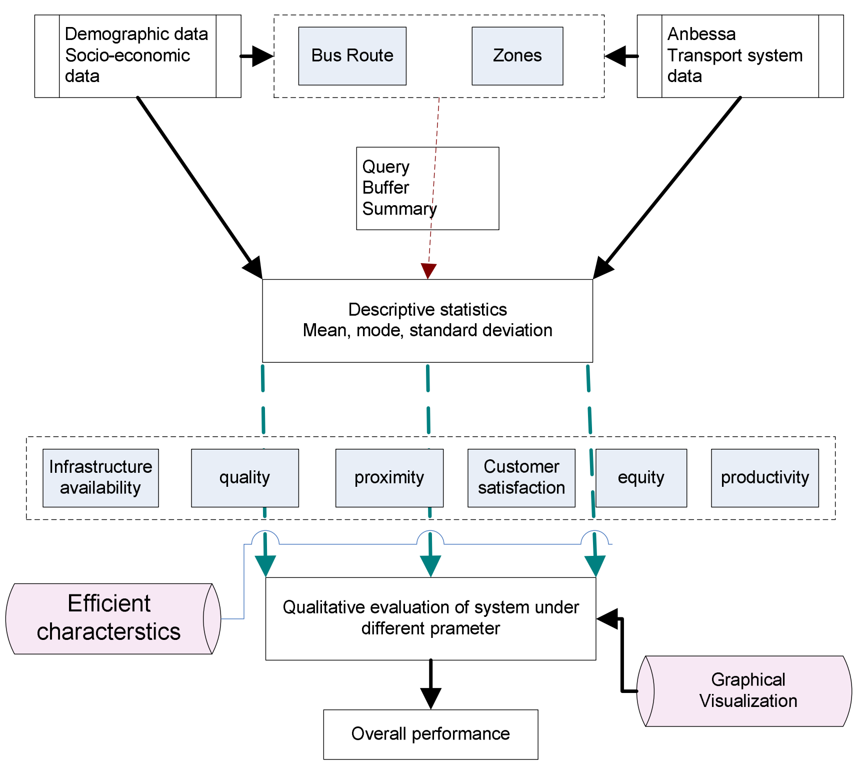



**Figure 4-1 Summary of Data analysis**

The second analysis identifies area with high prosperity of missing links based on travel demand. In this method based on (Rouwette et al. 2006), a comparison for the trip distribution between zones for the resistance along the existing route network and a direct link (least resistance) based on the gravity model are made. The larger the difference shows prosperous areas for missing link. Besides the trips can be assigned to the nearest network and shows the distribution of network along the routes. Moreover, the travel demand for each zone is computed by summing the trip flow on the direct origin destination links resulting from the trip distribution computation.

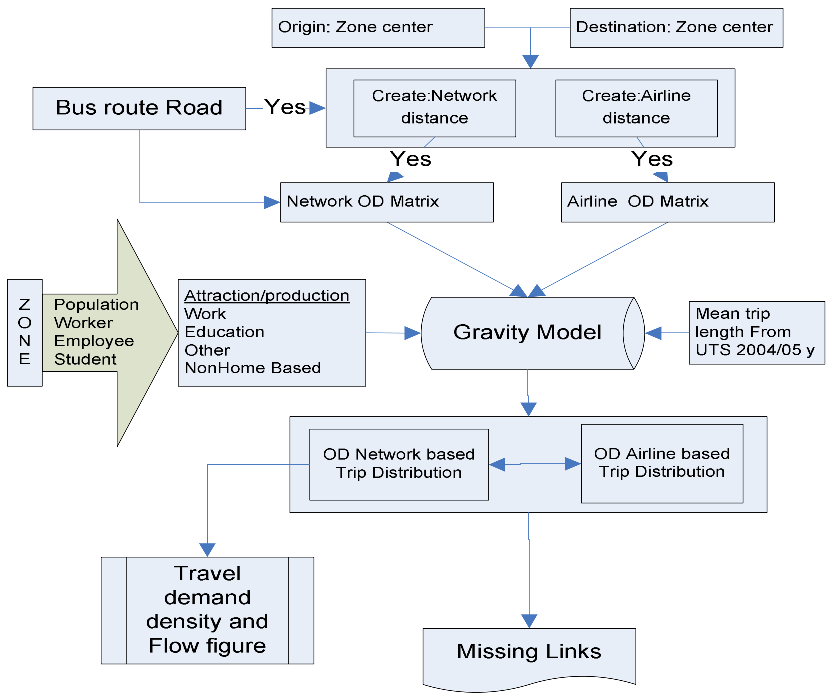



**Figure 4-2 Detailed analysis procedures**

# 5. Situational analysis

## 5.1. A brief background Of Anbessa Bus organization

Anbessa organization Started in 1935EC (1943GC) under the office called 'the Ministry of work and communication' using the vehicles and garage materials, which were the properties of the then Italian colonial government. Between 1943 and 1949GC, the company had a fleet of 10 green and yellow vehicles plying a total of four route lines. The tariff charged then was 0.4 birr for a round trip and 0.25birr for a single trip. The total number of staffs in the company including foreigners at the time was 120. In 1959, the company expanded its coverage from four to fourteen routes and increased the number of vehicles per route from 2 to 3. In August 1974, the outfit 'Ethiopian vehicle service office' became public organization. In 1994, following 'proclamation No. 187/1986', with a total capital of 14million birr the company was renamed as Anbessa City bus service. The company has since grown steadily, acquiring more vehicles in order to meet the increasing demand for its services. Currently the company operates on 93 routes and its vision is to 'give modern and fast service which satisfies the need of the public' (Anbessa Organization pamphlet).

## 5.2. Route characteristics

Bus route is defined as the infrastructure provided on a fixed alignment by buses operating on a predetermined schedule(Vuchic 2005). The bus routes in Addis are both radial and tangential. Most are radial routes, which operate from the three main terminals namely 'Merkato", 'Legehar' and 'Piyassa' to outer suburbs or towns beyond the city boundary; some routes operate across the city centre between one outer suburb and another. Most of the routes are along the two main roads which run from the north to south and west to east concentrated in the central part. As the demand for public transport increased driven by the rapid population growth and uncontrolled horizontal expansion of the city, Anbessa opened more new routes and expanded the existing ones (complemented by new vehicle injection) to cater for the demand following the existing road network. The data obtained from the organization record shows, the number of routes has increased from 42 to 93 in the years 1995 to 2004 GC. A total of 466 vehicles were purchased and injected to the system to achieve the mentioned expansion.

**Table 5-1 Number of route in different years**

| year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of route | 42 | 42 | 42 | 75 | 80 | 85 | 85 | 85 | 93 | 93 |

(Source: Anbessa Organization Record)

Despite the increasing demand for the service particularly in the peripherals, Anbessa could not open more routes currently due to financial and resource constraints. However, as revealed during discussions with the planning and data processing expert of Anbessa, recently some routes were shifted and extended since 2004 following customers demand. The table below shows the routes on which there has been major change since August 2005. This act, however, stretches the system at the cost of quality.

**Table 5-2 Routes with major change since August 2005**

| Route No. | August, 2005<br>Length, km | July, 2006<br>Length, km |
|---|---|---|
| 9 | 9.4 | 10.5 |
| 11 | 6.9 | 10 |
| 27 | 8.5 | 11.4 |
| 35 | 6.7 | 9.8 |
| 84 | 6.4 | 9.5 |

(Source: Anbessa Organization Record)

Currently, Anbessa city bus caters service along 93 routes. The longest route is route number 60, which runs from Legehar to Debrezeit. Its length is 47.2km. The shortest route is route number 49, which runs from Meri CMC to Megenagna. Its length is 6.8km. The average route length is 13.5km. The total route length is 1207km. The total daily km covered in July, 2006 is 73440.1km. On average a total of 6352 daily trips are made along all routes in this time. The table below summarizes the characteristics of Anbessa route.

**Table 5-3 Route Characteristics indicator parameters**

| **Parameters** | **Route length, km** | **Dead Mileage, km** | **Travel time, min** | **No of trips per route** | **Fuel consumption per km per route, litre** |
|---|---|---|---|---|---|
| Average | 13.5 | 19.31 | 48.5 | 68.8 | 2.1 |
| Total | 1239.9 | 1740.44 | 4460 | 6332 | 188.90 |
| Maximum | 47.2 | 67 | 100 | 210 | 3.1 |
| minimum | 6.8 | 8.4 | 23 | 2 | 1.8 |

(Source: Anbessa Organization record, Hamle 1998/ July 2004)

Figure 5-1(a) below shows the 93 routes with the bus stops. The average spacing between the stops is calculated to be 400 to 500meters. The stops are placed in this standard range unless there are some special restrictions like politically sensitive areas or topographic limitations (steep slopes). But there are no street infrastructures at the stops. Standing posts display the route numbers.

Headway is the time interval between the moments two successive buses pass a fixed point on a route in the same direction(Vuchic 2005). The headway for each route is given as the ratio of the travel time to the number of buses. Short headways means short waiting time for passengers. The longest headway is 180min, which runs from Legehar to one of the surroundings called Sendafa, while the shortest headway is 7.5min. The average head way is 30.1minutes. Anbessa organization uses 2 to 10 buses per route. The average number of bus per route is 4 buses. The long average headway and few number of vehicles per route, indicates that long waiting times at the stops are inevitable. On average, one is expected to wait for 30minutes. In other words, the shortest waiting time is 7.5minute which itself exceeds standards specification that the waiting time should not exceed 5minute Armstrong-Wright et al.(1987) for well-performing bus system in developing countries. This discourages people using the service and makes Anbessa less attractive compared to Mini-buses and taxi's despite its affordable fair.

Anbessa complements the basic service during peak hour on 34 routes. Figure 5-1(b) shows the peak hour routes. The 1998EC(2006GC) route performance record of the company shows, the peak hour service carry on average 53114 passenger per year, the average vehicle-km covered is 11008km and 37752.7 birr revenue has been collected in this period.

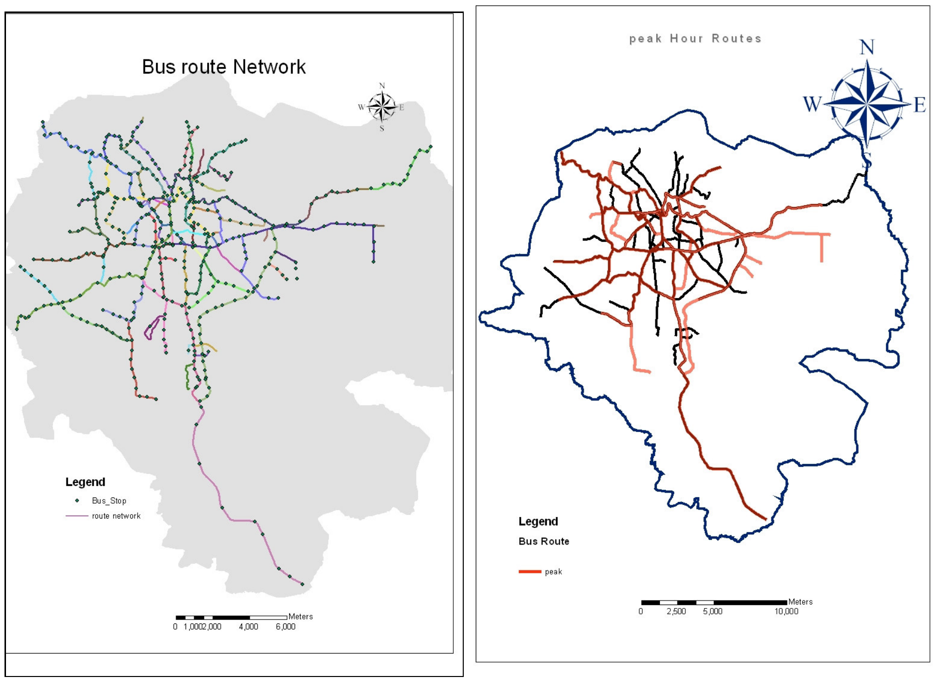



**Figure 5-1 a) Anbessa Bus route and b) Peak hour bus routes**

According to the data for 1998EC (2006) obtained from Anbessa records, the average travel time varies from 39.7min for the shortest route to 93min for the longest route. The average vehicle kilometre covered varies from 357917km for the longest route and 235718 for the shortest route. The average passenger volume carried is 478622 for the longest route and 2592167 for the shortest route. The tables in Appendixb-3 summarize the operational performance in terms of passenger volume, vehicle-km and revenue per route category. The route categories are similar to the ones used to set fare ranges.

Figure 5-2 below and Appendixb-3 show that short distance commuters are larger in volume. This is a direct result of population distribution, high density in the central areas; travel behaviour of people; and the short routes are also within the central area. The average revenue collected is high for routes of medium length i.e. from short to long. However, it is also observed that the revenue collected from the longest route is relatively higher. This is the result of variation in fare, though fixed for range of distance, is not proportional and there is considerable inflow to the city from the surrounding sub-urbs, where the number of alternative routes is less compared to the central area. The vehicle-km covered per route category has almost uniform characteristics. However, it is larger for medium length routes compared to the shortest and longest routes. Figure5.2 shows the performance of Anbessa route per length category based on the data obtained from 1998/2006 record of the company. Figure 5-3 also depicts the performance and the spatial variation of the service. The maps below show the spatial variation of daily trips, passenger volume, vehicle km and revenue per route for 1998/2006 data.

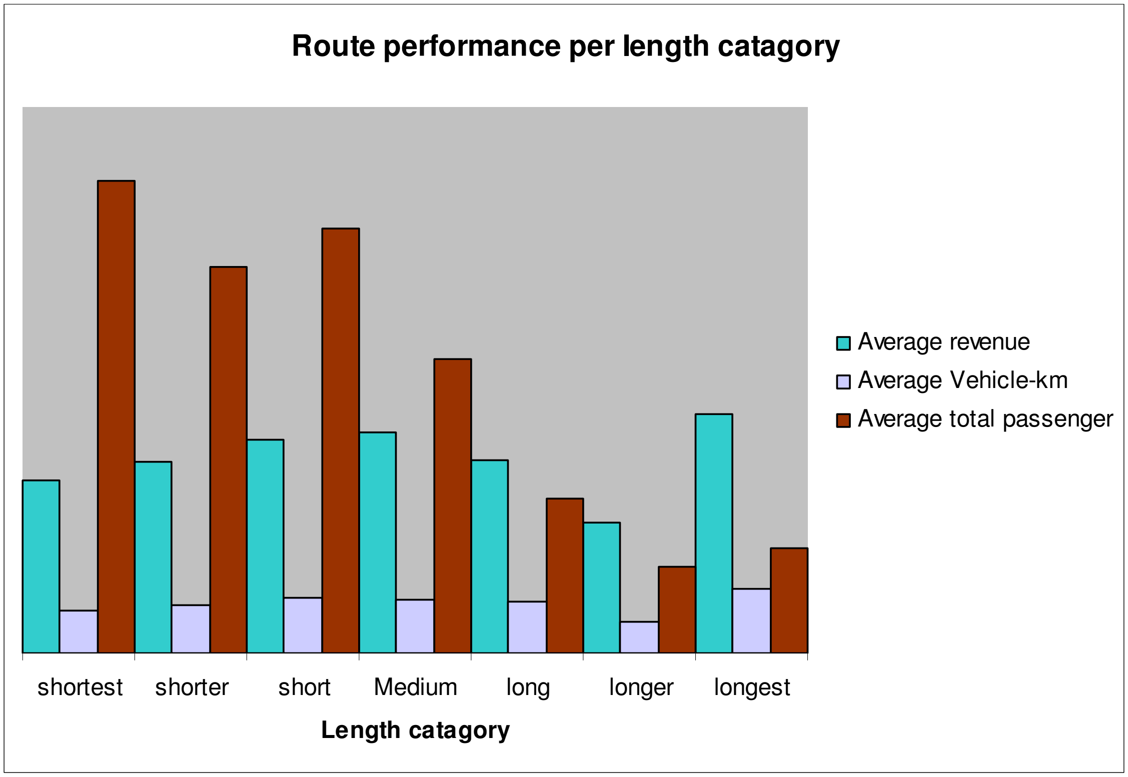
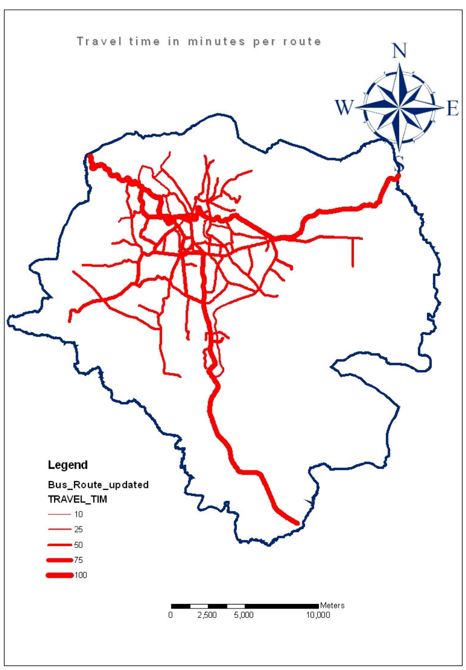
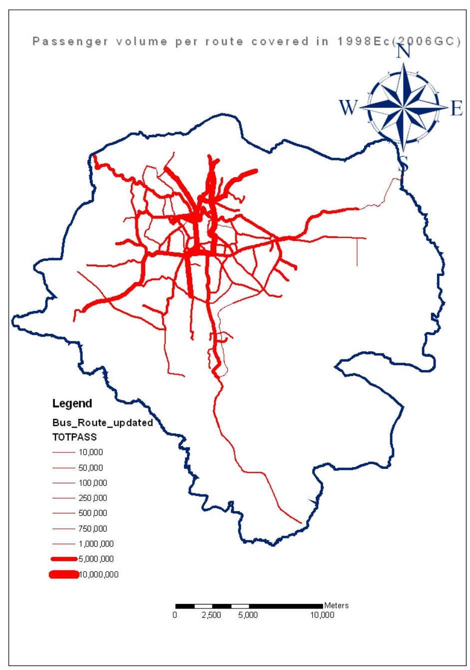



Figure 5-2   Passenger Volume, Vehicle-km, and revenue per length category



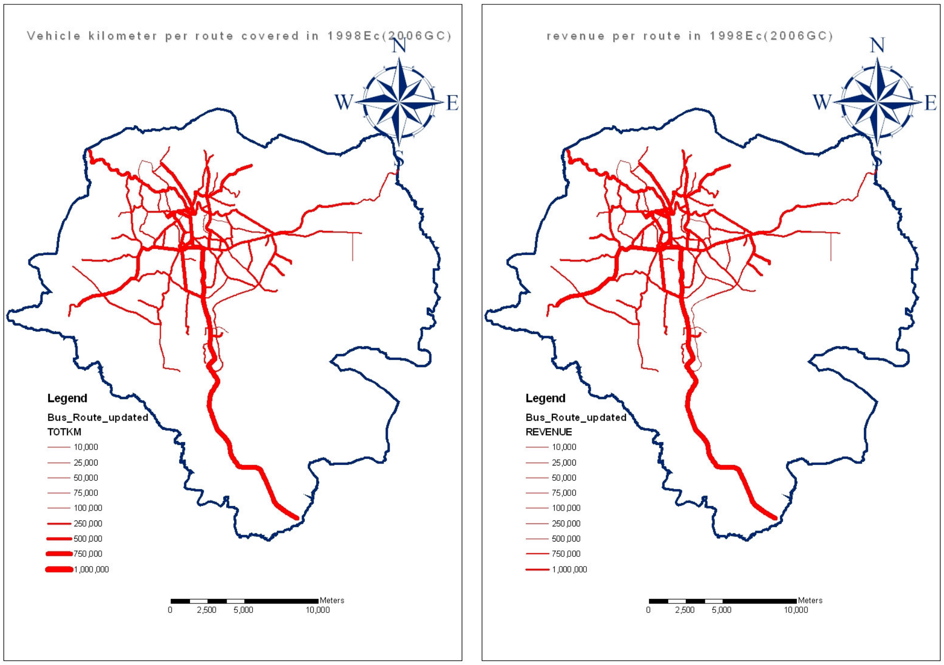



**Figure 5-3 Summary of Anbessa performance per route, 1998EC data**

## 5.3. Service productivity

As discussed in chapter two, different parameters can be used to measure the level of service of a given public transport system. Among the list of indicators identified during the literature review for service efficiency, Anbessa organization records data on passenger volume, vehicle-km and revenue monthly to monitor the performance of routes, vehicles and/or the system in general. These parameters focus on the productivity of the system. As revealed on discussion with the organization planning expert, they also conduct questionnaire survey to evaluate the level of customer satisfaction at times and have arranged opinion box. However, capacity and resource limitations constrain the applicability of such results.

**Passenger volume, vehicle-km and revenue**

The productivity of Anbessa Company can be measured by:

- *Passenger volume*- the number of passenger carried in a given time span, usually per day, month or year,
- *Vehicle-kilometre*- the kilometre or distance covered in a given time span, which is the product of the number of trips by trip/route length and
- *Revenue/expenditure*- amount of money collected/ expended

The productivity of Anbessa in 1998EC (2006GC) is summarized as shown below based on the data obtained from the organization record.

- Average passenger volume per bus per year(APVPY):

$$APVPY = Average\ (\frac{Total\ \ passenger\ \ per\ \ route\ \ per\ \ year}{No.\ Bus\ \ per\ \ route})=493530\text{passenger per year per bus}$$

This result shows, the average passenger carried per year falls in the range 1200-1500passenger per bus per day which is equivalent to 438000 – 547500 passenger per volume per year given by

Armstrong-Wright et al.(1987) for well-performing companies. However, this figure does not include the passenger carried by the peak hour service. It is also smoothed by the effect of long routes which carry less passenger most of the time. The result will exceed the upper limit if the peak hour services are considered in the computation and separate the short routes from the long ones.

- Similarly, the Average Vehicle-km per route per bus is 65054.39km per bus per year.

This result is below the lowest extreme given by Armstrong-Wright et al.(1987) for well-performing systems, which is in the range 210km/day to 260km/day equivalent to 76650km/year to 94900km/year. The possible explanations for such low figure from the prevailing situation are poor road condition, traffic congestion, old vehicle, and high rate of break down and poor maintenance and repair.

The trend for these indicators since the year 1987EC (1995) is as shown below. The number of dispatch bus is the dominant variable, which explains the trends as shown in Figure 5-4.

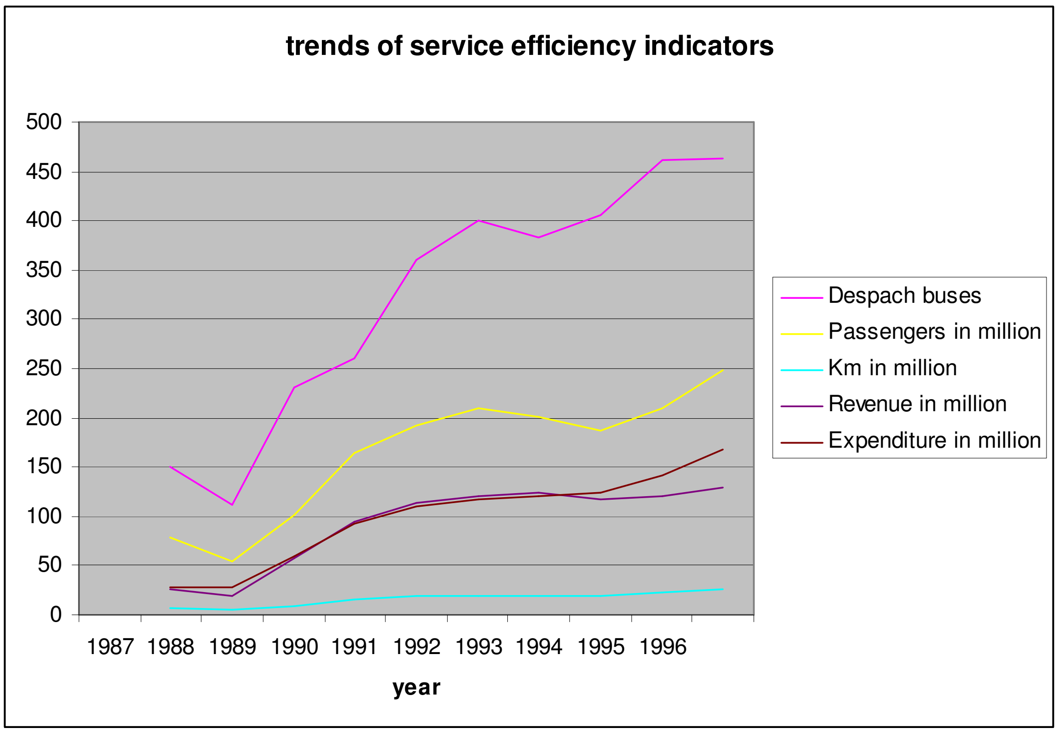



**Figure 5-4 Trends of passenger volume, Vehicle-km, Bus dispatches, Revenue and Expenditure**

The above figure shows, the trend for bus dispatch was decreasing before 1989 which is the result of aging of buses and break down. However in 1988 and 1989, the company purchased a total of 266 new buses. So, they expanded the service and increased the number of dispatch buses. As it is very expensive to continuously monitor and repair the buses the number of buses dispatched started falling in the years 1993 to 1995, which was again complemented by purchasing a total of 200 vehicles in 1994 and 1995.

The effect of the variation on the number of bus dispatch is directly reflected on the vehicle-km and passenger volume. The vehicle-km and the passenger volume carried reduced in the years from 1988 to 1989 and 1993 to 1995. The increasing number of passenger volume is a direct result of the population growth and the income level of the people. Since most of the people are low income group, it is not affordable to use other alternatives.

When we compare the revenue to expenditure, we see three distinct periods. In the years 1987 to 1989, the expenditure is higher than the revenue. This is mainly due to the fact that the vehicles were old and the cost of maintenance and repair was high. During 1989 to 1994, the introduction of new vehicles into the system and rise in the fare from 0.15cents per trip to 0.25cents per trip made the company profitable. However, the increase in fuel oil price, increase in maintenance and repair cost and the increase in salary following the policy change to improve the living standards and reduction in the rate of subsidy increased the expenditure despite a small increase in the fare from 1994 up to 1996.

The comparison of the two trends, expenditure and revenue, shows at present the company is operating under loss. Armstrong-Wright et al (1987) recommends the revenue to cost ratio to be between 1.05:1-to-1.08:1 for the system to be self sufficient and avoid subsidies. However, with subsidy the ratio is less than one for Anbessa. This shows that the cost of operation and maintenance is greater than the revenue collected from subsidy and tariff. Considering the fact that the limited vehicle resource are operating over capacity it is natural to expect the revenue to exceed the cost. However the opposite result suggests that the rate/cost of break down and/or repair is high.

## 5.4. Spatial coverage of the service

A critical factor in measuring the performance of public transport is the spatial coverage/ distribution of the service. Spatial coverage/ distribution measures the ease at which the service can be reached at different locations. It also measures spatial equity. It determines the access time or walking time and walking distance to get the service. The higher the spatial coverage of the service, the shorter will be the walking distance to the service. During the interviews, it was revealed that though the organization has no qualitative measure for the service distribution, they believe that they have extended the service to the needy areas. In this situational analysis number of routes per road segment, route density and proximity measures will be used to assess the spatial coverage. Other factors like number of vehicles in different zones, trip frequencies, etc. also should be used to evaluate the spatial coverage in a more complete way. Due to the limitation of data available only the three measures are used here.

### 5.4.1. Number of routes per road segment

Number of routes per road segment shows the number of overlapping routes on a segment. Higher number of routes per segment implies more opportunities to get the service in different directions. The number of routes per road segment varies from 1 to 20 in Addis Ababa. The average number of routes per segment is 4. As shown in the figure5.5 below, most bus routes in Addis run along the major South-North Axis and West-East Axis.

### 5.4.2. Route density

One parameter which is used to represent the coverage/distribution of bus service is route density, which shows the number of bus lines between origin and destination and whether it is a direct or indirect route when considering travelling by bus. Route density reflects the possibility of different travel directions and different destinations from a given origin along different transit routes, where they diverge. Route density is the quantity of bus route lengths divided by their whole service area. The denser the bus line is distributed, the more people are expected to choose travelling by bus because of greater opportunity for direct trips without transfers. It also means the denser the route density the shorter the walking distance. As shown in Figure 5-5, the spatial distribution of bus service in Addis is concentrated in the central area. The bus lines are dense in the central area than the peripheral areas. It shows that people in the peripheral area have to walk relatively long to reach bus route as compared to those in the central area.

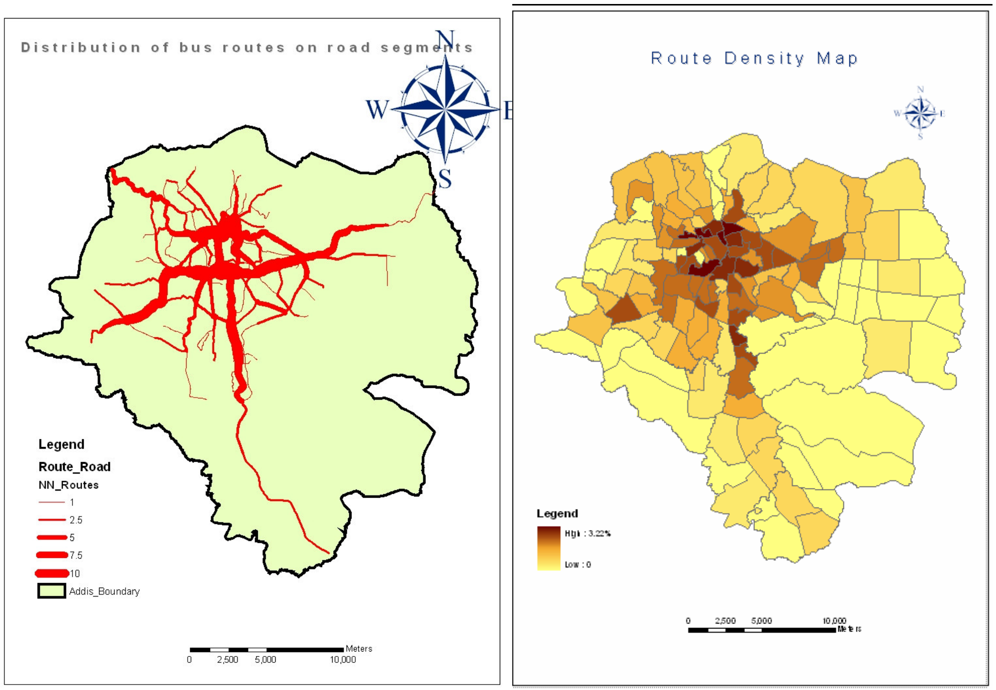



**Figure 5-5  a) Over lapping route distribution and b) Route Density**

### 5.4.3. Proximity to bus route

Another parameter which shows spatial extent of the service is proximity. Proximity measures the closeness of the service either to the origins or destinations of the people. A simple buffer analysis can be used to measure the proximity of people to the service. Data aggregated at traffic zone level identified by the urban transport study 2004/2005 are available. So this data are represented by the centroid of the zones and proximity of the centroids to the bus route and bus stops are measured based on airline distance. It is assumed that, if the centroid of a zone falls within certain buffer zone then all the population is within that reach distance from the route/stops. According to this analysis, 71% of the population in Addis are within a distance less than 500m.Armstrong-Wright et al. (1987) suggest that the walking distance should not exceed 300-to-500m. Figure 5-6 and Figure 5-7  proximity to bus route below show around 30% of the population has to walk more than 500m. Furthermore, Armstrong-Wright et al. (1987) suggest that the maximum distance that passengers have to walk should not exceed 1000m. However, about 13% of the population (Table 5-4) walk more than 1000m to get the bus service.

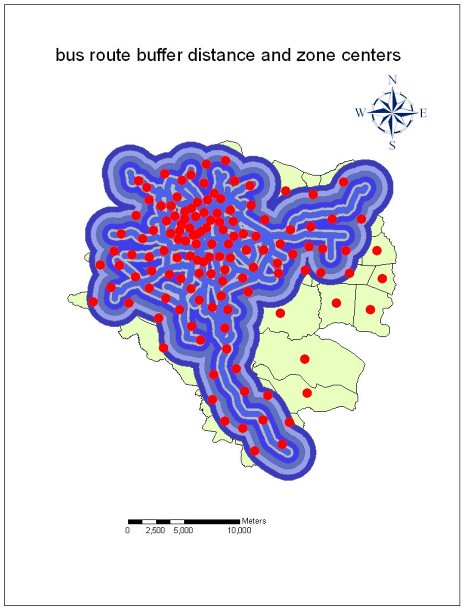



**Figure 5-6 Buffer distances from bus route**

**Table 5-4 Proximity to bus Routes**

| Distance from route(m) | Population (%) | Cumulative population (%) |
|---|---|---|
| 0-250 | 49.16 | 49.16 |
| 250-500 | 22.19 | 71.35 |
| 500-1000 | 16.35 | 87.7 |
| 1000-1500 | 6.9 | 94.6 |
| 1500-2000 | 3.57 | 98.2 |
| 2000-2500 | 0.45 | 98.6 |
| >2500 | 1.38 | 100 |

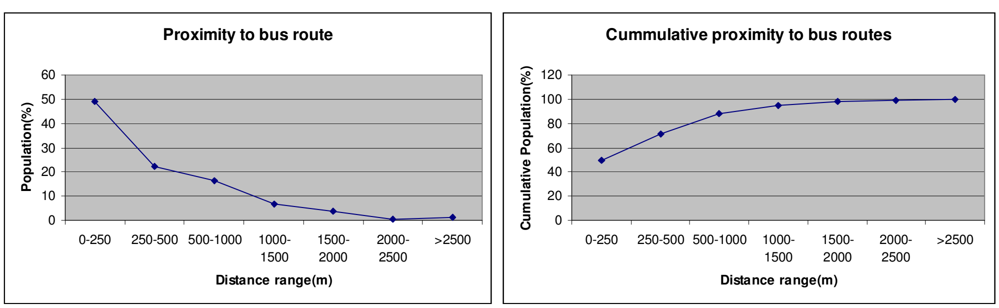



**Figure 5-7 proximity to bus route**

The limitations of the above analysis are; it uses air distance, computes proximity to the route and assumes all populations within a zone have equal access i.e. the populations are represented by the centroid of zones. We can overcome the limitations by considering the population density, using the road network along which the people walk to reach the bus stop and considering the proximity to the bus stop.

The next section analyses the proximity using the existing network, bus stops and population density. Table 5-5and Figure 5-8 show the proximity of population to the Anbessa service based on network distance. It shows 40% of the population walk less than 500m to reach the stops while 70.3% have to walk up to 1000m. It also shows that 10.5% of the population walk more than 2.5km.

**Table 5-5 Proximity to bus stop along road network**

| Distance from bus stop(m) | Cumulative % population covered |
|---|---|
| 0 | 0.0 |
| 250 | 12.7 |
| 500 | 40.1 |
| 1000 | 70.3 |
| 1500 | 80.4 |
| 2000 | 86.0 |
| 2500 | 89.6 |
| >2500 | 100.0 |

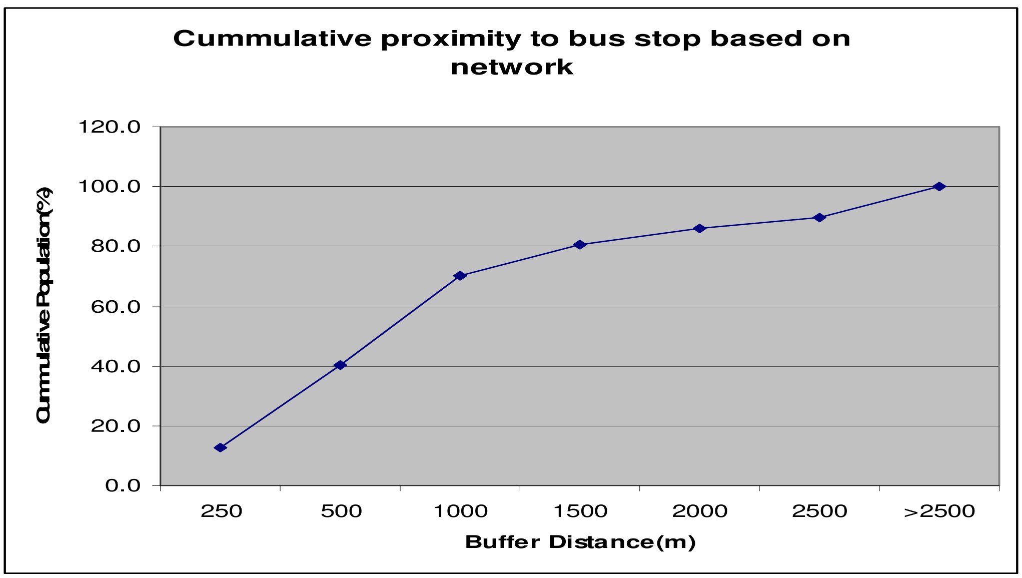



**Figure 5-8 Chart showing population covered VS Buffer distance**

The network based proximity computed above also does not consider the footpaths or other road section, which can be used to access the bus. Thus, the air distance based proximity analysis and network based analysis together give the range of values in which the actual service coverage falls. Hence, for the different distance classes the range of coverage is shown in Table 5-6 below. 40.1 to 71.35% of the population can get service within 500m walking distance, while 70 to 88% is covered in 1000m walking distance.

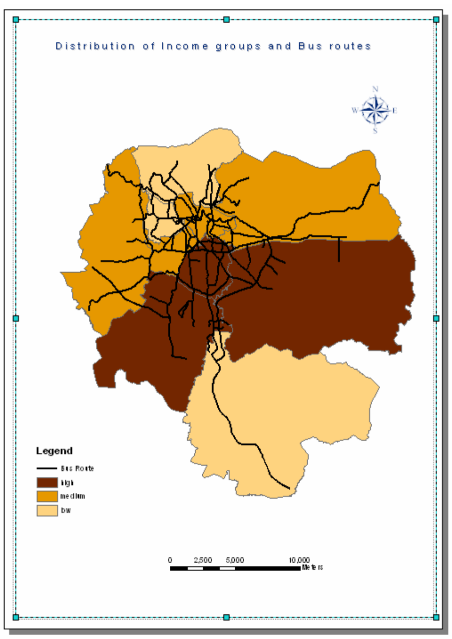
**Table 5-6 proximity range**

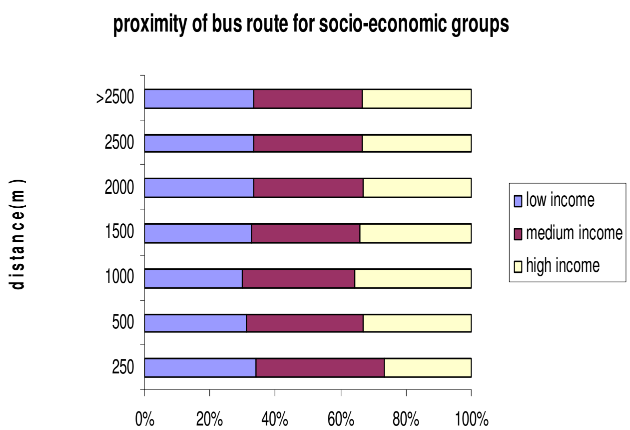
| Proximity distance (m) | 250 | 500 | 1000 | 1500 | 2000 | 2500 | >2500 |
|---|---|---|---|---|---|---|---|
| Population coverage (%) | 12.7 – 49.16 | 40.1 – 71.35 | 70.3 – 87.7 | 80.4 – 94.6 | 86.0 – 98.2 | 89.6 – 98.2 | 100 |

### 5.4.4. Spatial coverage by Socio-economic group

Anbessa organization is a service providing company. The need to give equitable service for all groups of the society considering the distribution of the service for different groups particularly for the disadvantaged group is one of its objectives. High income group population have the opportunity to use other modes as alternative while the poor rely on the bus or walking. So it has to focus more on the demand of the service by this group.

The proximity of the different income group to the bus route is analyzed to see whether the organization is giving equitable service to all groups of society. In this analysis, the city has been divided into low income, medium income and high income groups based on the data obtained from Urban Transport study (2004/2005). Since the purpose is to compare the proximity of the service to different groups, only the air distance based approach used. The procedure followed is the same as previous section. Accordingly, 49.6%, 57.2% and 38.9% of the population in the low, medium and high income group can get the service up to a distance of 250m. And also 77.8%, 75.7% and 93.1% low, medium and high income group respectively are covered within a distance of 1km. comparing the length of the bar for different income class at the proximity levels considered, it shows that Anbessa is providing equal percentage of spatial coverage for all groups. However, the mere fact that high income group have alternatives indicates the system is privileging more the high income group than the low income group. This result is not surprising because the spatial distribution pattern of infrastructure and the different groups is the same i.e. the high income group and the route network are located at the centre of the city.




| | 250 | 500 | 1000 | 1500 | 2000 | 2500 | >2500 |
|---|---|---|---|---|---|---|---|
| high income | 38.963 | 70.569 | 93.117 | 96.591 | 97.65 | 98.823 | 100 |
| medium income | 57.282 | 75.767 | 90.544 | 94.252 | 98.328 | 98.328 | 100 |
| low income | 49.622 | 66.264 | 77.79 | 92.827 | 98.527 | 98.789 | 100 |

relative percentage

**Figure 5-9 a) Income map b) proximity by Income class**

## 5.5. Vehicle operating Speed

Actual speed achieved is influenced by vehicle and alignment speed, as well as by stopping at passenger stops and general traffic conditions. Operating speed is the average speed of bus travel along bus route with 'N' spacing. It is the speed of travel offered to the public. During field work, the speeds along many routes were recorded using GPS-devices.

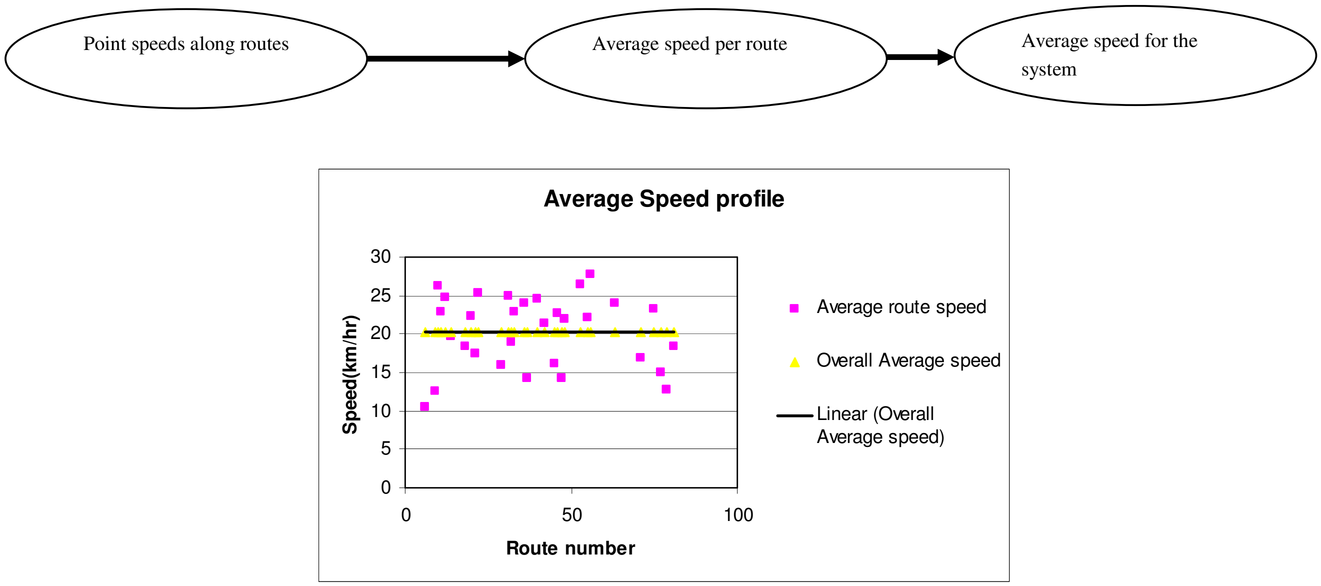



**Figure 5-10 Average speed profiles**

Armstrong-Wright et al. (1987) recommends public bus systems should operate with a minimum of 10-to-12kph operating speed for dense areas with mixed traffic. The Average operating speed is 20.28km/hr $\pm$ 4.7km/hr, which shows the minimum average operating speed of Anbessa exceeds the range. This suggests the operating speed of Anbessa is good enough.

## 5.6. Vehicle operation

Most of the buses are DAF buses complemented by some from Holland and Belgium. The buses are single deck with 30 seats and 70 standing capacities. The total capacity of each bus is 100. They operate from 6PM to 3AM, 15 hours per day. The current fleet size of the company is 521. It has 430 active fleet and 91 buses under maintenance. Few (not mentioned in number) are totally un-operational due to the lack of spare part. Most of the buses are 12 to 16 years old while some are less than 8 years old. It was estimated by the company at least 800 buses are required to give sufficient coverage for Addis to satisfy the demand. But the current fleet size is only half of the required. So, mostly vehicles are overloaded.

As an example, a summary of the annual operational performance for 51 buses from Belgium are given in the table below.

**Table 5-7 Vehicle operation performance summary per bus**

| | Working days | trips | passenger | Vehicle-km | revenue | Working Hour |
|---|---|---|---|---|---|---|
| Average | 334 | 5176 | 476907 | 59881 | 240297 | 3886 |
| Maximum | 356 | 5860 | 551144 | 67920 | 279744 | 4377 |
| Minimum | 312 | 4633 | 414406 | 53002 | 201230 | 3494 |

### 5.6.1. Vehicle utilization efficiency

Based on the data for 51 vehicles obtained from Anbessa records, the operational efficiency of each vehicle can be computed as the ratio of the working hour to the daily working hour. Thus,

$$Average\ vehicle\ Utilization(\%) = {}^{Average\ working\ hour}\!\Big/_{Daily\ working\ hour}$$

= 3886hr per year/(15hr per day*334day per year)

= 77.56%

Vehicle Availability is the ratio of the number of operational vehicle to the total vehicle. Thus, the vehicle utilization efficiency of Anbessa is 82.5%. This figure falls in the range 80-90 percent specified by (Armstrong-Wright et al.1987). It shows that the company has good maintenance and repair capability.

### 5.6.2. Load factor

Load factor is the ratio of the maximum load at a given section to the maximum vehicle capacity. It shows the level of crowdedness and level of vehicle capacity utilization. The vehicle capacity is 100 passengers. The maximum load was identified for 43 routes on which passenger count was conducted. The figure below shows the load factor for the 43 routes. The load factor curve below indicates during peak hour in some routes the vehicles carry more than twice their capacity and also during the off peak hours in some places the demand falls to the extent that the buses operate half full. In most routes they carry more than their capacity. The survey was mostly conducted on short routes which are within central areas and also few longer routes.

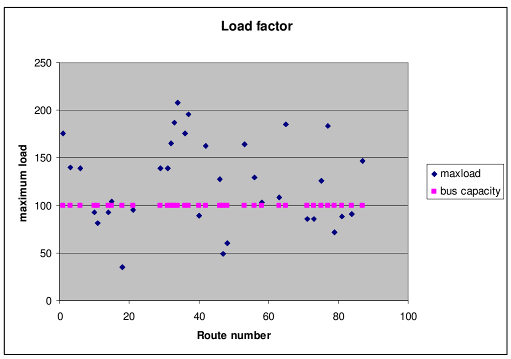



**Figure 5-11 Load factor**

## 5.7. Fare structures

Anbessa has a flat fare system which varies with the length of the route. Depending on the route length the fare varies from 0.25birr to 2.25birr. The fare scale is shown in the table below.

**Table 5-8 Fare structure**

| Route Length(km) | Fare(birr) |
|---|---|
| 0-9 | 0.25 |
| 10-12 | 0.35 |
| 13-15 | 0.50 |
| 16-20 | 0.75 |
| 21-25 | 1.25 |
| 26-31 | 1.50 |
| 32-47 | 2.25 |

Bus fares are subsidised by the city government, although the level of subsidy has been progressively reduced in recent years. The current subsidy is 8cent per journey. According to the status quo study, about 97% of the passenger in February 2004 used fares below 1birr. The percent of passengers using fares more than 1birr is only about 2%. This indicates that people mostly use the service for short journeys.

## 5.8. Staff

Currently Anbessa Company has 3052 employees. The number of administrative staffs is 323. The number of maintenance staff, drivers and conductors are 417, 903 and 888 respectively. The ratio of operating staff to vehicle is 3.5:1.

## 5.9. Customer opinion

A questionnaire survey was conducted to get the opinion of the public about Anbessa transport system. The survey was conducted on 500 customers, of which 43.4% are women and 56.6% are men. They were in the age range of 9 to 90. The average age was 28.54 years. The pie charts below describe the work condition, income group and trip purpose. The statistical results showed 40.1% of the respondents are employed, 35% are students, 9.6% are unemployed and 6% retired. Most of the customers are very low income group. 27.5% have no income, 16.8% below 150birr, 22.8 % have income between 150 and 300 birr, only 14% have income above 450birr. The main purposes of trip are work (46.7%) and school (32.6%). Very low percent (2%) use the bus service for recreation purpose. The above results show that, people using the Anbessa service are student and low income employee.

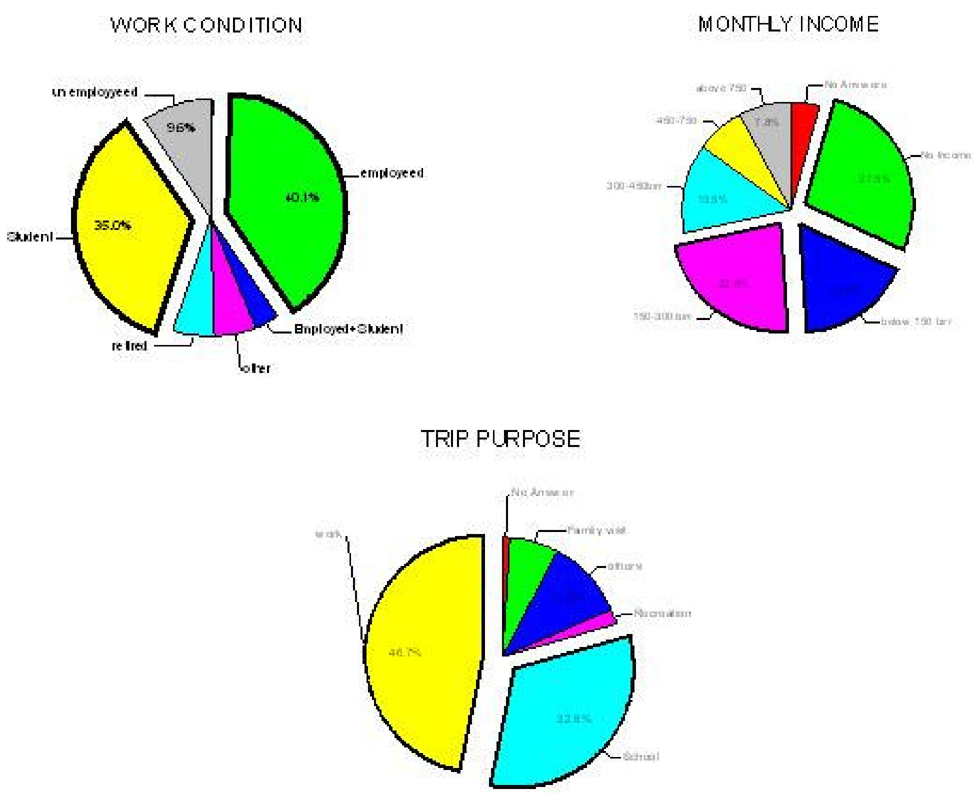



**Figure 5-12 charts showing work condition, income and trip purpose**

The pie charts below summarize the convenience of the service from the customers' perspective. About 40% of the customers walk less than 10minutes while about 30% walk more than 20minute to reach bus stops. Most of the respondents have responded that they get seats sometimes (60%) and considerable percent (27.8%) have showed that they have never got a seat on the bus. Only 3.6% of the respondents have got seats regularly. About 68.6% of the respondents wait more than 15minutes to get service, while only 4.9% of the respondents can access the bus with a waiting time less than 5minutes.

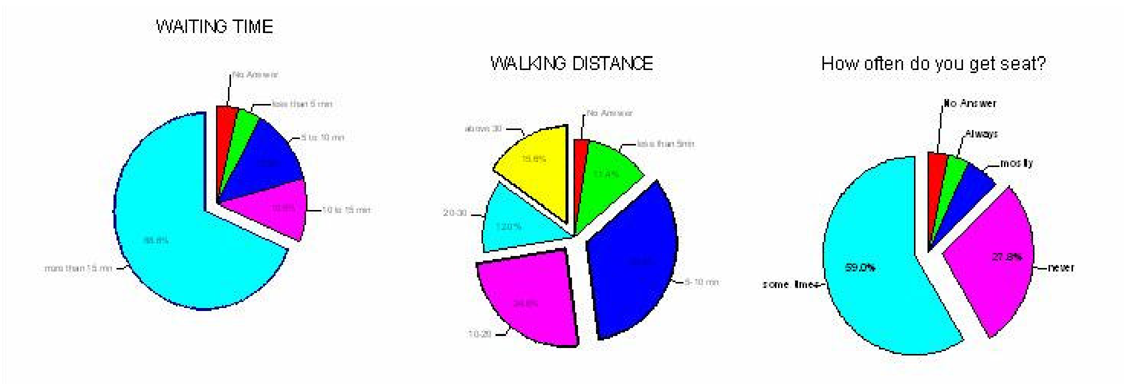



**Figure 5-13 Service conveniences**

Some of the questions for which the respondents gave answer were willingness to pay for better service and alternative means of transport. 60% have indicated their will to pay more for better service. And about 35% showed though they want the improvement their economic status does not allow them to pay more. 64% have indicated they don't have alternative means of transport.

The customers have indicated that crowdedness and failure of the bus to give service according to the schedule are the two main discouraging reasons. 29.6% and 21.3% of the respondents have indicated crowdedness and delay as the reasons discouraging them from using service respectively. Robbery, inconvenience and seat lack were indicated as discouraging factor by 13.5%, 13.2% and 10.2% of the respondents respectively.

21.1% of the respondents have shown that they value on time service more from a better service. Close service, proper seat and fast service are the next most expected factors indicated by the customer from better service. 18.5, 15 and 14.8 % of the respondents have indicated these factors respectively.

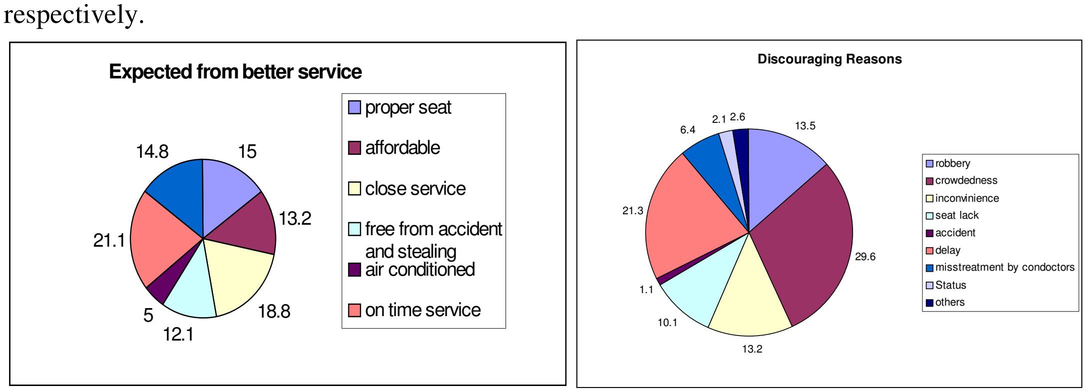



**Figure 5-14 Customers Opinion**

In general, the service of Anbessa is not satisfactory from the customer perspective. The two main complaints of the customer were longer waiting time and crowdedness. They have said these problems mainly arise due to poor operational management. They explain the problem by giving the case where all the buses assigned along a given route will either come or go together. They do not work as per the headway. These problems have been acknowledged by the company however the prevailing traffic congestion makes it difficult to solve.

## 5.10. Overall performance

In chapter-2, it was outlined about the different categories of efficiency. The previous sections have showed the existing situation in terms of some of the parameters defined under system efficiency categories. This approach called 'performance indicators approach' by Smith et al. (2005) focuses on specific aspects of performance. In this approach, the indicators are readily measured and validated, and are easy to interpret (in isolation, at least) and hence are very useful from local managerial perspective. However there are two major drawbacks as discussed by smith to this approach. These are;

- Partial indication of efficiency
- May provide conflicting message

And hence it is not straightforward to draw conclusions about system efficiency. However on the other hand Policy makers are increasingly seeking to develop overall measures of the efficiency of public service organizations Smith et al.(2005) to assess whether the enormous national resources devoted to the public services are used efficiently. Such overall measures are called composite indicators. Composite indicators are synthetic indices of individual indicators (Freudenberg 2003). Composite indicators are generally used to summarize a number of underlying individual indicators or variables. Smith 2003 has listed the arguments in favour of combining indicators as given below;

> (a) In contrast with piecemeal examination of single performance indicators, global indices of efficiency can offer a rounded assessment of system performance. This is particularly important when inputs (in the form of expenditure) cannot readily be attributable to specific activities, given limitations in data or accounting methods.
> (b) Unlike targets that are based on individual performance measures, global efficiency measures can offer local managers the freedom to set their own priorities, and to seek out improvements along dimensions of performance where they believe that gains are most readily secured.
> (c) Global measures of efficiency can be used to support other objectives, such as allocating finance or identifying the priority organizations for inspection and improvement of performance.
> (d) Global measures of efficiency facilitate the publication of 'league tables' or rankings of entire organizations. Some commentators believe strongly that such rankings nurture public interest in the public services, promote accountability and stimulate a search for improvement (Hibbard *et al*., 2003).

Freudenberg, 2003 acknowledges the usefulness and methodological difficulties of composite indicators as **'**Composite indicators are useful in their ability to integrate large amounts of information into easily understood formats and are valued as a communication and political tool. However, the construction of composite indicators suffers from many methodological difficulties, with the result that they can be misleading and easily manipulated.' The common way of composing indicators is aggregating their equivalent monetary value. However, some indicators value can not be converted into monetary value, e.g. social behaviour like equity. In such cases some form of index has to be used. The techniques used to compose indicators like graphical visualization and interpretation(Guyette 2000), empirical standardization and weighing (Moleman 2007) and fuzzy logic theory(Khatri 2006) follow four general steps.

These four major steps in developing composite indicators are explained below with composite index developing for service efficiency of Anbessa organization as example. However, since sufficient data is missing finally qualitative summary of the performance will be presented in the form of graph for better understanding.

Step-1) Developing a theoretical background

The theoretical framework gives an understanding and definition of what is being measured and helps to combine individual indicators into meaningful composite. A composite index has the form of:

$$I = \sum_{i=1}^{n} w_i x_i \quad \text{Where;}$$

I= composite index

$x_i$= score of each variable

$w_i$= weight of $x_i$, $\sum_{i=1}^{n} w_i = 1$ and $0<w_i<1$

The system efficiency in public transport as outlined in chapter-2 is the ratio of system out put to input. The system out put can be measured by productivity and system use which are explained by system productivity, proximity, quality, customer satisfaction, equity and the input indicator is infrastructure availability. Hence the overall efficiency indicator or the composite indicator is a combination of the above indicators. It has the form:

$$I = w_c x_c + w_p x_p + w_q x_q + w_a x_a + w_e x_e + w_I x_I$$

The system efficiency with its different components is described in the figure below;

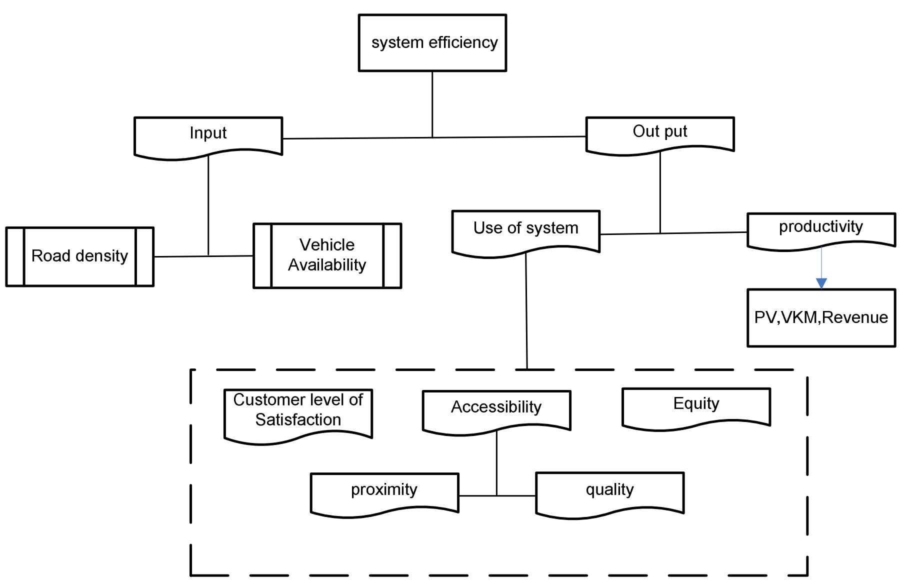



**Figure 5-15 Theoretical Framework for public transport efficiency**

Step-2) Selecting variables

As Moleman (2002) reckons; “it is most likely that there are more than enough variables” in evaluating efficiency. However, all the variables are not equally important. Thus, it is important to identify the most important or relevant variables based on certain criteria. He further summarizes the criteria for selecting variables as: policy (relevant), Simplicity, Validity, Time-series data, Availability of affordable data, Ability to aggregate information, Sensitivity, Reliability, and scale. Description of these criteria can be obtained from appendix.

In the case of the Addis Ababa bus transport system, the main criterion used in selecting the variables is availability of data. As a result, road density and vehicle availability are the variables considered under Infrastructure availability; waiting time, speed, and crowdedness are used under quality and together with proximity define accessibility, proximity of different income classes is used under equity and finally the average passenger volume, vehicle-km and revenue are used as variables under productivity.

**Table 5-9 Indicators Used to Evaluate System Efficiency**

| **System efficiency indicators** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Main indicators** | Infrastructure availability | | quality | proximity | equity | Customer satisfaction | productivity |
| | Road | vehicle | | | | | |
| **Sub-indicators considered** | -route density<br>-road percent<br>-overlapping route per segment | -vehicle utilization<br>-vehicle availability<br>-vehicle load | -waiting time<br>crowding<br>-speed | population coverage | Population coverage by income group | Reliability<br>Comfort<br>safety | -passenger volume<br>-vehicle-km<br>-revenue |

Step-3) Identifying scores and weight of the variables

The actual value of each variable is compared with respect to efficient behaviour or desired state to identify the performance under different category. However, different variables have different units and measures. Thus, the actual values are converted to standard scores or qualitative values. Score is a relative value for the indicator with respect to the efficient and worst behaviour. The efficient behaviour for each parameter is given by standards, policy goals or local expert knowledge. For the case where, all the variables can be quantified the actual value can be converted into standard scores using different empirical relations. For example, using linear standard scale where the current performance of the system is converted into a score between 0 and 1 on linear scale where the value one is given for the efficient behaviour and zero for the worst case. Nevertheless some variables can not be quantified and need subjective judgment. In such cases the score is given as ordinal value or can be computed based on fuzzy logic theories assuming some form of membership functions.

Anbessa public transport does not have a defined desired state or efficient behaviour. Thus, the efficient behaviour is defined from literature where appropriate and otherwise assumptions are made. Variables like equity are qualitative variables; the scores are given as qualitative values with personal judgment based on some characteristics. Summary of the qualitative evaluation of the parameters is given in the table below;

**Table 5-10 qualitative summary of Anbessa performance**

| parameters | Below poor | Poor to moderate | Moderate to good | Above good | Remark |
|---|---|---|---|---|---|
| Proximity | | | √ | | - 40 to 71% of population can get service within a distance of 500m |
| quality | | √ | | | -long waiting time<br>-overcrowding<br>-moderate speed |
| productivity | | √ | | | -high passenger volume<br>-low vehicle-km<br>-revenue less than expenditure |
| Customer satisfaction | | √ | | | -no operation schedule and long queue and waiting time make it less reliable<br>-difficult to get seat and over crowding make it uncomfortable<br>-as the customer's are exposed to pick pocketing it is less safe mode |
| equity | | | √ | | -93% of the high income<br>-90% of medium income<br>-78% of low income covered within a distance of 1km. |
| Infrastructure Availability | √ | | | | -vehicle to population ratio 1: 6550 of which only 82.5% are available with operational efficiency of 77.56%<br><br>-less than 7% road area<br>-small Road density : 0 to 3.5%<br>-More overlapping route per segment of road( Max 20 per segment)<br>-800 vehicle required but only 430 available |

Step-4) Aggregation

The ultimate aim of computing composite indicator is to come up with a single value which can summarize all the indicators considered. If the values for the indicators were converted into score between zero and one, the weighted sum or some other empirical relation could have been used to aggregate this score into a single value. However in our case, the scores are qualitative and subjective it is more appropriate to adapt fuzzy logic theory or a graphical technique.

The qualitative scores of the parameters used in this analysis are presented graphically below.

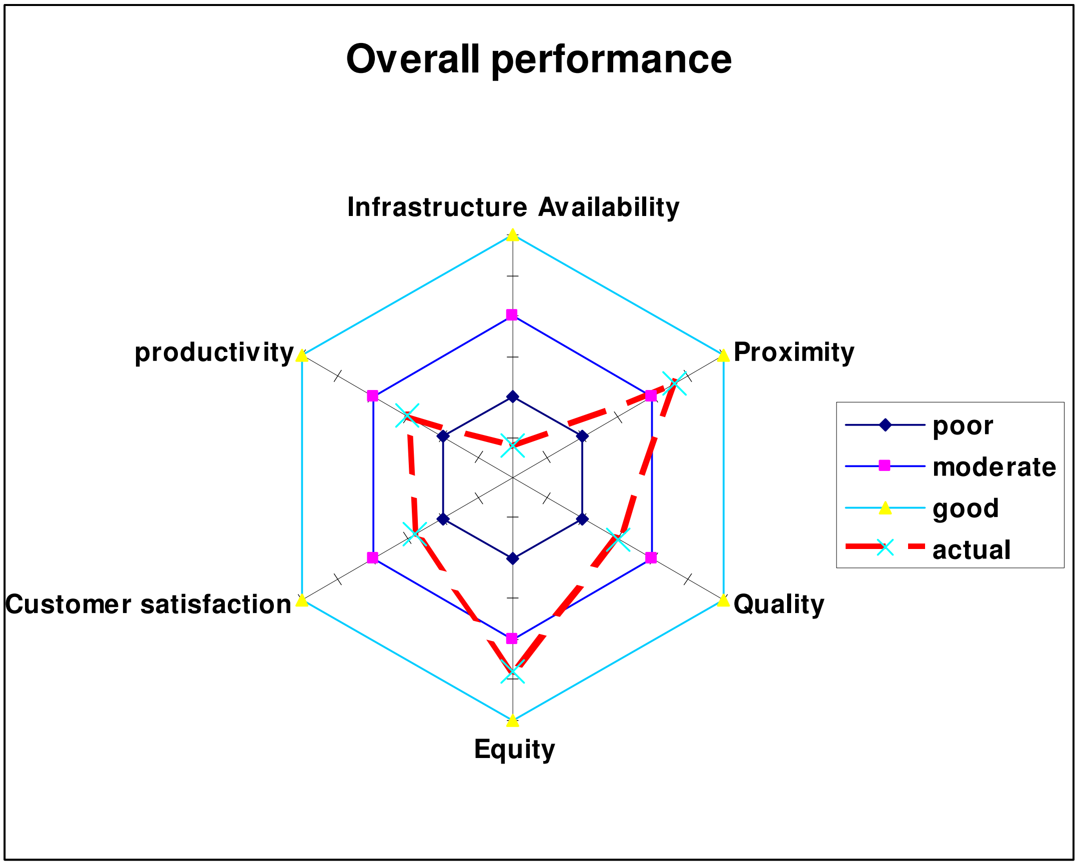



**Figure 5-16 Graphical Representation of the overall performance of Anbessa**

The above graph shows, the performance of the system is in the range poor-to-moderate for the parameters productivity, customer satisfaction and quality. The infrastructure availability is below poor while equity is in the range moderate-to-good. Thus in total the efficiency of the system is in the range poor-to-moderate.

As sown above, infrastructure deficiency is a critical problem in the operation of Anbessa. The road infrastructure and vehicle available are not sufficient enough to satisfy the ever increasing demand and hence there is a need to increase the infrastructure available. Increasing the amount of infrastructure available will improve the performance of the system in general. It will give an opportunity to take the service closer to customer, it boosts up the quality of service, and it enables the provider to give equitable service to all group of society and makes the system more reliable and satisfactory if well managed. Thus the coming chapter will analyze the route infrastructure deficiencies, using the method developed based on gravity model for identifying missing link in Dar es salaam and recommends for improvements in upgrading the route network.

# 6. Improving the bus route network

## 6.1. Introduction

The current Anbessa service is constrained by the limited infrastructure available. The effect of infrastructure deficiency is also reflected on other performance indicators as over crowding, long waiting time, and long walking distance as described in chapter-5. Moreover, Anbessa transport system is confronted with increasing transport demand, decreasing service quality and low productivity with the limited infrastructure available. This crisis has been acknowledged by the transport authority and currently they are encouraging the private sector to participate in providing 'city bus service' together with Anbessa. However, there was a discussion for this sector to provide services complementary to Anbessa rather than competitive. This needs identifying areas where the Anbessa service falls short.

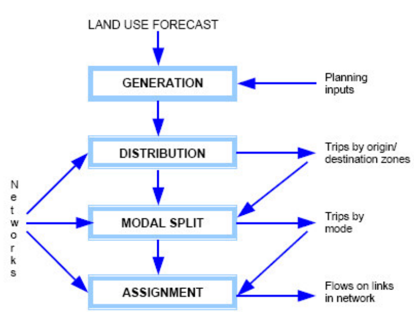
The previous chapter has shown the overall efficiency of the system and the performance of the system for different indicators is not good. Thus, needs proper identifying problems, deficiencies and opportunities under each indicator. However with the data available and scope of this research, it is not possible to include all indicators and the focus will be on identifying spatial deficiencies, exploring opportunities and analysing its effect on the other indicators.

Thus, this chapter analyzes spatial deficiencies of the bus route infrastructure using a method called 'cycle through' developed for the 'velo-mondial' project to quick scan the missing links for cycle route in Tanzania Dar-es-salaam. The method compares origin-destination trip distribution of the existing network with the possible distribution of trip for the case of a hypothetical direct link between origin-destination pair. Accordingly, large difference indicates that it is highly probable that some links are missing. This method was used for two reasons; first it uses the gravity model and follows the four step transport demand modelling principle which was calibrated for Addis by the UTS 2004/2005. Second some of the input data required were also available from this study.

## 6.2. The four-step transport modeling

The four step transport model is a recursive system with a uni-directional casual relationship. It involves four sub-models namely;

- Trip generation, the number of trips generated at a zone for given purpose
- Trip distribution, the choice of trip destination
- Modal split, the choice of mode for making the trip, and
- Trip assignment, the choice of travel route on transport network




Source: Bureau of Transport Economics, 1998

**Figure 6-1** **Schematic Diagram of A Conventional Four-Step Urban**

## 6.3. Trip production and attraction

The data collected by urban transport study 2004/05 is used to estimate zone trip production and attraction. The city has been divided into131 zones by this study mainly based on Kebele and some Kebele are further subdivided to ensure homogeneity of the zones. Data on population number, number of students, number of workers and employee capacity was available from the urban transport study for these zones. The UTS has fitted Regression equations based on house hold survey results and many equations were developed for trip production and attraction respectively. However, the equations which are sensitive to the work force change and number of students change were recommended for use. Thus, the equations recommended are:

**Table 6-1 Trip production and attraction equations**

| Trip type | Regression equation | | remark |
|---|---|---|---|
| | Production | Attraction | |
| Work trips | 1.48 ‘X’ W | 1.57 ‘X’ E | W=Workers |
| Education trips | 1.684 ‘X’ ST | 1.61 ‘X’ ST | ST=Students |
| Other trips | 0.199 ‘X’ pop | 0.86 ‘X’ E | Pop=population |
| Non home based trips | 0.023 ‘X’ pop | 0.0695 ‘X’ E | E=Employment |

The trips produced and attracted at each zone are calculated based on the above equations. The trip attraction is modified by a matching factor to ensure balance between the total number of trips produced and attracted in the city.

$$\text{Matching factor}= \frac{\sum_i O_i}{\sum_j D_j}\text{; where}$$

$\sum_i O_i$ : The sum of trips produced by all zones, I

$\sum_J D_j$ : The sum of trips attracted by all zones, j

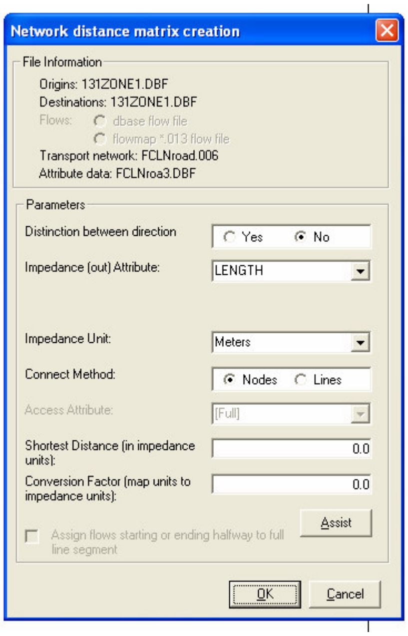
## 6.4. Trip distribution

The trip distribution simulates the travel pattern, by distributing the production and attraction end of trips, into different traffic zones, based on some deterrence function called decay function. The decay function used by UTS (2004/05) is different from the one used by flowmap7.2 and flowmap7.2 is the platform for analysis in this section. Thus, the gravity model is calibrated again in flowmap7.2.

### 6.4.1. Origin-destination distance matrix

In gravity model the underlying principle is the trip magnitude between the two zones is inversely proportional to the spatial separation of the two zones. Hence the spatial separation between the zones is computed using flowmap7.2.

Since the method is based on comparing the trip distribution based on existing network with a direct link network, two separation matrixes are computed. The first one is the network distance and the second is airline distance.




The network distance matrix is computed as the shortest distance between the origins and destinations along the network in Flowmap. The impedance attribute used is second. The average speed (20km/hr) obtained during the field survey was used to compute the impedance. So, the impedance is the length divided by speed in seconds. The shortest distance is assumed to be 5minutes. The off road speed used is 4km/hr.
Similarly, the airline (direct distance) between the origin-destination pairs is computed. In this case the impedance unit used is meter. The shortest distance is 500m.
The results are saved as a distance table in flowmap7.2.

### 6.4.2. Doubly constrained gravity model

The basic premises of the gravity model is the amount of interaction between two areas is supposed to be directly related to the attraction of the areas and inversely to the distance between the two. This shows the interaction between an origin and its surrounding destination decreases as the destinations are further away from the origins. The function describing the attraction value between origins and destinations within a certain distance is called a distance decay function.
Four types of decay functions are usually used:

- A neutral function
- An exponential function ( used by flowmap7.2)
- A power function
- A tanner function (Used by Urban Transport study 2004/05)

The distance function in the gravity model is calibrated based on the constraint the sum of the estimated number of trips from every origins must be equal to a preset number per origin and the sum of estimated number of trip to every destination must be equal to a preset number per destination. Thus, the model is called doubly constrained gravity model. The model consists of three formulas:

$$T_{ij} = A_i B_J O_i D_J f(C_{ij,}\beta)$$

$$A_i = 1 \Big/ \left( \sum_j B_j D_j f(C_{ij}, \beta) \right)$$

$$B_j = 1 \Big/ \left( \sum_i A_i O_i f(C_{ij}, \beta) \right)$$

$$f(C_{ij}, \beta) = \exp(-\beta C_{ij})$$

Where;

Tij= the estimated number of trips between origin i and destination j

Ai= the balancing factor for origin i

Bj= the balancing factor for destination j
Oi= the constraint value for origin i
Dj=the constraint value for destination j
β= the distance decay parameter
Cij= the distance between origin i and destination j

The balancing factors ensure the sum of estimated outflows per origin equals the known origin total and the sum of the estimated inflows per destination equals the known destination total.

In flowmap7.2, the doubly constrained gravity model is calibrated by recursively computing the value for 'β'. The trip between origin and destination pairs is computed using the previous formula using the value for "β", the distance table (distance matrix) and the trip production and attraction values. In addition to the distance table and the constraints the mean trip length is used in calibrating the model. This model is calibrated based on the network distance matrix and airline distance matrix for each trip type in flowmap7.2. I.e. work trip, education trip, other trip and non home based trip. The estimated values for 'β' are given in table6-2 for all the trip purposes.

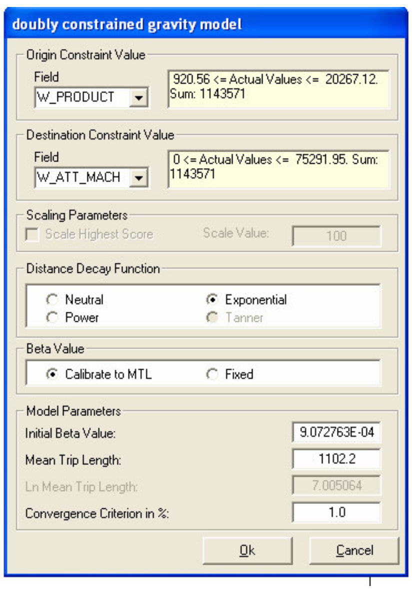



**Table 6-2 Parameters used to calibrate gravity model**

| Trip type | Mean trip length(sec) | Estimated 'β' value |
|---|---|---|
| Network based distance | | |
| Work trip | 1102.2 | 0.0026378 |
| Education trip | 847.8 | 0.0025028 |
| Other trip | 943.2 | 0.003446 |
| Non home based trip | 889.2 | 0.0040721 |
| Airline distance | | |
| Work trip | 1102.2 | 0.0021092 |
| Education trip | 847.8 | 0.0014323 |
| Other trip | 943.2 | 0.0024559 |
| Non home based trip | 889.2 | 0.0028396 |

## 6.5. Results

### 6.5.1. Travel demand density

The resulting flow files are converted into direct OD lines in flowmap7.2. The direct OD lines over each area are identified through query operation and their flow summed to compute the total flow for each area. This result could be improved by using smaller zones.

The limitation of converting the resulting OD interaction into direct OD line is it assumes the flow occurs along the direct OD link. However, the analysis can be improved by computing the shortest route along network and assigning the resulting OD interaction to this route.

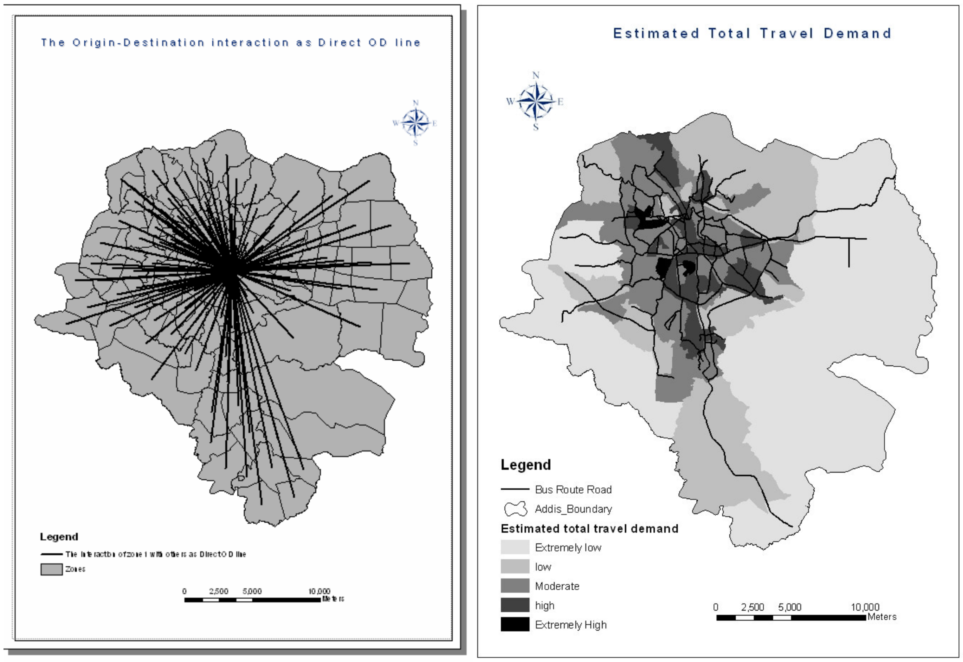



**Figure 6-2 a) OD Interaction as Direct line b) Estimated travel demand**

The results show the spatial pattern of the travel demand is the same for all trips by purpose i.e. the travel demand is higher in the central areas, where the road infrastructure, Anbessa service and the CBD are located, and northern end and southern end of the city for all trip types by purpose. The demand is lower in the western and eastern part of the city. Comparing this result with the spatial distribution analysis result in chapter5, two characteristics about Anbessa service are observed.

- Anbessa routes are allocated in the areas where the travel demand is high; however, the service quality is poor and falls short of demand as characterized by long waiting time and over crowding.
- The other point is from spatial equity point of view, since there are no service in the low travel demand area it is not giving equitable service to all groups.

It therefore shows that it needs to improve the level of service in the high demand area and expand the service to the low service area. However, with the current capacity of Anbessa it is not possible to satisfy these requirements. Thus, the mild participation of private sectors in providing services to areas with reasonably equal fair to Anbessa should be further encouraged. Anbessa should be strengthened with more resource.

In line with questionnaire survey results, most trips are made either for work or education purpose. The map below shows the travel demand estimated by purpose at zone level. The non home based trips are very few compared to the home based trips.

The travel demand estimated is maximum in Zone35 for work; other and non-home based trips while the maximum demand for educational trip is in zone89 (for Zone Identifiers see appendix). In general the total travel demand is very high in zones 8, 35, 20 and 37 while the newly expanding eastern zones have very low demand.

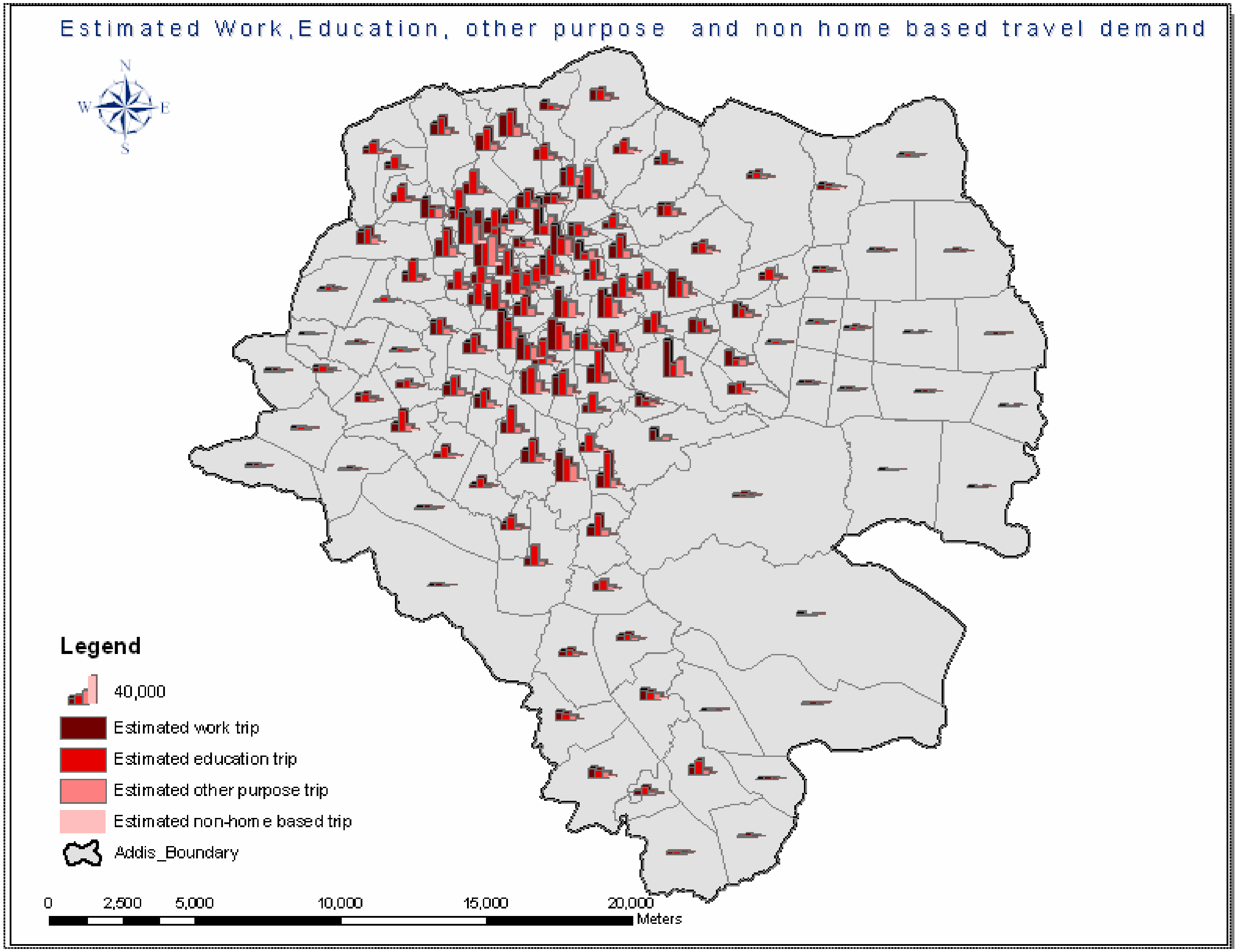



**Figure 6-3 A map comparing estimated trips by purpose**

### 6.5.2. Flow figure

The flows are assigned to the network link in flowmap7.2. The results are shown in the figure below. It shows the nearest road section to most travel demand is the one next and to the west of the major road running from the north to south. However, fig5.5 shows Anbessa service frequency is large on the major road and most routes are aligned on this section. This implies that, Anbessa's provision of service along the major road is dictated by the availability and quality of infrastructure. Thus, trips are diverted from the road parallel in the west to the major road to get service, however, this results increase in walking distance.

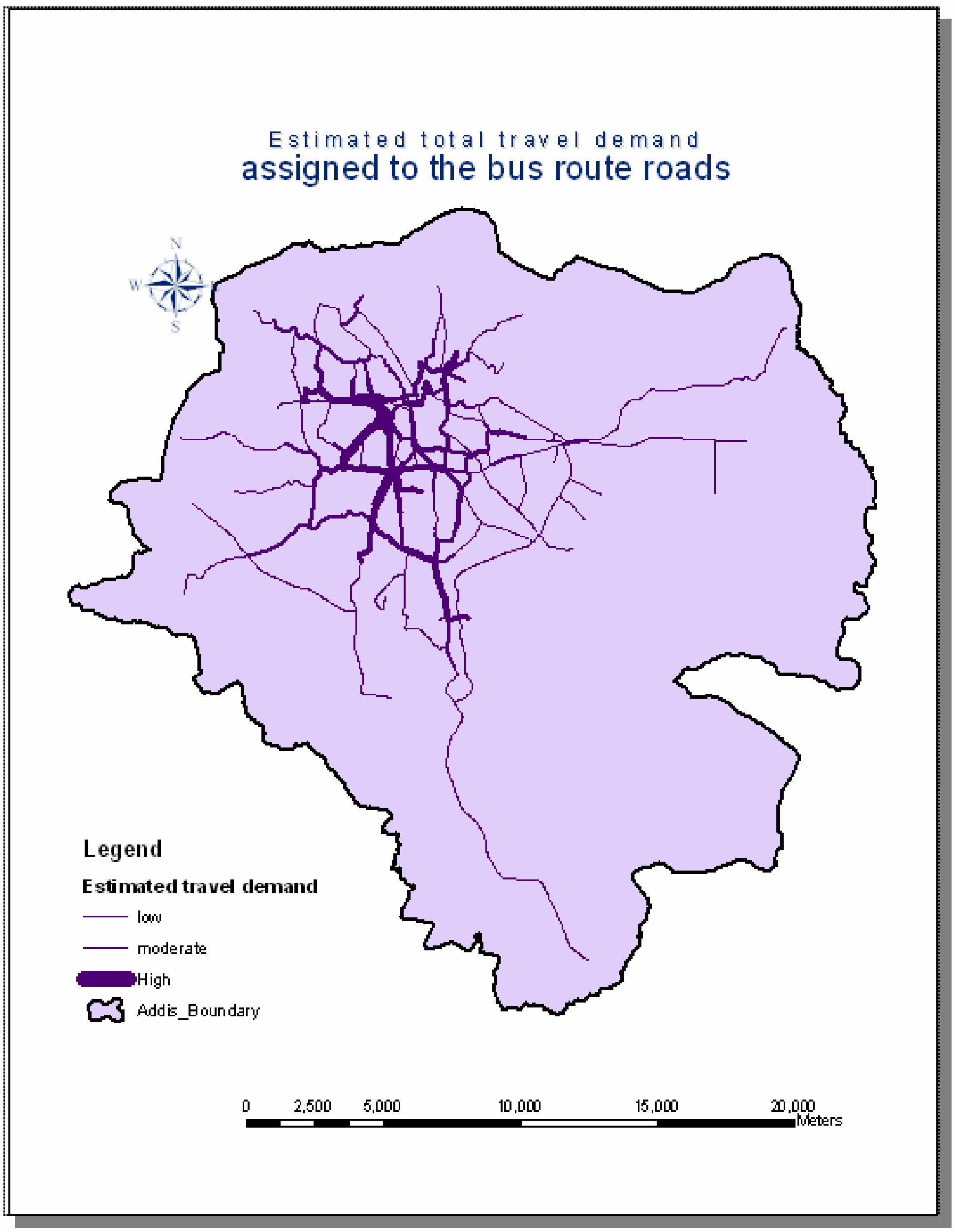



**Figure 6-4 Estimated trip assigned to the nearest bus route**

The travel demand assigned to the network can be compared with the existing capacity. The current distribution of bus per route ranges from 2 to 10. The mode for bus distribution per route is 4. The capacity per road segment is computed by multiplying the number of overlapping routes with the mode and the capacity per bus. For example if 9 routes overlap on one road section, then its capacity is nine multiplied by 400. Taking the ratio of the potential trip demand assigned per road segment and capacity calculated as explained above, areas where vehicle plied is deficient can be identified. The minimum demand to capacity ratio is 1.18. This indicates there is vehicle deficit on all the road segments. For some links as shown in Figure 6-5, the ratio is very high. Such big demand to capacity ratio is expected based on the assumptions that:

- Trips originate at zone center and are assigned to the network element based on the distance to these centers; and
- The mode underestimates the number of bus distributed in the central areas or short routes.

Despite the aforementioned limitation, the result shows the spatial variation of the demand to capacity ratio. The vehicle shortfall is critical in the central areas compared to the peripheries. As shown in Figure 6-5 below, the dark brown color shows segments where the ratio is more than 35. It implies that for these areas to satisfy the demand, each needs at least 35 times more capacity than the current one. In most road segments, the ratio is in the range 3.5 to 35, which shows at least 3.5 times more capacity is required to satisfy the demand.

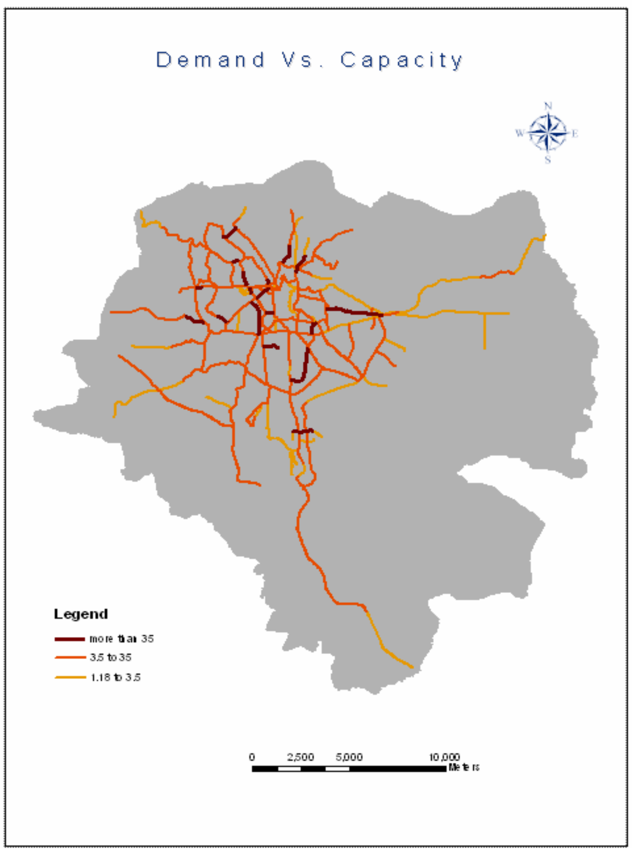



**Figure 6-5 the spatial distribution of variation in demand to capacity ratio**

### 6.5.3. Missing link areas

Taking the difference between the OD matrixes resulting from the trip distribution based on the direct OD link and the existing route road shows two important areas. The total OD matrix size should be 131 ‘X’ 131 which are 17161 however the size of OD matrix from the existing road network is 15416. This shows around 2000 OD pairs are totally missing or the interaction between these pairs is zero. The possible reasons for this are either the network resistance is large or it does not provide connections for these areas. The largest distance from any origin or destination to the route network is 7093.278seconds while the mean travel time used for calibration is 1102.2sec.The mean travel time given by World Bank study is so small that it enhances short distance interactions and discourages long distance interaction. Thus, results such big number of OD pairs with zero trip value. The OD pairs are mainly the ones which connect zone 61, 93, 99, 111, 112, 113, 114, 131, 136, and 137 with the other zones. In other words, the existing network does not provide a link for these zones with the others. Thus, the interactions of these zones are limited either to the intra or neighbours. The second important characteristics is the difference is very high for 12 OD pairs, which means the resistance of the existing route road is very large for these pairs. Hence, it is highly prosperous that a link is missing between the OD pairs shown below.

Attributes of Capacity_link

| LABEL1 | LABEL2 | Difference |
|---|---|---|
| 78 | 22 | 2729 |
| 12 | 35 | 2933 |
| 14 | 35 | 2916 |
| 16 | 35 | 4656 |
| 31 | 35 | 2900 |
| 32 | 35 | 2875 |
| 36 | 35 | 2993 |
| 77 | 35 | 4142 |
| 78 | 35 | 5844 |
| 86 | 35 | 3286 |
| 89 | 35 | 3194 |
| 78 | 79 | 3108 |

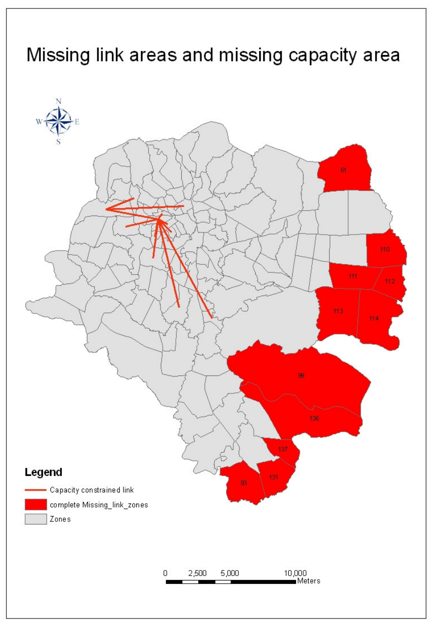



**Figure 6-6 a) Table showing missing links b) map showing missing links**

The deficiencies in the route network reflected from the above result are either due to the small mean travel time used for calibrating the gravity model or result from problem in the network. During the field survey however it was noticed that the average travel time for Anbessa from origin to destination is in the range 40 to 50 minute. The data of 1998EC shows the average volume of passenger travel length is medium i.e. 16 to 20km, which also needs 40 to 50min at a speed of 23km/hr. And also centralized location of services like school, health centre, market and other public services make longer waiting time inevitable. Thus, calibrating the model using 45minutes as the average travel time reduces the number of OD pairs with zero trip value considerably and hence shows areas where there is critical deficiency in the transport network. The red area in the map shows areas which are not connected by the route network with other areas. And the trip interaction is only limited to intra-zone.

#### 6.5.4. Can spatial deficiencies improve by plying Anbessa service along the major roads?

The missing link analysis has identified that there are service spatial deficiencies. These deficiencies can be solved by enhancing the existing route network with new ones. Economically and physically feasible option for such solution would be to ply service along the existing road network than constructing new roads. Thus, this section analyzes the possible improvements' by enhancing the existing route network with major road elements which could be used as a route but not used.

A new OD skim matrix is computed using the new route, 45minute is used as the mean travel time to calibrate the gravity model which generates OD trip distribution matrix. The size of the matrix 17161 indicates that there is an interaction from every origin to every destination which overcomes the problem of connectivity of some zones with the existing bus route. Thus indicates that if additional bus service is provided along road networks the problem of connectivity of zones or accessibility will improve. Furthermore, it reduces the resistance of moving from zones to zones. The figure below shows links where the resistance has reduced and the trip interaction has improved at least by 1000trips.

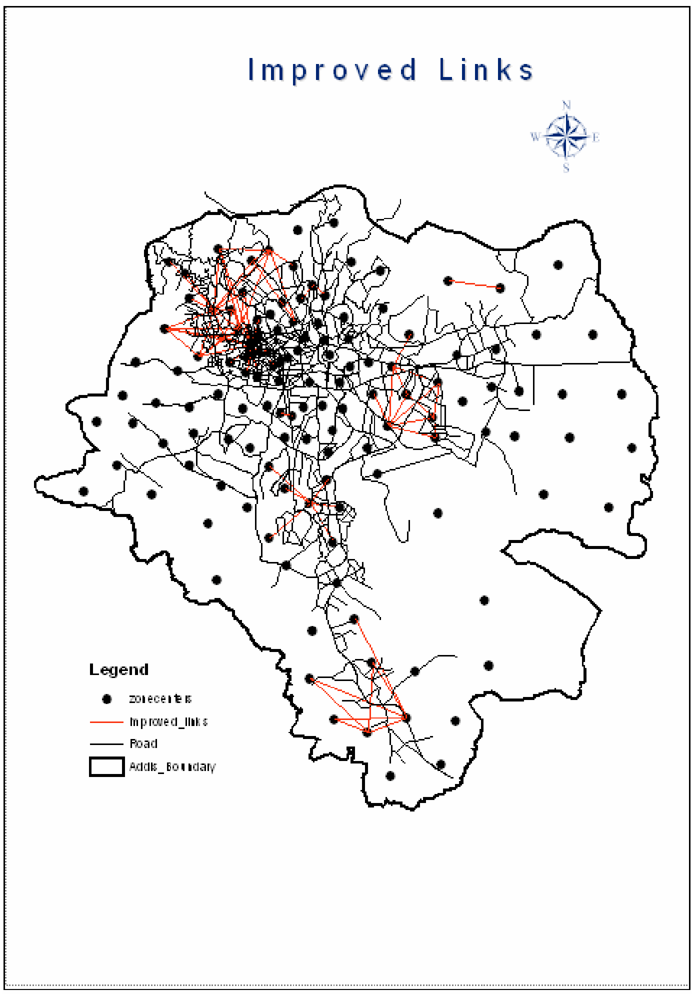



**Figure 6-7 A map showing improved OD interaction**

Assigning the OD distribution matrix to the road network gives the distribution of trip on the existing network. If we select the road elements which carry at least one trip to extend the existing route we will have the following (Figure 6-8c) road elements as potential routes to carry trips. We select those which will carry at least one trip to account for the fact that the road segments are digitized as many continuous small segments. This result can be further refined by setting a threshold value for the number of trips. The figure below shows the three networks i.e. road network, trip assigned and proposed route.

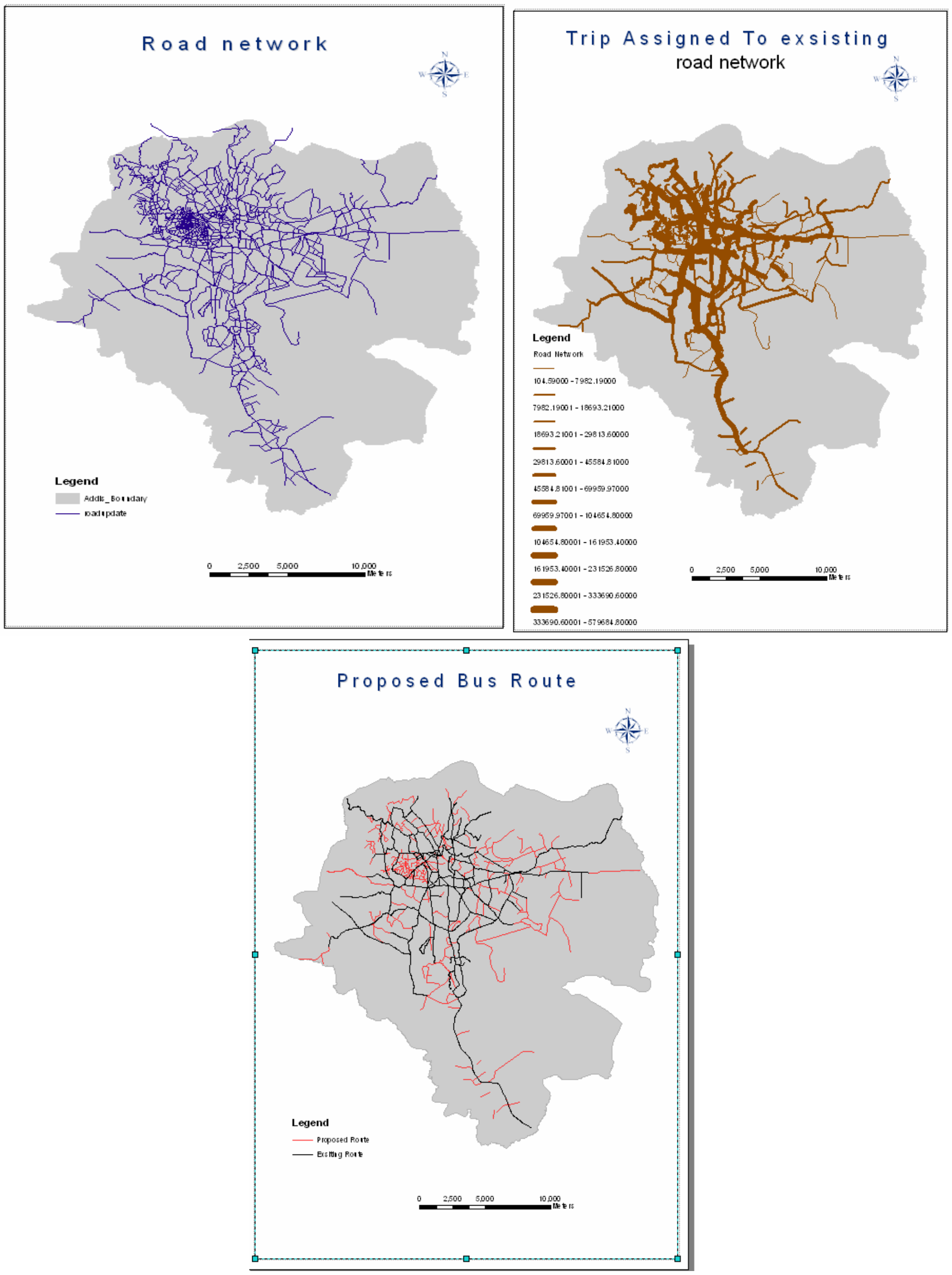



**Figure 6-8 a) Road network B) trip assigned to road network c) Proposed Route road**

### 6.5.5. What is the effect of using the improved road network on the service efficiency indicators?

Using the proposed road network to ply service will improve the availability of road for the service and encourages for the injection of more bus into the system thus contributes to the improvement of the general infrastructure availability. As the largest distance from any origin or destination to the network is 4856.583seconds, it reduces the worst walking distance (7093seconds) to get service considerably and hence the overall quality of the service. 89.83% of the total population can get service within a walking distance of 500m and also 97.4% of the total population can reach the service in 1km distance. Compared to the existing route the population covered in 500m distance has increased by 18.48% while the increase is 9.7% for 1km distance. Besides the population walking more than 2.5km to reach the service has reduced by 1.05%. The percentage of low, middle and high income group people who can get service within 500m has increased to 84.6%, 92.1% and 91.7% respectively. As all groups are getting better service we can say that it has contributed to the overall equity and also the spatial equity has also increased due to the extended service to the peripheries. Though, it is difficult to measure and quantify the productivity gained, as the opportunity to get service is improved by taking the service closer to the people the passenger volume carried will increase and also the vehicle-km covered will increase. Thus the productivity of the system will improve. In conclusion extending network to overcome spatial deficiencies contributes to improving infrastructure availability, elements of quality like walking distance, proximity, equity and productivity thereby improves the overall efficiency of the system. The relative contribution of this improvement on the different parameters considered is depicted as shown below.

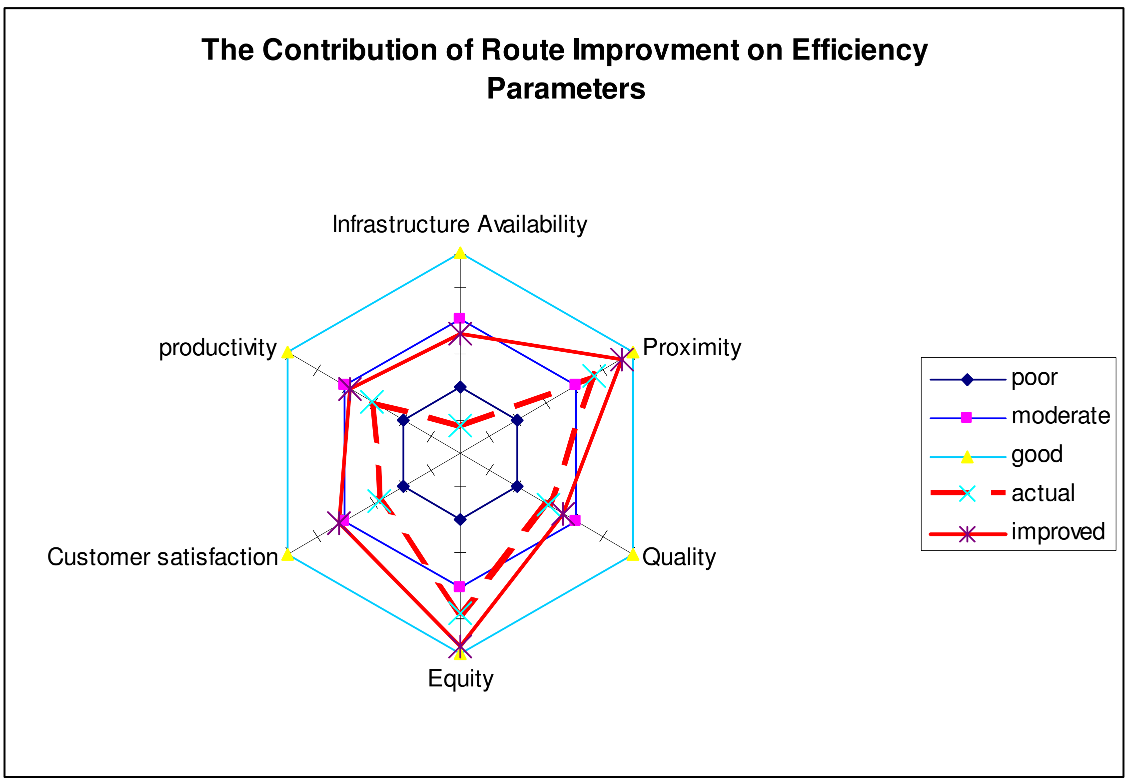



**Figure 6-9 Overall performance parameters**

# 7. Conclusions and Recommendations

## 7.1. Conclusions

The Anbessa transport system measures system-wide performance and individual performance using Passenger volume, Vehicle-km and revenue on monthly basis. However, these parameters measure only the productivity of the system or how much service is provided. For a complete evaluation of system efficiency other variables have also to be considered. These include customer satisfaction, quality of service, proximity, equity and infrastructure availability. These parameters must be considered together, not individually, with the goal to strike a balance between them, since improvements in one measure can often come at the expense of performance in the other.

Despite the fact that the lack of defined public transport policy made it difficult to evaluate and combine indicators in the context of Anbessa, the ‘radar’ visualization technique proved to be the most appropriate method. It is better than other techniques that compute a single value as the score for efficiency, such as standardizing and aggregating and the fuzzy logic theory. The radar technique was chosen because of its capability to show the values for each indicator simultaneously at a go in addition to its methodological simplicity. The indicators considered are interrelated i.e. improvement in one can improve the other. So the radar visualization technique can further be used to visualize the effect of improving one parameter on the others. And also it can be used to evaluate and prioritize improvement options.

The current Anbessa service is constrained because of limited physical infrastructure in Addis. The total road infrastructure in the city is less than 8% of the built up area of which the arterials and sub arterials have a small share. This limits the extent and spatial distribution of the service to a few corridors. The few corridors are aligned in the central part of the city along major roads. Thus, it caters its service to only 71% of the total population within a walking distance of 500m. 93% of high income people, 90% of middle income and 78% of low income people can get service within a walking distance of 1km. These results will improve considerably if roads other than arterial and sub-arterials are upgraded and used to ply the bus service. As shown in figure6.3 the route network based travel demand from zones (61,110, 111, 112, 113, 114, 99, 136, 137, 131, and 93) to the other zones is zero. This indicates that the aforementioned zones are not accessible via Anbessa city bus. Consequently, we can say that the low income group people and people living in the peripherals are disadvantaged.

The number and quality of vehicles available is another factor which determines the system efficiency. Parameters like frequency, waiting time, crowding, and the number of seats depend on vehicle type and quality. That the average number of bus per route is four, and the average headway time is 30 minutes suggest long waiting time; over-crowding and lack of seats are also inevitable characteristics of the Anbessa service. This was confirmed by the questionnaire survey results, which identified long waiting time, over-crowding, theft and lack of sufficient seats as the main discouraging factors for customers. The service is thus not satisfactory from a customer perspective, and the quality offered is poor on the one hand and on the other the system is overstretched at the cost of quality to reach the demand.

The average passenger volume per bus during the peak hour, especially for short routes, exceeds the upper limit given for a well-performing bus system. This shows that there is a high demand, though the capacity available is limited. On the other hand the average vehicle-km covered is below the lower limit; mainly due to poor road conditions, congestion, frequent break-downs and aging vehicles, and lack of proper maintenance and repair. The above contradicting findings suggest that the vehicles will carry over capacity per trip to cater for the current demand. The negative net revenue collected by the enterprise indicates that its operations are not profitable.

The spatial pattern of travel demand and service distribution is the same i.e. the travel demand is large in the central areas where the Anbessa service is available. However, as discussed above the quality is poor. This means that the demand exceeds the service offered in these areas and hence the need to improve service quality and capacity in these areas. The current route distribution does not provide a link for zones 61, 110, 111, 112, 113, 114, 99, 136, 137, 131, and 93 with others. It also provides larger resistance to access zones 35 and 22 from 12 other zones as shown in the fig6.6. Despite the availability of better service on the major road sections traversing the city from north to south, the nearest road section to most travel demand is the one parallel and to the west of this major transport corridor.

The missing link computation method adopted can give a quick glance at the connectivity between areas using the existing route network and also can be used to evaluate opportunities for further development. However, using the separation between the two areas as the only deterrence factor in calibrating the gravity model works better for simple cases where frequency, cost and other parameters are not a determining factor of the interaction. The aforementioned parameters however influence the performance of bus services. Thus, they should be considered together with the separation in calibrating the decay function as a cost for better result.

In general the current efficiency of the Anbessa organization is poor. There are service deficiencies in some place, though the system is overstretched for the current fiscal and financial capacity at the cost of quality. Moreover the bus route network has deficiencies that make equal spatial accessibility of the service difficult. On the other hand the increasing demand for affordable public transport due to population growth, city expansion and urbanization and modal shift in search of affordable service is increasing the pressure on Anbessa service. Thus opportunities for improvements should be identified and implemented to tackle the spatial and non-spatial problems of the system and thereby make the system attractive and productive.

## 7.2. Recommendations

The research has investigated the current Anbessa city bus service and the bus route network deficiencies which prevent equitable spatial accessibility to all groups based on the available data. It has identified deficiencies and opportunities that can be developed for improvement. More comprehensive and robust results can be obtained by investigating the temporal characteristics; refining the spatial analysis to indicate the missing corridors, stops and other network elements; and also comparing and contrasting the results for Anbessa in the context of the general public transport system available. This however, calls for better data quality and time. Thus, it provides an opportunity for further research. Some recommendations for improvement are given below.

The main difficulty in measuring the efficiency of Anbessa Transport system encountered is the lack of defined public transport policy. So for better and accurate evaluation, monitoring and improving the performance a target goal should be defined in the policy for the efficiency parameters.

One of the challenges of Anbessa service at present is resource limitation. The ratio of number of bus to population 1: 6500 indicates Anbessa can not satisfy the demand. Hence, the private sector should be encouraged and stimulated to invest in this sector through appropriate tax incentives and affordable arrangements for financial credit.

Despite the availability of service in the central areas, the quality is poor. Thus to improve the quality, the frequency of the service should be increased in these areas. Besides, some links are missing along the bus route for which the appropriate roads can be selected and upgraded into new routes.

The newly-expanding city peripheries are lacking in service and Anbessa is already overstretched. So in order to meet the mobility demand of those areas, Anbessa routes should be extended and upgraded and also cost effective feeder services should be provided.

The prevailing traffic congestion within the city makes Anbessa's operations more difficult. Thus, bus priority measures like separate lanes, providing flyovers and giving priority for bus turning movements at over loaded junctions should be implemented. Providing separate bus lanes should be considered along the nearest road section to the highest trip demand segment, which is to the west of the major road traversing the city north-south.

Some of the apparent inefficiencies and low productivity are the result of poor operation reflected as unkind treatment of customers by the bus crew. This is an indication of frustrated and unmotivated workforce, hence the need to provide incentives for operations, maintenance, and administrative staff in order to encourage and motivate them for better performance.

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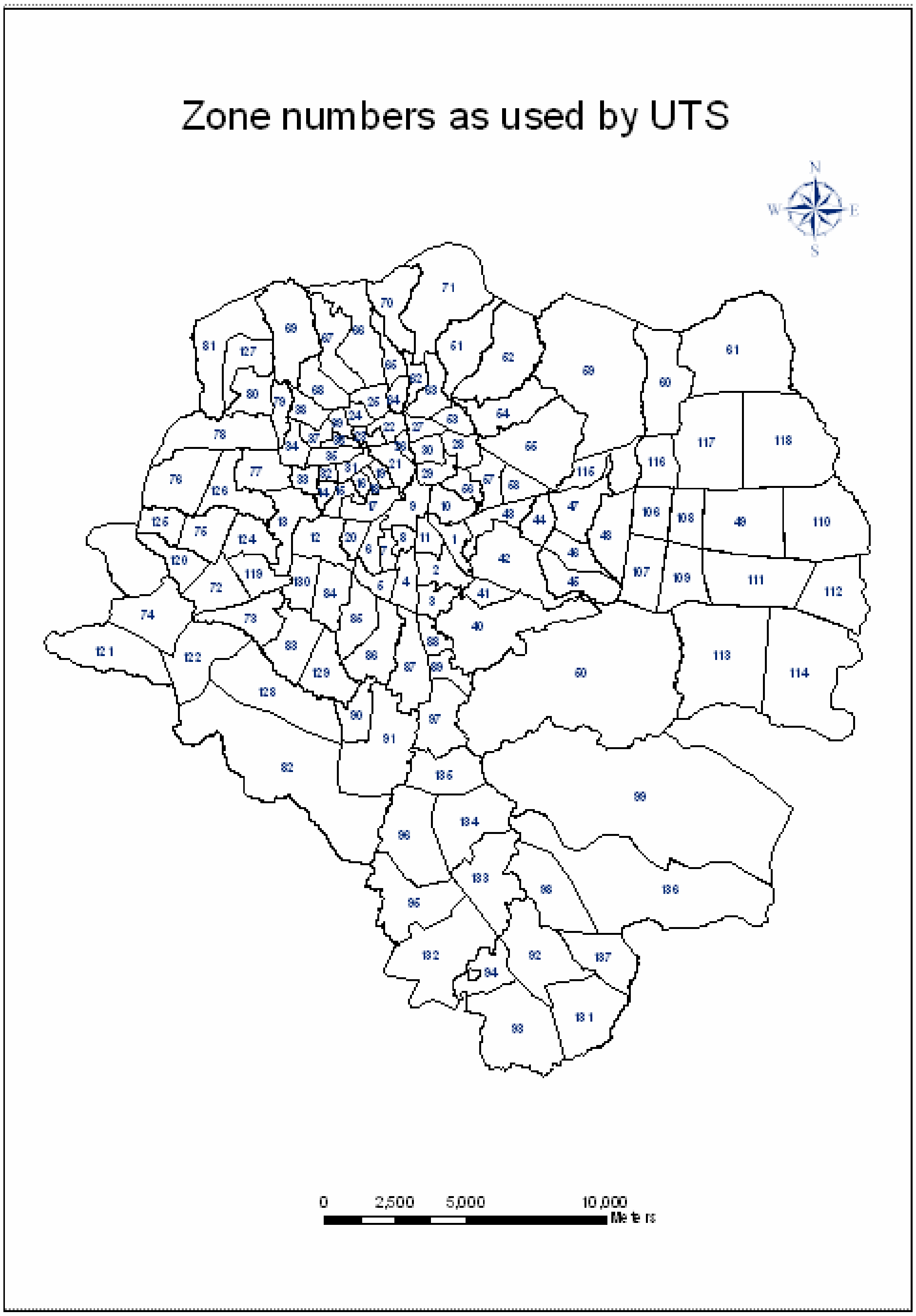
# Appendix A- Socio economic data

This data is obtained from the urban transport study 2004/2005. It divides the city into 131 based on the smallest administrative units called 'kebele'. The data collected includes the number of population, student, workers and employment opportunities. The map below shows the 131 zones with their zone identifier number and the attributes are presented on the table.



| Zone ID | Population | Resident Students | Vehicles | Resident Workers | Employees |
|---|---|---|---|---|---|
| 1 | 29556 | 8757 | 1368 | 4379 | 6,765 |
| 2 | 38281 | 15035 | 1066 | 8744 | 7,672 |
| 3 | 24273 | 8395 | 5840 | 5658 | 1,973 |
| 4 | 37820 | 12685 | 117 | 10923 | 12,061 |
| 5 | 33057 | 11991 | 324 | 8750 | 15,219 |
| 6 | 23415 | 7057 | 0 | 4972 | 18,374 |
| 7 | 36896 | 10666 | 288 | 6198 | 2,432 |
| 8 | 37969 | 11940 | 119 | 9433 | 23,756 |
| 9 | 23022 | 7276 | 760 | 5430 | 22,873 |
| 10 | 39232 | 8805 | 777 | 9970 | 17,454 |
| 11 | 30368 | 8358 | 836 | 10216 | 4,860 |
| 12 | 38533 | 10261 | 218 | 9934 | 1,643 |
| 13 | 29776 | 7152 | 933 | 6608 | 6,900 |
| 14 | 35588 | 11443 | 210 | 9028 | 1,038 |
| 15 | 38255 | 12303 | 0 | 9408 | 4,951 |
| 16 | 39115 | 11421 | 373 | 12019 | 306 |
| 17 | 35769 | 8504 | 270 | 6479 | 5,461 |
| 18 | 21731 | 7322 | 78 | 7088 | 5,837 |
| 19 | 27162 | 7461 | 699 | 5829 | 5,268 |
| 20 | 46541 | 13885 | 257 | 12599 | 30,934 |
| 21 | 37199 | 11541 | 1121 | 10869 | 6,150 |
| 22 | 37438 | 4265 | 158 | 11216 | 27,423 |
| 23 | 34255 | 1865 | 1187 | 6953 | 1,398 |
| 24 | 20503 | 6609 | 0 | 5592 | 1,455 |
| 25 | 39924 | 8206 | 473 | 8837 | 4,881 |
| 26 | 21846 | 7773 | 670 | 5093 | 25,020 |
| 27 | 32200 | 5691 | 599 | 8088 | 4,072 |
| 28 | 41189 | 10266 | 495 | 9277 | 3,958 |
| 29 | 34259 | 10575 | 0 | 6830 | 1,983 |
| 30 | 21812 | 2819 | 297 | 5787 | 11,747 |
| 31 | 44116 | 11329 | 267 | 11862 | 2,349 |
| 32 | 34138 | 9448 | 178 | 8913 | 446 |
| 33 | 30386 | 8446 | 0 | 5660 | 1,674 |
| 34 | 39188 | 12943 | 360 | 8988 | 9,255 |
| 35 | 48035 | 12799 | 249 | 13131 | 50,214 |
| 36 | 35037 | 10199 | 120 | 9719 | 1,433 |
| 37 | 38105 | 12898 | 689 | 8074 | 26,936 |

| Zone ID | Population | Resident Students | Vehicles | Resident Workers | Employees |
|---|---|---|---|---|---|
| 38 | 32082 | 14002 | 680 | 7613 | 2,209 |
| 39 | 37033 | 10344 | 0 | 9516 | 2,854 |
| 40 | 26384 | 1377 | 4589 | 11013 | 8,853 |
| 41 | 26384 | 2932 | 1099 | 8428 | 3,744 |
| 42 | 37289 | 6132 | 5138 | 12098 | 27,803 |
| 43 | 37770 | 12590 | 323 | 11137 | 6,504 |
| 44 | 36937 | 7221 | 1111 | 12497 | 2,239 |
| 45 | 26384 | 6957 | 525 | 7876 | 1,257 |
| 46 | 26384 | 3873 | 2179 | 9198 | 10,678 |
| 47 | 36937 | 7027 | 1441 | 13694 | 1,613 |
| 48 | 37607 | 9678 | 236 | 7947 | 9,740 |
| 49 | 6833 | 932 | 0 | 3727 | 3,970 |
| 50 | 7322 | 2371 | 0 | 1738 | 474 |
| 51 | 27109 | 8652 | 433 | 6201 | 3,351 |
| 52 | 27958 | 6926 | 0 | 4617 | 2,000 |
| 53 | 19219 | 6443 | 0 | 4666 | 1,693 |
| 54 | 32892 | 8689 | 207 | 7654 | 11,251 |
| 55 | 29397 | 8183 | 455 | 7273 | 5,897 |
| 56 | 37398 | 9285 | 1161 | 9801 | 3,300 |
| 57 | 30495 | 8713 | 1005 | 8713 | 5,462 |
| 58 | 32440 | 8196 | 462 | 8312 | 19,509 |
| 59 | 40700 | 11035 | 237 | 9018 | 2,045 |
| 60 | 20052 | 5529 | 165 | 4786 | 7,733 |
| 61 | 17941 | 5741 | 0 | 4844 | 2,155 |
| 62 | 32018 | 9364 | 0 | 6947 | 9,597 |
| 63 | 41581 | 15762 | 150 | 8856 | 2,078 |
| 64 | 20115 | 3468 | 0 | 6705 | 574 |
| 65 | 33125 | 10717 | 0 | 9603 | 8,058 |
| 66 | 42420 | 14696 | 152 | 11817 | 16,767 |
| 67 | 35289 | 11450 | 751 | 10605 | 6,850 |
| 68 | 35776 | 11798 | 1149 | 7814 | 4,036 |
| 69 | 36937 | 12182 | 130 | 6480 | 10,624 |
| 70 | 23627 | 3731 | 311 | 7772 | 4,887 |
| 71 | 35249 | 9479 | 296 | 9923 | 5,060 |
| 72 | 40755 | 10631 | 403 | 12484 | 7,446 |
| 73 | 37992 | 11462 | 129 | 7470 | 1,019 |
| 74 | 15031 | 5963 | 248 | 3354 | 6,212 |

| Zone ID | Population | Resident Students | Vehicles | Resident Workers | Employees |
|---|---|---|---|---|---|
| 75 | 10686 | 3130 | 153 | 2824 | 1,577 |
| 76 | 18604 | 4370 | 80 | 2445 | 1,166 |
| 77 | 36313 | 13068 | 377 | 7288 | 1,719 |
| 78 | 39573 | 12281 | 152 | 11372 | 6,355 |
| 79 | 16937 | 4759 | 350 | 3080 | 17,408 |
| 80 | 25405 | 10343 | 502 | 6628 | 1,707 |
| 81 | 34395 | 11685 | 0 | 8599 | 2,354 |
| 82 | 6332 | 2111 | 0 | 2111 | 467 |
| 83 | 24484 | 10202 | 360 | 6601 | 1,238 |
| 84 | 47269 | 19444 | 582 | 10944 | 15,915 |
| 85 | 48018 | 16567 | 1685 | 9126 | 4,555 |
| 86 | 44216 | 14691 | 2282 | 11696 | 3,379 |
| 87 | 44367 | 15153 | 2867 | 9692 | 28,652 |
| 88 | 26384 | 7682 | 334 | 4843 | 1,169 |
| 89 | 48546 | 18393 | 3317 | 10855 | 1,529 |
| 90 | 26384 | 8795 | 0 | 5363 | 5,439 |
| 91 | 32716 | 14590 | 0 | 6484 | 6,164 |
| 92 | 32529 | 10648 | 0 | 6553 | 3,150 |
| 93 | 16259 | 3495 | 0 | 3799 | 1,674 |
| 94 | 25587 | 6727 | 0 | 4445 | 4,060 |
| 95 | 37176 | 12218 | 483 | 6057 | 17,710 |
| 96 | 42986 | 15370 | 0 | 7248 | 13,889 |
| 97 | 31718 | 10092 | 123 | 6554 | 3,930 |
| 98 | 7102 | 2367 | 0 | 2367 | 1,994 |
| 99 | 8557 | 3775 | 0 | 1888 | 0 |

# Appendix-B Data From Anbessa organization

**B-1) Vehicle distribution and trend data**

During the field work secondary data were collected from Anbessa city bus enterprise Organization record. The table below shows the trends of Anbessa bus dispatch and the respective service offered and revenue collected by the company since 1987 to 1996 according to Ethiopian calendar. The Ethiopian Calendar lags by 8 years.

| Year | Number of routes | Dispatch Buses | Bus hours in thousand | Passengers p in million | Km k in million | Revenue R in million |
|---|---|---|---|---|---|---|
| 1987 | 42 | 150 | N.A | 78 | 6.5 | 26.3 |
| 1988 | 42 | 112 | N.A | 55 | 4.9 | 18.7 |
| 1989 | 42 | 231 | N.A | 102 | 9.2 | 56.9 |
| 1990 | 75 | 260 | N.A | 165 | 15.6 | 93.6 |
| 1991 | 80 | 361 | 1274.5 | 192 | 18.8 | 113.2 |
| 1992 | 85 | 401 | 1354.5 | 209 | 20 | 120.2 |
| 1993 | 85 | 383 | 1269 | 201 | 19.1 | 123.5 |
| 1994 | 85 | 405 | 1258 | 187.5 | 18.7 | 117 |
| 1995 | 93 | 462 | 1474.1 | 210.6 | 22.1 | 120.6 |
| 1996 | 93 | 463 | 17633.2 | 249.1 | 26.4 | 128.6 |

**B-2) Route characteristics in hamle 1998 Ethiopian calendar**

| Route NO. | ORIGIN-DES | NO.OF BUS | Length(Km) | TARIF | Travel time(min) | DAILY TRIP |
|---|---|---|---|---|---|---|
| 1 | KASANCES--ADISKETEMA | 2 | 8.1 | 0.50 | 37 | 44 |
| 2 | Kore Mekanisa-Addis Ketema | 5 | 11.1 | 0.50 | 48 | 84 |
| 3 | Ayer Tena-Minilik Square | 10 | 10.8 | 0.50 | 44 | 194 |
| 4 | Kaliti-Addis Ketema | 6 | 19.4 | 0.75 | 69 | 71 |
| 5 | Kore Mekanisa-Minilik Square | 4 | 12.7 | 0.50 | 48 | 68 |
| 6 | Kera-Semen Addisu Gebeya | 10 | 9.9 | 0.35 | 41 | 200 |
| 9 | Bras cilinic Bole School-Piassa | 4 | 10.5 | 0.50 | 40 | 88 |
| 10 | Kotebe Teacher Training-Piassa | 6 | 12.7 | 0.50 | 49 | 102 |
| 11 | Mesalemia-Minilik Hospital kolfe | 4 | 10.0 | 0.50 | 40 | 80 |
| 12 | Ferencay Film Center-Addis Ketem | 8 | 9.9 | 0.35 | 41 | 160 |
| 13 | Bella-Addis Ketema | 4 | 9.9 | 0.50 | 41 | 80 |
| 14 | Saris Abo-Piassa | 4 | 12.3 | 0.50 | 48 | 70 |
| 15 | MEGENAG---ADISKETEMA | 2 | 10.4 | 0.50 | 46 | 36 |
| 16 | Kidane Mihiret-Addis Ketema | 6 | 7.9 | 0.25 | 40 | 122 |
| 17 | Kuskuam-Addis Ketema | 6 | 9.1 | 0.35 | 45 | 108 |
| 18 | Keraniyo-Addis Ketema | 6 | 7.3 | 0.35 | 45 | 110 |
| 19 | Asko-Piassa | 6 | 12.2 | 0.50 | 50 | 108 |
| 20 | Dil Ber-Addis Ketema | 3 | 8.6 | 0.50 | 31 | 79 |
| 21 | Fetno Derash-Addis Ketema Piassa | 3 | 8.6 | 0.50 | 30 | 80 |
| 22 | Samit Leghare | 2 | 12.3 | 0.50 | 43 | 37 |
| 23 | Lamberet-Addis Ketema | 4 | 12.4 | 0.50 | 50 | 64 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 24 | Burayu-Degol Square | 3 | 17.7 | 0.75 | 75 | 32 |
| 25 | Legehar-Akaki | 6 | 19.0 | 0.75 | 73 | 70 |
| 26 | Addis Ketema-Sebeta | 4 | 25.5 | 1.25 | 62 | 52 |
| 27 | Legehar-Saris Abo Korki F | 8 | 11.4 | 0.50 | 50 | 138 |
| 28 | Asko Sansuz-Addis Ketema | 4 | 11.1 | 0.50 | 42 | 79 |
| 29 | Addisu Sefer-Addis Ketema | 6 | 12.7 | 0.50 | 55 | 93 |
| 31 | Legehar-Shiro Meda | 8 | 7.4 | 0.25 | 30 | 210 |
| 32 | Hana Mariam-Legehar | 6 | 10.6 | 0.35 | 43 | 116 |
| 33 | Kotebe Gebriel-Arat Killo | 5 | 11.4 | 0.50 | 44 | 93 |
| 34 | Gofa Camp-Addis Ketema | 4 | 9.8 | 0.35 | 45 | 72 |
| 35 | Cherkos-Addis Ketema Mesalemia k | 3 | 9.8 | 0.50 | 50 | 48 |
| 36 | Kara Kore-Legehar | 4 | 11.7 | 0.50 | 52 | 64 |
| 37 | Keraniyo-Minilik Square | 4 | 12.0 | 0.50 | 52 | 64 |
| 38 | Gofa Camp-Sidist Killo | 4 | 11.0 | 0.50 | 45 | 72 |
| 39 | Bole School-Addis Ketema | 4 | 9.6 | 0.50 | 40 | 88 |
| 40 | Kara Alo-Addis Ketema | 3 | 17.9 | 0.75 | 65 | 36 |
| 41 | Eyesus-Merkato | 4 | 8.5 | 0.25 | 40 | 80 |
| 42 | Megenagna-Bole Legehar | 4 | 9.8 | 0.35 | 35 | 95 |
| 43 | Menagesha-Merkato | 2 | 30.2 | 1.50 | 90 | 16 |
| 44 | Legedadi-Merkato | 2 | 30.4 | 1.50 | 90 | 16 |
| 45 | Legehar-Dil Ber | 3 | 8.6 | 0.50 | 35 | 72 |
| 46 | Gergi-Arat Killo | 6 | 11.2 | 0.50 | 50 | 99 |
| 47 | Yenegew Fire School-Merkato | 2 | 8.3 | 0.35 | 35 | 48 |
| 48 | Bole Michael Square-Minilik Squa | 3 | 10.9 | 0.50 | 42 | 61 |
| 50 | Total No. 3 roundabout-Megenagna | 3 | 12.1 | 0.50 | 45 | 54 |
| 51 | Behere Tsige-Lagehar Balcha | 3 | 10.1 | 0.50 | 45 | 55 |
| 52 | Gergi-Merkato | 6 | 14.1 | 0.50 | 59 | 92 |
| 53 | Bole-Shiro Meda | 3 | 11.5 | 0.50 | 40 | 62 |
| 54 | Lafto-Lagehar | 4 | 9.5 | 0.50 | 42 | 77 |
| 55 | Legehar-Ferencay Kella | 2 | 9.5 | 0.50 | 38 | 44 |
| 56 | Saris Abo-Shiro Meda | 3 | 14.2 | 0.50 | 50 | 46 |
| 57 | Kara-Lagehar | 4 | 14.4 | 0.50 | 55 | 60 |
| 58 | Legehar-World Bank | 2 | 12.0 | 0.65 | 45 | 36 |
| 59 | Belet Hospital-Minilik Square | 4 | 11.5 | 0.50 | 38 | 88 |
| 60 | Debre Zeit-Lagehar | 6 | 47.2 | 2.25 | 90 | 52 |
| 61 | Meri CMC-Legehar through Kasanch | 3 | 13.8 | 0.50 | 48 | 53 |
| 62 | Sebeta-Lagehar | 2 | 23.8 | 1.25 | 63 | 24 |
| 63 | Bole Michael-Wello Sefer | 3 | 9.1 | 0.35 | 35 | 70 |
| 64 | Sidist Killo-Megenagna Gorf Aswg | 4 | 9.5 | 0.50 | 40 | 102 |
| 65 | Merkato-World Bank | 2 | 11.0 | 0.65 | 43 | 40 |
| 66 | Addis Ketema-Kara Kore | 4 | 10.5 | 0.50 | 47 | 68 |
| 67 | Mekanisa Square through Ring Roa | 4 | 10.2 | 0.50 | 37 | 77 |
| 68 | Minilik Hospital --Torehailoch | 4 | 10.2 | 0.50 | 48 | 72 |
| 69 | | | | | | |
| 70 | Kasanchis-Ayer Tena | 4 | 11.0 | 0.50 | 40 | 80 |
| 71 | Bole Gumruke Brass Clinic-Balch | 3 | 10.6 | 0.50 | 50 | 50 |
| 72 | Addisu Serer Saris-Legehar | 2 | 9.6 | 0.35 | 40 | 62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 73 | Legehar-Winget School | 4 | 10.2 | 0.50 | 42 | 80 |
| 74 | Gurd Sholla Michael-Merkato thro | 4 | 13.3 | 0.50 | 54 | 66 |
| 75 | Sidest Killo-Kera | 4 | 10.4 | 0.50 | 40 | 81 |
| 76 | Megemagma Zerihun Building-Saris | 3 | 12.1 | 0.50 | 50 | 49 |
| 77 | Ayer Tena-Saris Abo | 4 | 13.0 | 0.50 | 48 | 72 |
| 79 | Megenagna-Galcha Hospital | 4 | 11.4 | 0.50 | 48 | 72 |
| 80 | Semen Gebeya-Megenagna | 5 | 12.4 | 0.50 | 48 | 88 |
| 81 | Arat Killo-Yenegew Fire School | 2 | 10.7 | 0.50 | 35 | 48 |
| 82 | Yerer Ber-Balcha Hospital | 3 | 11.3 | 0.50 | 52 | 48 |
| 84 | Kolfe Efoyta Mesalemia-Lagehar | 3 | 9.5 | 0.50 | 53 | 46 |
| 85 | Addis Ketema-Holeta | 2 | 45.0 | 2.25 | 99 | 16 |
| 87 | Kolfe Square Ring road-Ayer Tena | 2 | 10.5 | 0.50 | 35 | 48 |
| 89 | Addis Ketema-Sendafa | 1 | 44.0 | 3.00 | 90 | 2 |
| 90 | Betel Hospital-Legehar | 3 | 10.0 | 0.50 | 40 | 60 |
| 92 | Hana mariam Bridhe through Ring | 3 | 9.6 | 0.50 | 43 | 40 |
| 93 | Bole bulbulaSaris Abo through R | 2 | 12.3 | 0.75 | 37 | 19 |

**B-3) Vehicle performance data**

Anbessa uses buses of the same capacities which are either produced in Holland, Belgium or DAF. The table below shows the performance records obtained from Anbessa record for 51 buses of Belgium.

| side_no | working days | trips | totpass | totkm | revenue | bus hour |
|---|---|---|---|---|---|---|
| 6286 | 330 | 4942 | 454359 | 56130.8 | 232714.2 | 3669.09 |
| 6287 | 347 | 5535 | 503274 | 62667.2 | 257695.6 | 4031.71 |
| 6288 | 322 | 4970 | 456151 | 54267 | 226217.8 | 3555.62 |
| 6289 | 343 | 5358 | 491279 | 60587.4 | 246459.4 | 3889.3 |
| 6290 | 356 | 5860 | 522732 | 65762.9 | 263926 | 4257.72 |
| 6291 | 340 | 5162 | 443558 | 58153.7 | 214123.6 | 3866.01 |
| 6292 | 348 | 5519 | 498779 | 63002.4 | 248242.9 | 4151.87 |
| 6293 | 314 | 4803 | 429714 | 57331.1 | 223306.5 | 3713.98 |
| 6294 | 342 | 4984 | 470103 | 58456.5 | 234929.1 | 3772.3 |
| 6295 | 349 | 5412 | 474686 | 61579.2 | 239639.2 | 4054.63 |
| 6296 | 333 | 5138 | 463637 | 58609.2 | 231038.9 | 3839.71 |
| 6297 | 342 | 5533 | 522586 | 62144.8 | 251401.9 | 4095.67 |
| 6298 | 340 | 4840 | 456980 | 55573.2 | 228213.2 | 3624.34 |
| 6299 | 341 | 5214 | 451355 | 63125.8 | 235778.6 | 3970.2 |
| 6300 | 343 | 5321 | 481108 | 64151.2 | 255177.8 | 4022.39 |
| 6301 | 322 | 4797 | 445296 | 57584.4 | 231892.7 | 3632.95 |
| 6302 | 343 | 4875 | 424976 | 61500.9 | 241149.2 | 3745.16 |
| 6303 | 328 | 5194 | 472099 | 61390.2 | 253927.4 | 3868.79 |
| 6304 | 312 | 4946 | 417690 | 58203 | 221275.9 | 3709.27 |
| 6305 | 334 | 5184 | 465536 | 61537.2 | 250665 | 3914.39 |
| 6306 | 342 | 4977 | 438897 | 60653.7 | 236254.4 | 3845.99 |
| 6307 | 338 | 4972 | 446405 | 58391.8 | 235908.6 | 3746.86 |
| 6308 | 342 | 5237 | 491531 | 62726 | 258240.3 | 3969.94 |
| 6309 | 348 | 5251 | 484035 | 62887.3 | 250522.4 | 4017.72 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6310 | 346 | 5701 | 551144 | 67920.4 | 279743.8 | 4376.93 |
| 6311 | 348 | 5485 | 488798 | 63274.9 | 242641.9 | 4110.27 |
| 6312 | 341 | 4996 | 449877 | 60846.4 | 237599.3 | 3853.45 |
| 6313 | 341 | 5284 | 492528 | 63001.8 | 259482.7 | 4041.64 |
| 6314 | 330 | 5107 | 487323 | 62305.1 | 251078.7 | 3928.89 |
| 6315 | 347 | 5246 | 493758 | 63910.1 | 255716.5 | 4022.08 |
| 6316 | 330 | 4633 | 412406 | 53838.5 | 201230.2 | 3494.31 |
| 6317 | 340 | 5251 | 525707 | 59589.7 | 242823.3 | 3877.8 |
| 6318 | 334 | 4983 | 514331 | 55633.7 | 240236.8 | 3699.46 |
| 6319 | 327 | 4997 | 490969 | 54953.7 | 228300.1 | 3702.98 |
| 6320 | 342 | 5170 | 504473 | 57786.6 | 236860.6 | 3880.93 |
| 6321 | 344 | 5404 | 508751 | 60247.5 | 248217.6 | 4032.12 |
| 6322 | 338 | 5036 | 488529 | 56326.6 | 234479.8 | 3738.41 |
| 6323 | 315 | 4937 | 451440 | 54779.9 | 216008 | 3646.45 |
| 6324 | 344 | 5237 | 475850 | 59947 | 238732.8 | 3913.79 |
| 6325 | 330 | 4717 | 437951 | 54837.6 | 222772.7 | 3544.02 |
| 6326 | 346 | 5430 | 508351 | 62435.5 | 254915 | 4061.15 |
| 6327 | 351 | 5579 | 536539 | 60822.1 | 257309.3 | 4108.41 |
| 6328 | 330 | 5234 | 481338 | 57524.2 | 234558.3 | 3864.63 |
| 6329 | 342 | 4965 | 446566 | 53001.7 | 209046.6 | 3616.18 |
| 6330 | 326 | 5129 | 495248 | 56227.8 | 234085.2 | 3791.78 |
| 6331 | 353 | 5441 | 491997 | 64237 | 248845.1 | 4153.04 |
| 6332 | 341 | 5387 | 505996 | 63389.7 | 254805.7 | 4115.37 |
| 6333 | 334 | 5177 | 469023 | 60490.3 | 244243.1 | 3939.65 |
| 6334 | 333 | 5112 | 454650 | 59253.6 | 229021.6 | 3865.17 |
| 6335 | 336 | 5097 | 475056 | 61057.6 | 243402.6 | 3916.85 |
| | 337.76 | 5175.18 | 476907.3 | 59881.12 | 240297.1 | 3885.227 |
| | 356 | 5860 | 551144 | 67920.4 | 279743.8 | 4376.93 |
| | 312 | 4633 | 412406 | 53001.7 | 201230.2 | 3494.31 |

**B-4) route performance per length catagory**

Summary of Anbessa route performances per length category according to the data for 1998EC obtained from the company record.the tables below show the minimum, maximum and average values for the indicators passenger volume, vehicle-km and revenue.

| Route length category | Min Daily Trip | Max Daily Trip | Average Daily Trip | Total Daily Trip |
|---|---|---|---|---|
| Medium | 32 | 71 | 52.2500 | 209 |
| long | 24 | 52 | 38.0000 | 76 |
| longer | 16 | 16 | 16.0000 | 32 |
| longest | 2 | 52 | 23.3333 | 70 |
| short | 46 | 92 | 64.8333 | 389 |
| shorter | 19 | 194 | 73.4524 | 3085 |
| shortest | 40 | 210 | 89.0417 | 2137 |

| Route length category | Min Revenue | Max Revenue | Average Revenue | Total Revenue |
|---|---|---|---|---|
| Medium | 782534 | 1807034 | 1213096.0000 | 4852384 |
| long | 737955 | 1384370 | 1061162.5000 | 2122325 |
| longer | 690758 | 745107 | 717932.5000 | 1435865 |
| longest | 139728 | 2831713 | 1312379.0000 | 3937137 |
| short | 836125 | 1707029 | 1166941.5000 | 7001649 |
| shorter | 434912 | 2577192 | 1047636.4762 | 44000732 |
| shortest | 49004 | 2182431 | 946621.9167 | 22718926 |

| Route length category | Min Vehicle-km | Max Vehicle-km | Average Vehicle-km | Total Vehicle-km |
|---|---|---|---|---|
| Medium | 198966 | 452214 | 293141.5000 | 1172566 |
| long | 181679 | 391527 | 286603.0000 | 573206 |
| longer | 173137 | 176533 | 174835.0000 | 349670 |
| longest | 77176 | 770540 | 357917.0000 | 1073751 |
| short | 226618 | 421928 | 303858.8333 | 1823153 |
| shorter | 100870 | 534272 | 262255.8571 | 11014746 |
| shortest | 12832 | 558954 | 235718.1667 | 5657236 |

| Route length category | Min Passenger volume | Maximum Passenger volume | Average passenger volume | Total passenger volume |
|---|---|---|---|---|
| Medium | 1043379 | 2409378 | 1617461.0000 | 6469844 |
| long | 590364 | 1107496 | 848930.0000 | 1697860 |
| longer | 460505 | 496738 | 478621.5000 | 957243 |
| longest | 46576 | 1258539 | 578104.3333 | 1734313 |
| short | 1672249 | 3414057 | 2333882.5000 | 14003295 |
| shorter | 644632 | 5154384 | 2125709.7143 | 89279808 |
| shortest | 98007 | 7043819 | 2592167.4583 | 62212019 |

# Appendix C-Interview and questionnaire

**Interview check list questions used with AATA**

What is the Addis Ababa public Transport policy?

*(How is mobility and accessibility defined?)*

*What are the parameters used to assess accessibility of Public transport?*

Who are the providers of public transport?

Private Public Mixed

Is there competition between the providers of public transport?

Yes / no

If yes, what kind of competition?

*(What is the share of each sector (I.e. private and public)? How is the trend shifting?)*

How does your organization rate the performance of Anbessa transport?

What is the spatial coverage of Anbessa transport?

Is Anbessa transport coverage in time and space the same in the city?

Yes / no

If not, which areas are disadvantaged?

What plans are in place to address the shortages?

What is spatial equity?

How do you provide feeder service?

How do you determine the network coverage?

How do you expand the network?

10. What are the future plans to improve the service?

Which factor do you give priority?

Commercial/ Environmental/ Safety/ equity

How far have the objectives of Addis transport strategic plan been achieved?

What part was most successful?

What is the power of AATA to control Anbessa?

Are you member of International organizations like UATP?

What are the challenges faced in providing public transport?

**Interview check list used with Anbessa Organization officials**

a) Vehicles and staff

How many staff do you have?

Administrative staff_______________

Maintenance Staff_________________

Operation staff: Drivers_______________ Conductors________________

What is the fleet size?__________________

Are they all operational? Yes/No

If No, how many are operational?___________________

What are the reasons for those not in operations?

A B C D

How many are under maintenance?_____________
How many are totally out of service?____________
What is the capacity of each vehicle?_______________
Do you have records or study about passengers carried? Yes/no
What is the average number of passenger per vehicle per trip?________
Is the trend of demand increasing? Yes/No……………..why?
What are the average vehicle-km and passenger-km?
Do you conduct performance measure studies? Yes/no
If yes, how often do you measure performances?___________
How do you measure it?________________(parameters)
Who measures it?________________(Anbessa/ other organization like…)

b) Routes, spacing and travel time

How many routes do you serve?___________________
Do you have digital route map? Yes/No
How does the routes increase come? New area/ increased demand/ others
Do you consider any of these routes overloaded?
Which routes are most critically overloaded?
How far are stops spaced? Why? How do you identify it?
What is the frequency of service?
Does this vary with different routes?
Does this vary during morning/ night peak?
If so, what are the factors in this variation?
What are the average waiting time, and walking distance?
Do you provide service on time according to the schedule?
If not, how much delay is tolerated?
What is the average travel time per trip?

c) Coverage

Do you have information on spatial distribution of different groups by income?
Does your service follow the demand pattern?
Is the service reaching the demand?
If no, how does your service address spatial equity?
Which areas are served well?
Which ones are poorly serviced?
What are the possible reasons for poor service?
Is road network one of the reasons?
Were there improvements on the service to reach disadvantaged areas?
What future plans do you have for improving spatial equity?

d) General

What are the strategic plans of your organization? (Vision, mission, goal)

How does your organization rate the service offered by Anbessa?

**Questionnaire used for Anbessa customers**

The objective of this survey is to collect information on Anbessa service- and network- deficiency and identify the problem area and make recommendations on network and policy options for future improvements.

Instruction: Please fill in the questionnaire by putting 'X' on the blank space.

Interview route:______

Information about respondent

Gender: ☐ Female ☐ Male

Age (Years) ______________

Employment status (indicate all applicable)

☐ Employed ☐ Student (post secondary) ☐ Student (grade 1 -12)

☐ not employed ☐ Retired ☐ Other

For what purpose do you use public transport? Rank according to frequency

☐ WORK ☐ SCHOOL ☐ LEISURE ☐ Family visits ☐ other..............

What is the distance between your residence and place of work (one way distance)?

___________________

Less than 500m less than 1km Less than 2 km

2-5 km 5-7 km More than 7 km

___________________ in minutes

Information about current Anbessa Bus service:

which route do you use regularly?__________(Route Number)

How many times do you use public transport?

_________________per day/week/month

How many times do you get seat?

In every trip once per two trips once every five trip

Once in every ten trip I don't get seat at all

How long do you wait at the bus stop?

Less than 5min 5 to 10min 10 to 15 min more than 15 min

How long do you walk to reach the bus stops?

Less than 500m 500 to 1000m more than 1000m

Which problems discourage you from using the ANBESSA?(Give rank)

☐ Robbery inside the bus ☐ Number of interchanges

☐ Robbery at the bus stop ☐ speed(High/low)

☐ Crowdedness ☐ lack of seat

☐ Risk of accident ☐ poor treatment by operators

☐ Delay others_______________

☐ Status

☐ Price

Questions about your preferences to improved service:

Please, rank the factors that will decrease your comfort in the bus.

Crowdedness lack of seat

Neatness Safety others____________

Please, rank the factors that will decrease your comfort outside the bus.

Long waiting security

Lack of bus shade others____________

Lack of information about schedule

Please, rank the factors below according to your priority of preference for better service.

Good quality bus getting seat affordable price

Safety punctuality high frequency service

Air conditioning less walking distance

What price will you be willing to pay for better and improved service?

Questions related to spatial coverage:

In which kebeles do you find it difficult to get Anbessa service?

__________________Kebele number/s

What are the reasons?

No service at all

In sufficient services

No road network

Others___________________

# AppendixD- Description of the criteria for selecting veriables in making composite indicator

| Criteria | Explanation |
|---|---|
| (Policy) relevant | Sustainability indicators are intended for audiences to improve the outcome of decision-making. Therefore indicators must be appropriate to a local perspective, but should also be intelligible at a broader level. Defining and implementing policy requires political commitment, as does encouraging community participation. If the indicator can be associated with one or several issues of the key policies and with critical decisions, it will motivate action. |
| Simplicity | The gathered information must be presented in an easily understandable, appealing way to the target audience. Even complex issues and calculations should eventually yield clearly presentable information. |
| Validity | The indicator needs to be a reflection of facts. That means that the data that is represent must be reproducible and verifiable. The technique to collect data must be scientifically and must be understandable for experts and laypeople. |
| Time-series data | An indicator reflecting a process over time is preferable. Several point in time are necessary before conclusion can be drawn form these indicators. When there are several observations available it is possible to see to what direction the development goes. |
| Availability of affordable data | It might prove useful to use information that is available. Many authorities have developed a wide range of methods for collecting and reporting on data which could be useful for wider purposes. If the available data is of good quality using it should be considered. It is important not to forget that not all available data can be used. It is not the ease of measurement that is of interest, but the quality of the data.<br>Part of the availability of data is the measurability. The data that the indicator uses needs to be measurable. |
| Ability to aggregate information | Indicators that can aggregate information are preferable. With aggregated indicators other indicators can be forgotten, because they are part of a higher level indicator. |
| Sensitivity | The indicator needs to detect small changes in the system. Beforehand needs to be determined if small or large changes are relevant for monitoring. The smaller the change that is relevant the more sensitive an indicator must be. The goal of this research is to determine a global direction of development. An indicator does not need to be very sensitive. |
| Reliability | If an indicator is reliable people will trust them. If more then one measurement is taken they all need to arrive at the same result. If the test is repeated by other researches the result must stay the same. |
| Scale | To what extend is a variable applicable on local or national scale? In the analysis a distinction between local and national must be made. If a local variable is searched only the local applicability is taken into account. Otherwise only the national criterium. |

(Source: Moleman 2002)