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Evaluating the Economic Impact of Bus Stop design in Addis Ababa City

A Thesis submitted for the partial fulfillment of the requirements of Degree of Master of Science in Road and Transport Engineering Stream

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Addis Ababa

The undersigned have examined the thesis entitled **“Evaluating the Economic Impact of Bus Stop Design in Addis Ababa City”** presented by **Eyob Hilemichael**, a candidate for the degree of **Master of Science** in **Road and Transport Engineering** and we hereby certify that it is worthy of acceptance.

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DECLARATION

I certify that this research work titled **"Evaluating the Economic Impact of Bus Stop Design in in Addis Ababa City"** is my own work. It has been carried out by me under the supervision of Dr. Alemayehu Ambo, Addis Ababa Institute of Technology, Addis Ababa University, during the year 2016-2017 for the partial fulfillment of the requirements for the Degree of Master of Science in Road and Transport Engineering. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

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CERTIFICATE

This is to certify that this thesis entitled **"Evaluating the Economic Impact of Bus Stop Design in Addis Ababa City"** is an authentic work carried out by **Eyob Hilemichael** under my guidance and supervision. This is the actual work done by Eyob Hilemichael for the partial fulfillment of the requirements for the Degree of Master of Science in Road and Transport Engineering, from Addis Ababa University, Addis Ababa Institute of Technology.

Dr. Alemayehu Ambo

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Dedicated to my mother who gave me a continuous support and inspiration to strive for meaningful pursuits.

ABSTRACT

Public bus transportation system plays a key role in shaping transportation structure of large and fast-growing cities most importantly in combating air pollution and traffic congestion compared to small cars. As a result; most urban transportation needs are served with public bus transportation which is also one of the most important modes of transportation in Ethiopia in general and in Addis Ababa in particular by providing intra-city transportation services with bus stations. Despite, these scattered contact points provide access, decision on how many bus stops to provide along service routes significantly influence financial & ridership performance of the agency and the community at large. For this reason evaluation of economic impacts is essential in order to have a sustainable transport system, which can be performed from efficiency and equity objectives, where "Efficiency" assumes that policies should strive to maximize social welfare while "Equity" is a highly subjective concept which assumes policies should ensure benefits and costs are spread in a fair way. Unfortunately, economic impacts of bus stop designs have not been seriously dealt with in Ethiopia; hence the purpose of this paper is to successfully evaluate the economic impacts of bus stop for selected routes. In line with this, to evaluate the perceived compromise between equity and efficiency with in local context; the impact on the primary recipients of public transit (i.e. users), nonusers to ensure equity of the system benefits and costs to the society at large and agency costs in the course of service are considered. As doing so the geographical scope of evaluation is limited to three major routes of ACBSE with fixed stop patterns whereas the temporal scope of impacts is limited to short term to minimize the effects of influencing factors. Taking bus stations as a point of interest two cases are defined: (1) Base line scenario the existing spatial distribution of bus stops and (2) Alternative scenario: bus stop location's that can balance of possible concerns and feasible courses of action are modelled by transit expert's opinion through AHP-derived weights and DCPMP to optimize bus stops in order to promote greater geographic coverage with a limit in number of stops in ArcGIS.

To further understand what costs and benefits that could be related with base line scenario in the absence of change against the costs and benefits predicted in the alternative scenario in terms of service coverage, environmental effects and road user costs are examined. These key indicators used are further boiled down to reflect the magnitude and values of monetary and non-monetary costs and benefits economic effects (operating cost reductions), environmental affects, (emission reductions) and service coverage. Subsequently, the research used two different questionnaire surveys to capture the general public and transport experts opinion which are analysed in SPSS, ArcGIS for inventory of existing stops, determine accessibility & conduct suitability analysis, HDM4 to quantify the vehicle operating costs and resulting emission, online tools to calculate the VOC during idling of vehicles, IPCC guideline to calculate the carbon footprint in idling and route level fare recovery ratio to gauge the efficiency of ACBSE. The said impacts are brought together to demonstrate the overall benefits, costs and net benefits. Results in route of interest provide positive evidence on an alternative scenario that proposed change of bus stops' (about 8% of current stops) could increase agency direct operating costs by 4.89% as compared to baseline. Besides, vehicle fleet and idle exhaust pipe CO_2 emissions decline by 12.3% from base case. Surprisingly, the gain in coverage due to elimination and addition of bus stops is large (7%) of the total population of Addis Ababa city when compared to the baseline. On the other hand, the total land required for clearing polluted air by the biosphere using tree plantation slightly decreased by 0.19% while the total sapling, land, agency management and conservation work cost for 25 years maintained by 0.19% from 621,832 Birr of baseline. While this is the case assessment on financial and ridership efficiency indicated ACBSE is recovering the direct operating cost during 2016/2017-2017-2018 from ticket sales in the case study routes. Summing up by comparing the present values of net benefit and costs the proposed alternative has greater economic worth and ACBSE service provided is moderately equitable but not efficient.

Key words:

Addis Ababa, Bus Stop, Efficiency, Equity, ACBSE, GIS, AHP, EIA, DCPMP

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Eyob Hilemichael

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AACA	Addis Ababa City Administration
AACGPC	Addis Ababa City Government Planning Council
AARTPO	Addis Ababa Road and Transport Office
AACRA	Addis Ababa City Road Authority
AATA	Addis Ababa City Transport Authority
ACBSE	Anbesa City Bus Service Enterprise
AALRT	Addis Ababa Light Rail Transit
CBD	Central Business District
CDC	Central Disease control
CSA	Central Statistical Agency
DCPMP	Distance constrained P-Median problem
FDRE	Federal Democratic Republic of Ethiopia
EIA	Economic Impact Analysis
IPCC	Intergovernmental Panel on Climate Change
AHP	Analytical Hierarchy Process
GHG	Green House Gas

Definition of key words

Bus stop/station	A space for buses to stop to pick up and discharge passengers.
Bus stop spacing	Distance between subsequent bus stations.
Efficiency	A measure of how well assigned resource is utilized.
Equity	As Litman (2017) puts it, "Equity refers to the distribution of impacts (benefits and costs) and whether they are appropriate"
Economic Impact Analysis (EIA)	It is an analysis made to determine the value of a change in terms of economic variables qualitatively and quantitatively.
Walking distance	Distance along pedestrian pathway to access bus stop.
Idling	When a vehicle's engine is on but the vehicle is not in motion.

CHAPTER 1
INTRODUCTION

1.1 Overview

Transport plays a vital role in the development of the modern era as an integral part of the socioeconomic and political structure of a country. It involves fixed facilities of network links and nodes, with variety of transportation modes as flow entities and numerous flow control systems that facilitate people and goods to move from origin to destination efficiently, safely and sustainably to participate in desired activities by arriving on time.

Thus; transport system encompasses different modes which have evolved through time in order to accommodate the complex pattern of the world trade and globalization, integrated with technological and operational improvements. As a result, today's transportation system is a highly developed, complex network of modes and facilities that provides shippers and travelers with a wide range of transportation modal choices in terms of services provided (Garber & Hoel, 2009).

Usually transportation system can be categorized into four major subsystems according to the medium on which the flow elements are held. These subsystems are land, air, water and pipeline transportation that provide freight, passenger traffic, public transportation and highway transportation services in-cooperating diverse classifications within the realm of each mode offering a unique set of service characteristics in terms of travel time, frequency, comfort, reliability, and safety (Garber & Hoel, 2009; Papacostas & Prevedouros, 2001) that can be provided either privately or publicly. However; relative to other transit services public transportation plays a key role in shaping transportation structure of populous cities by providing transit services to urban and suburb residents.

According to (Garber & Hoel, 2009), public transportation is not a single mode but a variety of traditional and innovative services which include:

- **Mass transit**, characterized by fixed routes, published schedules, designated networks, and specified stops with buses, light rail (trolleys) or rapid transit that operate either share space in mixed traffic or on grade-separated rights of way.
- **Para-transit** is characterized by flexible and personalized service intended to replace conventional fixed-route and fixed-schedule mass-transit lines. It is available to the public on demand, by subscription, or on a shared-ride basis. Examples include taxi and car rental.
- **Ridesharing** as the name implies it is characterized by two or more persons traveling together by prearrangement, such as carpool, vanpool, or shared taxi.

1.2 Statement of the problem

From variety of mass transit services buses are capable of transporting large numbers of people while occupying relatively little road-space which enables them to play a vital role in combating air pollution and traffic congestion compared to small cars, thus offering a highly cost-effective use of resources. Buses also, provide mobility to those who do not have and/or interested to drive a car. Aside with these specially equipped public transportation vehicles can also provide accessible transportation for people whose mobility is impaired while maintaining their flexibility in operation and responsiveness rapidly to changing patterns and levels of demand (Papacostas & Prevedouros, 2001; Teklu, 2012).

Moreover, urban public bus transportation encourages and creates walking opportunities which is comparable or more from CDC recommended 22-minute moderate physical activity; which health experts say critical in decreasing an individual’s risk for heart disease, obesity, stroke and diabetes; which also reduce air pollution and oil dependency that result from auto use.

Further; urban public bus transportation is also one of the most important modes of transportation, in Ethiopia in general and in Addis Ababa in particular by providing interurban and commuter services. Thus I agree with (Zergas & Litman, 1997) that the value that public bus transportation brings should be prioritized as a key transportation goal by policy makers, since car based transport is network is not a sustainable development path neither in regard to urban planning nor to the environment; only public transport can ensure mobility in larger cities. This can be achieved by making public transport competitive with auto-based alternatives through reducing walking distances to bus stops; reducing the wait time and/or perceived wait time for bus and reducing the actual in-vehicle travel time.

Urban public bus transportation is also notable for its remarkable benefits; the role of accessible and efficient service provision is not good enough as the demand is much greater than the supply in the case of Addis Ababa city due to financial and managerial constraints. As it's claimed by (Eshete), despite the prevailing problems, efforts to conduct an empirical study of the public transportation in Addis Ababa city is negligible (Eshete, 2015; Samson, 2006). I agree with Eshete's view that limited researches were conducted in context of public transportation, however in my prospect several recommendations of researches done are not yet fully realized because of so many factors. Thereupon the current provisions of public transportation have not yet met the demand.

It is therefore important to understand that with increasing consideration given to the public transportation system in Addis Ababa; the provisions of optimum bus stop spacing's are needed to improve the efficiency and effectiveness of public transportation services. Thus; in order to provide efficient urban public bus transport service as an acceptable alternative to the public, proper bus stop designs are most likely to assist effective operation through facilitating the provision of a high-quality bus transportation service in-line with economic developments of the city.

Besides, public bus transportations comprise bus stop stations which facilitate accessibility to transportation services at an operating carriageway while slowing down other vehicle operations and increasing travel time; which requires decision as to what number of stops should be provided; especially along critical networks. Despite the above, the economic impacts of bus stop designs have not also been seriously dealt with in Ethiopia in general and in Addis Ababa in particular.

1.3 Objectives

1.3.1 General objective

The purpose of this research is to conduct economic impact analysis of bus stop in case of Addis Ababa city.

1.3.2 Specific objectives

The following are the specific objectives of the research:

- To study the current practices of bus stop location, spacing and design in Addis Ababa;
- To provide an integrated approach for bus stop spacing design and conduct economic analysis for critical routes accordingly;
- To forward pertinent recommendations for possible application in Addis Ababa and replication to other cities in Ethiopia.

1.4 Research structure

The organization of this research is designed following a review of associated literatures available within the limitations of knowledge at the time of the study. As noted in literature most of the researches done specifically (Litman, 2006) in economic evaluation have indicated bus stop design is subject to different variables which are not equally important that necessitates a comprehensive process to insure all significant costs, benefits and equity effects are considered.

Bearing this in mind and considering pros and cons each works reviewed the flow and construction of this research is structured as illustrated in Figure 1-1, tailored to present snapshot of the state of practices as it exist today and develop an integrated economic analysis which suit local context.

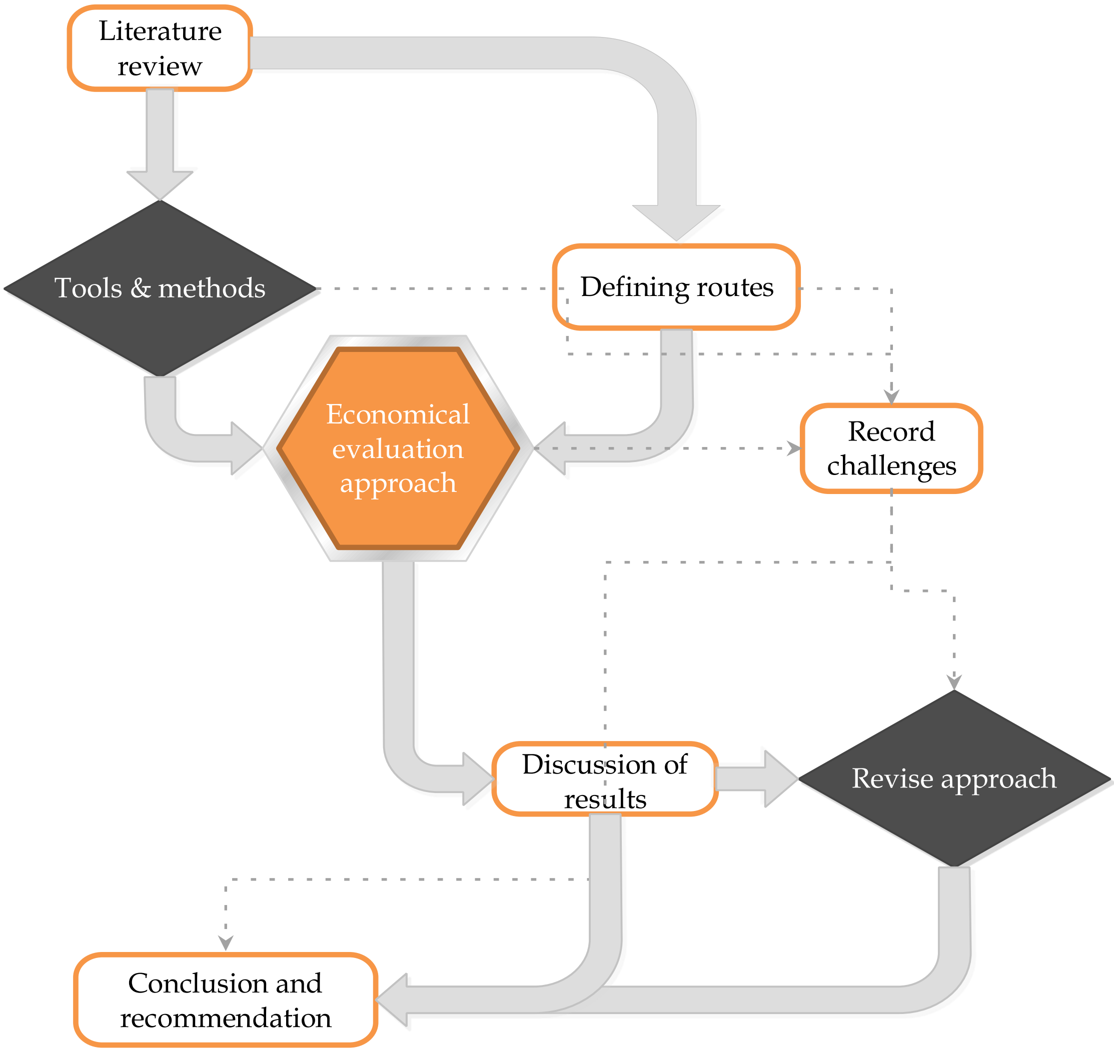


Figure 1-1 Research structure

1.5 Scope and limitation of the study

Due to practical constraints, the research will only focus on evaluating the economic impacts of three major intra-city fixed stop bus service routes stop spacing in mixed traffic condition for further investigation as it exist today in Addis Ababa through qualitative and quantitative data.

1.6 Significance of the study

The benefits of the results of the research are envisaged in a wide range that can be viewed from different directions. The most important benefit of the research is integrated framework for evaluating the economic impact of bus stop spacing that are easily transferable and valuable to other researchers and pertinent recommendations that will enhance the competitive edge of the service over other transit modes. As a result, it will reduce the vehicular traffic on the streets that generating downstream traffic congestion, which in turn enhance travel and waiting time, which are the major factors that discourage passengers in Addis Ababa. On the other hand, the results offer important insight as a base to estimate service coverage of other operators that share similar bus stops. Moreover, this work offers a useful ready-to-use tool for investigating bus stop spacing in GIS framework, monetize environmental and road user effects of public transit, serve as useful information in the current practice and & planning guidance for organizations like ACBSE, AATA, AACRA, AARTPO.

1.7 Organization of the research

The research paper is organized under five subsequent chapters as follows:

Chapter 1 is an introduction part; which discusses the problem statement, objectives, scope and limitation of the study and its overall significance.

Chapter 2 offers a review of literature and relevant researches in bus stop design.

Chapter 3 presents the materials and methods used in the research.

Chapter 4 contains analysis of the data and presentation of the results.

Chapter 5 deals with succinct conclusions and forward recommendations for possible use by pertinent policy makers and lists propositions for future research study to enhance the research efforts.

Finally, bibliography and appendices are attached at the end of the text.

CHAPTER 2
LITERATURE REVIEW

Currently, public transportation financing and expansion is becoming highly reasonable to develop social justice. Hence, methods for evaluating the economic impacts of bus stop design program are important component of transportation planning and management processes, which can be performed from efficiency and equity objectives. Efficiency assumes that policies should strive to maximize social welfare while equity a highly subjective concept which assumes policies should insure benefits and costs are spread in a fair way which makes it difficult to make judgments (Ambo, 2016; Immers & Stada, 2004; Litman, 2006).

2.1. Equity

Given the fact that public transportation plays a key role in ensuring equitable accessibility and all the components of bus stop design are important, it is usually specified in terms of spacing between stops or distance to stops which makes it an inherent tradeoff between the costs and benefits. Thus, it can be distinguished that there are many scenarios which will impact stop operations; for-example, as Huang and Liu (2014) argues closely spaced bus stops provide a short walking distance for passenger access with high operational costs and low efficiencies; when compared to large spaced stops that minimize travel time.

Thus, one of the key issues for locating bus stops is to have an understanding of the walking distance for equitable accessibility to distribute the benefits of transportation fairly. As Daniels and Mulley (2013) identified the main influence on walking distance was mode of public transportation walked to whether train or bus which largely reflects the differences in supply of stops and stations for bus and trains respectively (A case of Sydney, Australian public transportation). Thus; to balance efficiency and equity, operation costs should be reduced without impacting accessibility.

In doing so H. Li and Bertni (2008), had derived expressions for an aggregate total cost function, including minimizing access cost which favors small spacing and minimizing riding cost which favors large spacing. The findings of (Li & Bertni) indicate that total costs of access and riding per unit length is convex (See Figure 2-1) and costs over longer trip length can be optimized by minimizing spacing per unit length.

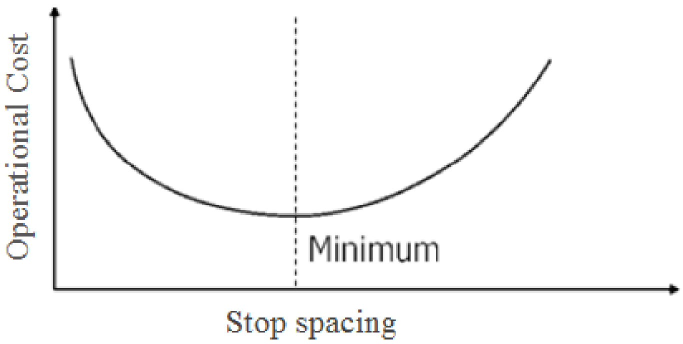


Figure 2-1 Operational cost Vs. Stop spacing

Source: (Li & Bertni, 2008)

In a related study that was done by El-Geneidy and Surprenant-Legault (2010) to evaluate limited bus stop service a case of Montreal, Quebec in Canada using archived vehicle location and passenger count data. The authors used before and after studies which is similar with El-Geneidy, Strathman, Thomas J. Kimpel, and Crout (2006), running time model and on-site survey on selected routes and found-out that limited bus stops contribute 13% of running time savings during peak hour. Their findings indicated most of the riders participated in on-site survey have confirmed their satisfaction in total travel time improvements. In view of the above, it is evident that there is a great need to improve the spatial distribution of bus stops in cities. Thus (A, S, & B, 2014) and (Adebola & Enosko, 2012); investigated distribution of stops in Nigeria Ilorin Metropolis and Ibandan north Oyo state respectively. Both authors bear similar approaches using questionnaire survey and inventory of existing stops using GIS. Exceptionally, (Adebola & Enosko) considered 8m shelter buffer away from carriageway, spacing interval of 400m & 50m spaced contour map. The results of both authors confirmed enhancements in bus mobility require optimal locations are best achieved by harmonizing access with walking distances and adjacent land use.

In this aspect several bus stop spacing optimization researches had been done, that focused in different prospects of stop-consolidation methods. (Furth & Mekuria, 2005), have made an investigation in Boston, United States to analyze stop spacing using historic analysis of stops, to effectively determine each stop service area, demands at each parcel and un-delayed running times in conjunction with GIS tool to determine the likely impact of stop elimination in walking, riding and running times. Their results indicate that removing Mt. Hood Rd stop and assigning most of alighting's and boarding's to alternative stations will decrease the cost of serving the same demand slightly.

(Xuebin, 2010), also studied stop location to optimize tradeoff in reducing stop redundancy while maintaining accessibility a case of Wuhan, China. As Xuebin asserts, stops in Wuhan are irrationally distributed which have resulted low service quality. Thus, the author generated and categorized candidate stops based on walking distance for selected stops in GIS. Followed by optimization using expansion models in FLOWMAP and relocation model is applied to minimize average stop distance. A comparison of served demand and service coverage between optimized stops with existing ones indicate that if redundant stops are reduced in city centers walking will range within 400 to 500 meters.

On top of optimizing stop locations with walking distance (Shrestha & Zolnik, 2013) explored transportation equity by emission reduction benefits that could be apprehended by eliminating stops (a case of Virginia, United states). As the authors cited (lily 1984), emission rates for heavy-duty vehicles are higher due to their operation in a higher combustion pressure. Further (Shrestha & Zolnik) argues emissions are a function of several variables which make analyzing the tradeoffs of eliminating stops difficult to be monetized. Thus, the authors undertook 800m walking thresholds to the closest stop and eliminated stops that were not with in 800m. Their evaluation point out that, eliminating stops will reduce travel time, operating cost and Green House Gas (GHG) emissions without affecting service area which agrees with (Alam, 2015).

The UN Framework Convention on Climate Change calls for the stabilization of the atmospheric concentration of GHGs but, at present, there is no settlement on what the specific level should be (IPCC, 2005). Yet, it can be recognized that improving the energy efficiency and sequestering CO2 over the enhancement of natural, biological sinks are cost effective and acceptable solutions. These can be achieved by improving the efficiency of energy conversion, transport and end-use and enhancing natural sinks through agricultural and forestry practices (IPCC, 2005). (IPCC, 2000b) and (Freund and Davison, 2002) cited by (IPCC, 2005) that, Carbon sequestration by forests have the potential to reduce net CO2 emissions and/or concentrations through capturing and storing it away from the atmosphere for a very long time that makes it a promising near-term mitigation option look more favourable at prices of 0.8 to 1.1 US$/tCO2 (3-4 US$/tC).

As it can be observed from the aforementioned discussion it can be understood that equity is more broad qualitative term which makes judgments hard. As Litman (2017) puts it, "Equity refers to the distribution of impacts (benefits and costs) and whether they are appropriate". Another significant aspect of equity according to (Litman, 2017) is it can be broadly classified into horizontal, vertical equity with regard to income and social class and vertical equity with regard to mobility need and ability.

According to a definition provided by Litman (2017, p. 4):

<u>Horizontal equity</u> concerns with the distribution of impacts between individuals and groups considered equal in ability and need.

<u>Vertical equity with regard to income and social class</u> is concerned with the distribution of impacts between individuals and groups that differ, in this case, by income or social class differ

<u>Vertical equity with regard to mobility ability and need</u> is the degree to which the transportation system meets the needs of travelers with mobility impairments.

Yet, aforementioned explanation differs slightly from that of Litman (2006) who has categorized equity types into two as horizontal and vertical equity by comprehensively condensing vertical equity assumption in favoring physically, economically or socially disadvantaged people. So far numerous equity investigations have been conducted. Still, authors on one hand argue that walking distance to bus stop is best measure of equitable accessibility. On the other hand, others argue that bus stops should be optimally distributed in order to enhance service quality, reliability and walking distances. As a result, (Immers & Stada, 2004; Litman, 2006; Tyree, 2010) argues evaluation of transport equity is more qualitative which makes it tough. Thus, despite there are various types, impacts, measurement units, and categories of people to consider, it is best to consider various perspectives and impacts.

2.2. Efficiency

Apart from appraisal in context of equity, efficiency also plays a key role in transit performance measurement. Hence, it is getting a significant momentum as a result of an increase in competitive environment aside with tight financial constraints (Georgiadis, Politis, & Papaioannou, 2014). As a result, data envelopment analysis (DEA) is being used to gauge the relative efficiency of set of peer units called decision making units (DMU) among transit firms. Some of the studies are; a short and long run efficiency in Indian public bus companies by (Venkatesh & Kushwaha, 2017), an enhanced DEA model for transit operator efficiency assessment by (X. Li, Liu, Wang, & Gao, 2016), measuring and improving the efficiency and effectiveness of bus transit systems by (Georgiadis et al., 2014), performance evaluation of bus lines with DEA and GIS by (Lao & Liu, 2009). Unlike other researchers (Georgiadis et al., 2014) and (Lao & Liu, 2009) evaluated the performance of individual bus routes, a case of Thessaloniki in Greece and California in United States respectively. Despite (Georgiadis et al.) used DEA alone, (Lao & Liu) have tried to inspect and make comparison of operational and spatial aspects of bus lines by integrating DEA and GIS.

Both (Georgiadis et al.) and (Lao & Liu) have summarized three critical issues including perspectives to measure public transit system, application of DEA to compare public transit agency at national level and use of GIS for public transport planning. However, their results did not clearly show the relationship between efficiency and operational effectiveness. Moreover, in the literature on Cooper et al. (2007) cited by (Kang, Khan, Feng, & Wu, 2017) discussed the drawbacks of DEA include its assumptions like: (1) all inputs and outputs are real valued and all outputs are marketable and (2) inputs and outs are proportional to each other. Though, in practice it is inconsistent with transit business, because emissions may be produced along with transportation services and inputs and outputs may not vary proportionally at all times.

Thus, a complete efficiency analysis should take into account desirable and undesirable outputs to make accurate measurements (Kang et al., 2017). Hence, to overcome aforementioned gaps of DEA model (Kang et al., 2017) used slack based model (SBM) considering their capability to provide a more useful index with higher discriminating power when desirable and undesirable outputs are considered simultaneously to measure the technical and environmental efficiency with and without emissions a case of Taipei transit system. Apart from focal point of equity conducted by (Shrestha & Zolnik, 2013) and (Kang et al., 2017) empirical results had showed transit operators can at the same time improve their desirable outputs, by increasing the desirable outputs of passenger-km and vehicle-km, while reducing their inefficient inputs and non-separable ‘‘bad” outputs like air pollution emissions.

Another significant way of gauging efficiency as (Benn, 1995) points out, is through evaluating the financial and ridership route performance criteria’s which can be viewed as absolute measures (i.e. including passenger per hour, cost per passenger, passenger per mile, passengers per trip, passenger miles, revenue per passenger per route, subsidy per passenger, route level minimum variable cost recovery ratio and route level minimum costs) and relative measures like route level performance relative to other routes in the system.

Tyree (2010), also argues performance measures can be grouped into two broad categories based on whether they measure qualitative or quantitative characteristics. Together with (Benn, 1995) these study outlines that performance measures are variable and too many. Yet (Tyree, 2010) argues that quantitative approaches are more helpful than qualitative one's since they measure qualities such as on-time performance, cost efficiency, revenue generation, labor efficiency, and service utilization, which are more closely linked to revenues and expenses. Other researchers, however, who have looked at performance measures, have different prospects TRB (2000), for example, lists operator point of view, vehicle operation and passenger point of view to show how quality of service fits into the spectrum of transit performance measures. According to (TRB) the major difference between this perspectives lies in passenger point of view directly measures passenger's perception on quality of service whereas operator point of view indirectly measures passenger's satisfaction with the quality of service by dealing with the service capacity of an operator can afford, while vehicle operation tends to focus on speed and delay. More information about performance measures is presented as follows:

- <u>Passengers per hour</u>: number of passengers on a route carried in one bus per hour either counting passenger boarding and alighting or excluding them (Benn, 1995; Tyree, 2010).

- <u>Average fare per passenger</u>: is the route's costs divided by its ridership (Benn, 1995). It is useful for evaluating the impacts of changing cost elements over time to show the long-term trend of the agency's fiscal performance (Tyree, 2010).

  <u>Passengers per km</u>: it is similar to passengers per hour but this criterion considers the number of passengers carried in one bus Km. It is applicable for routes that make relatively frequent stops, and have the potential of turnover, i.e., as one rider gets off another gets on, (Benn, 1995). According to (Tyree, 2010) this approach is tailored to roughly reflect the capital investments related to the length of the route being considered.

- Passengers per trip: is the total number of passengers on a one-way trip. It is useful for routes where there is no on-off traffic. Another significant aspect of passenger per trip is the easiest one to explain to the public, a notable example include "there were 21 people on that trip."(Benn, 1995)
- Passenger Km: is the sum total of commuters carried times the total kilometers operated in a one-way trip of transit system. This criterion is best applied for routes either that have relatively little turnover, or operate at relatively great distances with significant loadings. This is an excellent example of a criterion that is best measured internally to routes on similar system only (Abreha, 2007; Benn, 1995).
- Revenue per passenger (per route): it is the ratio of revenues collected on a route divided by total boarding's. It is used to address the variability of different fares being paid(Benn, 1995).
- Subsidy per passenger: is the finance given to fill the difference between cost per passenger and revenue per passenger; simply the reverse of cost per passenger (Benn, 1995). Yet, each subsidy measures have different benefit cost ratios. For example in most recent studies conducted by (Abrantes, 2015) to assess the economic value of public funding through benefit to cost ratios of three different subsidy types namely free travel for elderly and disabled, fuel subsidy and subsidy of non-commercial bus services. The results of the survey conducted by (Abrantes) offer an interesting insight into how subsidy for fuel and noncommercial bus services contribute a lot to the economic benefit of the society at large.
- Route level minimum cost recovery ratio: is a percentage of costs for a route that are recovered from the fares paid by its travelers using the service these costs can be further classified in to variable cost and direct operating cost recovery ratios(Benn, 1995). Despite (Tyree, 2010) described used Farebox recovery ratio to describe route level recovery ratio interchangeably, the author argues a healthy recovery ratio indicates service that is both well used and well delivered.

- Route level performance relative to other routes: a route's percentile rank in an overall ranking of other routes in the particular system. Seventy-five percent of the transit firms who take part in the survey conducted by (Benn, 1995) confirmed that they use this measure.

- Operating Cost per Hour/km: is a measure of efficiency which shows expense of a firm to deploy an hour of service or cost per kilometer. It takes an attempt to account for either the cost of labor or capital investments that track with route length (Tyree, 2010).

- Vehicle kilometers: is the distance travelled in giving transportation service. Also, in the literature on Vehicle productivity by (Abreha, 2007) vehicles should be used as used optimally, provided there are sufficient passengers to cover their direct costs. Further the author argues that this measurement method may not accurately reflect the viability of kilometers operated which are influenced by a lot of factors. However (Iles 2005) cited by (Abreha, 2007) argues most urban buses on all day service will normally operate between 150 and 300 kilometers per day. Thus (Armstrong-Wright et al.1987) cited by (Abreha, 2007) argues in order to reasonably run bus service the average should be in the range of 210 to 260 Kilometers.

It can be observed that despite transit agencies take the same stand in the importance of performance measurement, few of them agree on how best to do so (Tyree, 2010). For example Benn (1995), explored bus route evaluation practices in five broad categories most importantly criteria's in measuring the financial and ridership efficiency of an already existing service at a route level. Benn's study was conducted in the form of a survey, with data being gathered via questionaries' distributed to 111 transit agencies. The study offers important insight into performance measurement and its findings indicate that 78% of the agencies surveyed used passenger per hour.

Other studies like Urbitran Associates, Khasnabis et al., and Mistretta et al cited by Tyree, J. D.(2010) also agree with (Benn, 1995), that passenger per hour is most widely used. However, it is apparent that evaluation standards are evolutionary with the supplementary advancements in Technology, thus (Benn) insists "Simply because changes, foreseen and unforeseen, routinely happen, it is suggested that bus route evaluation standard reviews be undertaken more routinely in the future". Thus, in this paper I argue that investigating efficiency is a continuing concern with in public transportation economics.

Hence, the number of measurement variables is likely to increase, as the baseline for successful performance measurement of the system is set by the transit agencies goals and objectives. For example, together with serving low income group ACBSE visions include providing reliable and efficient transport with affordable fare. As a result, the enterprise is currently using vehicle-kilometer and passenger per day performance measures to assess its financial and ridership efficiency in all of it service routes. However, these measures don't give accurate picture of the ACBSE efficiency, for example despite ACBSE provides services in flexible fares average fare passenger is not included in assessing the efficiency of the firm.

To sum up previously discussed bus stop economic evaluation studies have focused mainly on primary influence of stop spacing and walking distance/time to station on travel time and operating cost which makes bus stop designs a balance between equity and efficiency. Therefore, from the literature presented thus far on this subject, it can be shown that purpose of stop optimization is twofold, (1) equitable accessibility to make the service both horizontally and vertically equitable for all users, particularly to the special needs of users, seniors and passengers with disabilities (2) optimize costs and create acceptable option to transit commuters, agencies and authorities associated with the system. In doing so it is also observed that, GIS go hand in hand with analyzing bus stops.

Overall, these cases support the view that even though there are many approaches to conduct economic evaluations which appear to be relatively different, they turn out to have one goal optimizing costs and conferring to provide acceptable option to all participants of the system. Hence, from the literature it can be inferred that in-cooperating the various variables in decision making process plays a pivotal role in reaching an optimum solution which balances the tradeoff between efficiency and equity. In fact, a decision maker may have several criteria's in making a decision instead of just a single objective have raised a higher interest to adopt multi-criteria decision-making approaches.

In response, various multi-criteria decision making approaches are developed to tackle these challenges. (Taylor, 2013) list some of the techniques that can be used to solve problems when they have multiple objectives as goal programming, the analytical hierarchy process, and scoring models. For instance, goal programming models are set up in the same general format as linear programming models, with an objective function and a linear constraint, which assumes all parameters and values in the model were known with certainty. Whereas the analytical hierarchy process and scoring models, are based on a comparison of decision alternatives for different criteria that reflects the decision maker's preferences to rank the alternatives.

In a general scoring model, the decision criteria are weighted in terms of their relative importance, and each decision alternative is graded in terms of how well it satisfies the criteria (Taylor, 2013). Though there are several versions of scoring models which are mathematically simpler than models, numerous researches have utilized AHP developed by Thomas Saaty in the late 1970s, which is one of the mathematical multi-criteria decision making technique for ranking decision alternatives (Taylor, 2013). In context of public transportation, for example (Taye, 2016) have integrated AHP and GIS to conduct suitability analysis of light rail station location in Addis Ababa. The results of his study confirm that AHP assists decision maker to evaluate multi-criteria issues yet it only indicates preference; it doesn't pinpoint absolute values.

2.3. Bus stop infrastructures

Bus Stop design has been discussed in a number of transport engineering textbooks, researches, guidelines and manuals; much of the literature on the design of bus stops is briefly developed and maintained, unsurprisingly, by bus operators (TRB, 1995). The usual topics covered focus on operational, safety, access and cost components in this context most literatures argue that considerations should be given to the characteristics of public transit especially when designing footway and carriage way infrastructures to ensure safe, fast-moving, economical, comfortable and convenient operation. Besides; current and future transit demands should be well-thought-out for warranting operational flexibility and establish adequate geometric design standards most importantly turning radius, parking restriction zones, lane width, roadway grade, roadway pavement, bus pad pavement, curb height and curb radii for smoother maneuvering and synchronize all multimodal traffic interactions with pedestrian access (Garber & Hoel, 2009, pp. 57-93; Higgins & Audirac, 2008; RTA, 2015; Samson, 2006; Teklu, 2012; TRB, 2015; TriMet, 2010).

Thus, pedestrian access is a central element of good bus stop design and should be given high priority in the design including the clear demarcation of pedestrian crossings to guide pedestrians at longer crossings and the provision of properly designed sidewalks to reduce conflicts between pedestrians and other travel modes (Higgins & Audirac, 2008). Agrawal, Scholossberg, and Irvin (2008), have also studied pedestrian preference to access rail stations through a questionnaire survey of 328 respondents who walk to train stations to determine how far and how long respondents walked to the station, what factors influenced their choice of route, their attitudes towards walking, and some basic demographic questions. Respondents specified that their primary consideration in choosing a route is minimizing time and distance followed by safety and, to a lesser extent, attractiveness of the route, sidewalk quality and the absence of long waits at traffic lights.

Complementary to this Fitzpatrick, et al. (1997) cited by (Martino, 2014) asserted that incomplete, inadequate, poorly maintained and indirect pedestrian connections discourage transit use by increasing walking time, limiting direct access between the bus stop, sidewalk and land use. Thus, together with carriageways agreeing to local geometric design standards; accessible footway to passengers should be provided while overseeing problems. Yet; a single improvement measures may not solve all the issues since it is subject to variety of variables like; age groups, environmental contexts, diverse period of time and disables. Consequently; there are no universal design standards that suit all conditions; but most transit agencies have devised their own guidelines (COTA, 2014; GCRTA, 2015; GMPTE, 2007; PT, 2005; RTA, 2015; TL, 2005; TriMet, 2010).

2.4. Bus stop location

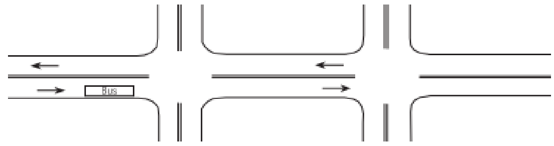
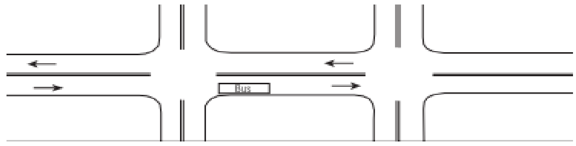
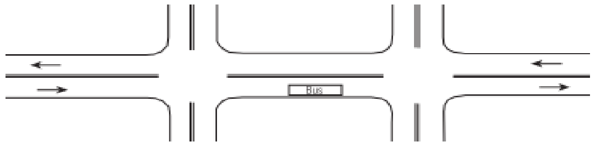
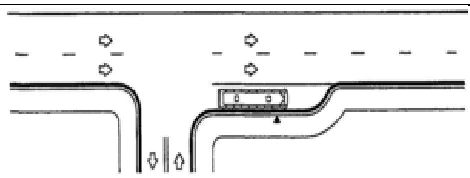
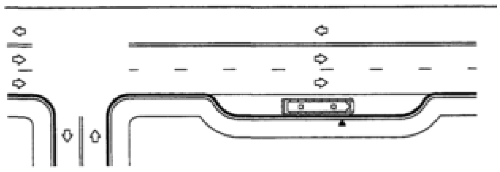
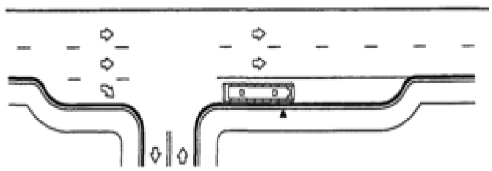
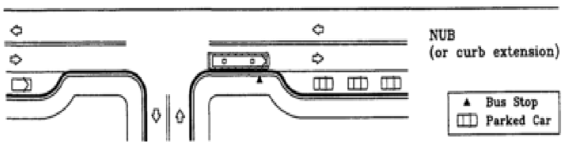
The first point where commuters get into contact with the transit vehicles is stop location. It is a loading area in which buses load and unload passengers that may be on-street or off-street which are influenced by volume, probability of queue formation and loading area types.

Although; the loading areas consist of one or more types; the usual forms are placed in the travel lane where on-street parking is allowed; that restrict following buses to pass the stopped bus while infrequent off-street stops allow skip-stop operations (FDT, 2007; TRB, 2000). Further refer Table 2-1 to see the various types of loading areas and configuration of stop.

As it’s shown in Table 2-1, on-street bus stops are located on curbside are classified in relation to intersections; at the near side (upstream) of the intersection; at the far side (downstream) of the intersection; or at mid-block (halfway between intersections) (COTA, 2014; GCRTA, 2015; Higgins & Audirac, 2008; PT, 2005; RTA, 2015; TRB, 2000; TriMet, 2010). On the other hand (TRB, 1996b) and (RTA, 2015); divide stop configurations into curbside, bus bulbs, nub, bus bay (i.e. bus turnouts, open bus bay and queue jumper bus bay) which can be included in the realm of on-street and off-street stops (further refer Table 2-1)

Table 2-1 Types of loading areas and configurations

Source: (TRB, 2000, pp. 14-17, 14-10)

<table>
<tr><th colspan="2">Type of loading area</th><th>Configuration of stop</th></tr>
<tr><td rowspan="3">On street</td><td>Nearside
(curb side)</td><td></td></tr>
<tr><td>Farside</td><td></td></tr>
<tr><td>Midblock</td><td></td></tr>
<tr><td rowspan="4">Off-street</td><td>Open bus bay</td><td></td></tr>
<tr><td>Closed bus bay</td><td>
Note: with acceleration and deceleration lanes</td></tr>
<tr><td>Queue jumper
bus bay</td><td>
Note: with acceleration lane</td></tr>
<tr><td>Nub
curb extension
bus bulb</td><td></td></tr>
</table>

Despite the fact each of the loading area configurations have broad advantages, they also have disadvantages which makes selection process complex. For example, on-street stop locations influence capacity, when passenger vehicles are allowed to make right turns from the curb lane. In spite of farside /nearside debate has a long history in the transit industry (COTA, 2014; TRB, 2000) indicate that farside stops have least effect in the capacity, facilitate faster travel times and safety for pedestrians followed by midblock and nearside stops. As it is witnessed by the review of results from international surveys and investigations in operational differences of bus bays and curb-side stops, a case of Singapore as Liu, Yang, Meng, and Rau (2017), identified bus bays have longer deceleration and acceleration delays than curb-side bus stops due to re-entry delays during departure from the bus bays. It can be shown, as (Chand & Chandra) does, that presence of stop ominously reduces speed and capacity of an urban road (further refer Table 2-2 and Table 2-3).

Aside from aforementioned factors, conflicts with other vehicles, transfer opportunities, and traffic signal timing must be considered when placing stops (TRB, 2000). Moreover, RTA (2015) argues that locations should be examined to determine volumes, speeds, frequencies, dwell times, pedestrians, bicycle facilities, infrastructure and its improvements and accessibility. In spite of the importance of transportation, there is little information available concerning best practices for safely managing the bus stop and transit riders while construction is underway (Cevallos, Parlade, Pickering, Meneses, & Aldajuste, 2014).

Table 2-2 Comparative review of on-street stop locations

Source: (Higgins & Audirac, 2008, p. 54)

Advantages	Disadvantages
Near side	
1) Minimizes interfaces when traffic is heavy on the far sides of the intersection 2) Passengers can access buses closest to the crosswalk 3) Intersection is available to assist in pulling away from curb 4) Does not require double stopping thus Buses can service passengers while stopped at the red light 5) It provides driver with opportunity to look for oncoming traffic including other buses with potential passengers.	1) Increased conflicts with right turning vehicles 2) Stopped buses may obscure curb-side traffic control devices and crossing pedestrians 3) Sight distance is obscured for cross vehicles
Far side	
1) Minimizes conflicts between right turning vehicles & buses 2) Through lane may be blocked during peak periods by queuing buses 3) It minimizes sight distance problems on approaches to intersection 4) It encourages pedestrian to cross behind the bus 5) Require shorter deceleration distance for buses 6) Gaps in traffic flow are created for buses re-entering the flow of traffic at signalized intersections'	1) Intersections may be blocked during peak periods by queuing buses 2) Sight distance may be obscured for crossing vehicles 3) Increases sight distance problems for crossing pedestrians 4) Bus gives stopping far-side after stopping for a red light interferes with bus operations and all traffic in general 5) It may increase number of rear –end accidents since drivers do not expect buses to stop again after stopping at a red light
Mid-block	
1) Minimizes bus stop sight distance problems for vehicles and pedestrians 2) Passenger waiting areas experience less pedestrian congestion 3) Passenger access busses closest to crosswalk	1) Requires additional distance for no-parking restrictions 2) Encourages patrons to cross street at mid-block 3) Increases walking distance for patrons crossing at intersections

Table 2-3 Comparative review of off-street stop configurations

Source: (TRB, 1996b, pp. 22, 23)

Advantages	Disadvantages
Bus bay	
1) Allows patrons to boards and alight out of the travel lane 2) Provides a protected area away from moving vehicles for both the stopped bus and bus patrons 3) Minimizes delay to through traffic	1) May present problems to bus drivers when attempting to re-enter traffic, especially during periods of high roadway volumes 2) Is expensive to install compared with curbside stops 3) Is difficult and expensive to relocate
Open bus bay	
Allows the bus to decelerate as it moves through the intersection See bus bay advantages	Similar with bus bay disadvantages
Queue jumper bus bay	
Allows buses to bypass queues at signal Similar with open bus bay advantage	May cause delays to right-turning vehicles with a bus is at the start of the right turn lane See bus bay disadvantages
Nub	
1) Removes fewer parking spaces for the bus stop 2) Decreases the walking distance (and time) for pedestrians crossing the street 3) Provides additional sidewalk area for bus patrons to wait 4) Results in minimal delay for bus	1) Costs more to install compared with curbside stops 2) Similar with curb-side disadvantages

As it can be seen from the different loading area configurations in Table 2-1, Table 2-2 and Table 2-3, it can be observed that various configurations require different environments for conducting safe and efficient stops. However, some of the critical circumstances which are identified by (GCRTA, 2015); include parking and curb radius. More importantly as it is argued (TFL, 2014) if stop configurations are harmonized with stop infrastructures and especial low floor vehicles they may facilitate bus ridership by the disability community, thus avoiding mobility impairment and cut unnecessary Para-transit costs Figure 2-2 below shows sample low floored vehicle access.

Figure 2-2 Sample low floored vehicle access

Source (TFL, 2014, p. 4)

In doing so TriMet (2010) suggested that a stop should remain in service for at least 5-10 years if there is heavy use by riders who are elderly or disabled since a new location would clearly degrade service for those riders. Thus, it can be noted that stop placement decision is dependent on local variables like ease of operation, users, space, speed, and traffic volume and safety considerations. As a result it is difficult to develop generic guidelines since the local variables involved are complex (Chen & Tsao, 2012; Furth & Mekuria, 2005).

Kikuchi and Vuchic (1982) as cited by Tirachini (2014); identified three typical stopping regimes as: (i) demand stopping; (ii) on-call stopping; (iii) fixed stopping. However, the implementation of any stopping regime also reflects a need from the user side which are often difficult to be met due to supply-side constraints (FDT, 2007). For example, when demand is very low and there is a need to comply with disability policy it is reasonable to provide demand-stopping at any location where passengers wish to get on and off, but as demand grows it will be appropriate to group passengers in a limited number of fixed locations, providing on-call stops in close proximity to each other. Finally, when demand is high, it is more reasonable to locate stops further apart and stop at all of the stations, providing fixed stopping (Tirachini, 2014).

2.5. Bus stop spacing

One of the key determinants of the average operating speed of buses on a line, which have a significant effect in the cost and quality of service perceived by travelers, is stop spacing. Thus, in deciding the number of stops on a route, it is important to realize that each stop causes minimal time losses for decelerating to a stop, unloading and loading passengers at loading area, and pullout from loading area, accelerate back to running speed and reemerge into traffic (COTA, 2014; Eshete, 2015; TRB, 2000). Commonly, when stops come closer together, service coverage is enhanced which makes reduces walking distance to a stop while average speed of the transit vehicles declines (see Figure 2-3). According to (TRB, 2000), assuming 1.22m/s acceleration and deceleration rate as buses enter and exit from stops, it is expected that the average bus speeds decrease as stop spacing decreases while average dwell time per stop increases.

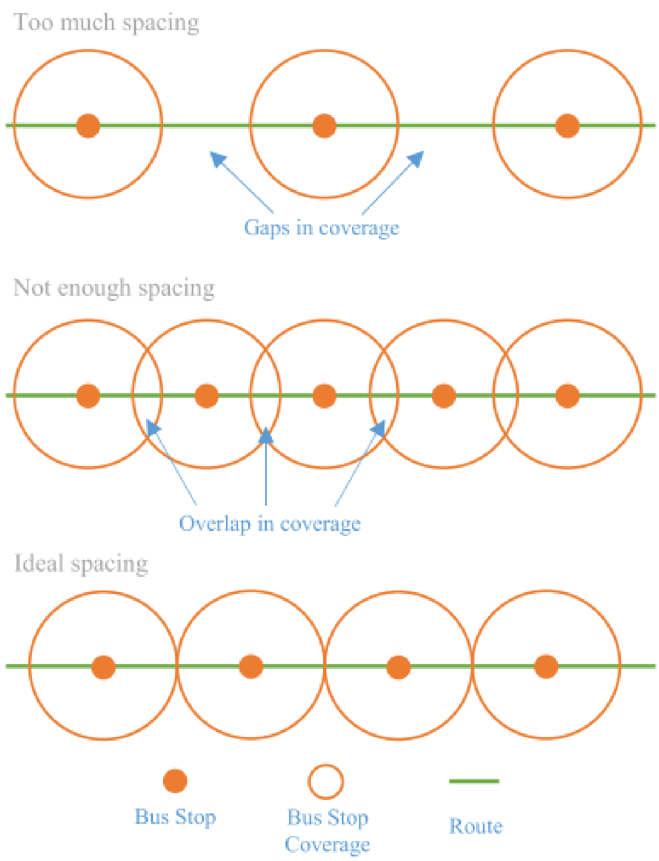


Figure 2-3 Service coverage of stops

Source:(Bus Network Improvement Project of Maryland MTA, 2014, p. 3)

These reduction of bus speeds as stop spacing decreases holds true even in freeways as reported by TRB (2000) see Table 2-4 Estimated speeds of buses.

Table 2-4 Estimated speeds of buses operating in freeway HOV lanes

Source: (TRB, 2000, pp. 27-15)

Stop spacing (km)	Dwell time(s)			
	15	30	45	60
80.5km/hr. running speed				
1.6	34.2	29.9	26.6	23.9
2.4	38.2	34.5	31.5	29.0
3.2	40.6	37.4	34.7	32.4
88.5km/hr. running speed				
1.6	35.8	31.1	27.6	24.7
2.4	40.5	36.4	33.1	30.3
3.2	43.4	39.8	36.7	34.1

In spite of the fact dwell time is a time bus is stopped at the curb to serve passenger movement; (Tsegaye, 2018) outlined longer dwell times and variability of dwell times result in an increase in total travel time which in turn results passenger delay and passengers' discomfort. Further (Tsegaye, 2018) have examined bus dwell time in Addis Ababa city bus enterprise agencies by statistical and multiple regression techniques along with public questionnaire survey and found that it constitutes 14% on average of the total travel time of the studied routes (i.e. average dwell time is 25.64seconds).

What stands out from aforesaid literature is that; bus stop spacing can be understood as a tradeoff between speed and access which makes accessible and efficient services the vital features of well utilized public transit systems, so optimum spacing of stops that will have positive effects on quality of service as well as operational effectiveness, reliability and efficiency; characterized by attractive operating speed and travel time are critical (COTA, 2014; Higgins & Audirac, 2008; Mihretie, 2013; RTA, 2015). In doing so; Feder (1973) cited by Eshete (2015); optimal spacing between fixed-stops should be 0.8 km whereas (Alan Black, 1995) suggested on demand-stops per 1.6 km.

Further, different agencies recommend diverse bus stop spacing guidelines for example: despite (TL, 2005) and (TriMet, 2010) are noticeable for spacing determination more by the frequency of side road accesses than by the distance travelled; the differences between them is; (TL, 2005) specifies is 250 – 350m for fixed-stop spacing along the route where there are few side accesses; whereas (TriMet, 2010) proposition is spacing will be governed by a mixture of variables like density, available alternatives, safety, public input and efficient operations.

On the other hand despite COTA (2014) and TriMet (2010) have devised spacing ranges based on population concentrations; yet COTA uniquely examines ridership, crosswalk accessibility, special populations, nearby destinations, and transfer opportunities during placement of stop. However, stop spacing standards have slight variances for dense, medium to low- and low-density areas. The two widely accepted research programs in the transit industry namely TCRP and NCHRP found out that the range of spacing practiced is between about 90m and 800m (refer Table 2-5) respectively which confirm a moderately uniform spacing should be provided except in few points where there are acceptable conditions. Despite (Adebola & Enosko, 2012) recommends spacing must not be less than 300metres interval in any case, (Furth & Mekuria, 2005) argues that, the tradeoffs involved do not lead to simple, generalizable stop spacing guidelines such as "optimal stop spacing is X meters". Further refer Table 2-5 to see the variance of stop spacing's recommended for different areas.

Table 2-5 Bus stop spacing industry practices

Source: Higgins and Audirac (2008, p. 51)

Description	TCRP Report 19 (m)	NCHRP Report 69 (m)
High density residential areas CBDs, and major employment centers	91.44 - 304.8	134.1 - 160.9
High density residential and employment centers	152.4 - 304.8	201.2 - 268.2
Suburban residential centers	182.9 - 762	321.9 - 804.7
Rural areas	198.1 - 804.7	402.3 - 804.7

Thus, studies should be conducted to assess the local conditions which suit both passengers and transit agencies to reap their advantages in an economical way. Besides according to (Adebola & Enosko, 2012; Higgins & Audirac, 2008), it is also apparent that stop locations may be added or eliminated along existing routes due to various reasons; thus, periodic stop audits should be made simultaneously to maintain their functionality with respect to the changes and/or enhance the cost's associated and either maintain or enhance quality service perceived by commuters.

For example, El-Geneidy et al. (2006); examined a bus stop consolidation project of TriMet, a transit provider for the city of Portland, Oregon in the United States (US). Using archived automatic vehicle location and automatic passenger counter data recorded at the bus stop level; they initially linked each scheduled bus trip before and after consolidation for producing a paired sample. Paired-sample t-tests and regression models were used to evaluate the statistically significant differences in transit performance and demand between pre-implementation and post-implementation periods and control and treatment segments. The findings indicated that stop consolidation achieved the intended objective of concentrating passenger movements among fewer stops, thus reducing time lost from deceleration, dwell, and acceleration.

2.6. Profile of Addis Ababa

2.6.1. Evolution

In the late 19th century Emperor Menelik II and his wife Empress Taitu founded the city of Addis Ababa which is the capital city of Ethiopia (Addis Ababa means 'New Flower' in English). The city is located at 9°1′48″N and 38°44′24″E coordinates with present-day administrative subdivisions of ten sub cities and twenty seven Wereda's (Berhan, 2013; Eshete, 2015) with an area of over 540sq.km, and situated at an altitude ranging from 2,100 meters at Akaki in the south to 3,000 meters at Entoto Hill in the North which makes it the third highest city in the world, after La Paz and Quito in Latin America (CGAA, 2013).

As of the current year the city is 123 years' old which makes it relatively young as compared to other capital cities. The city has evolved from a small rural settlement of the 1950s into a vibrant modern metropolis today. Much of this urban transformation began during the period of Imperial Rule but accelerated in the post-1991 era (UN-Habitat, 2017).

2.6.2. Urban planning

Further according to (UN-Habitat, 2017), since the establishment of Addis Ababa in 1886 the city had evolved organically without formal planning practices. However, (Mahiteme, 2007) and (Tufa, 2008) cited by (UN-Habitat) mentions historians believe that there existed an informal master plan led by Empress Taitu, often referred as "Taitu's era master plan", that guided city development until the Italian colony occupied Ethiopia from 1935 through 1940.

During this short occupation of Italy, the first attempt to prepare a master plan were made by architect Le Corbusier in 1936 without a due consideration of city's topography. As a result, architects Guidi and Valle in 1938 proposed a new orthogonal street plan, by means of proposed housing development, waste management, road construction and public transportation system.

Subsequent to the Italian occupation era (1935-1940) the quest to modernize the city of Addis Ababa is also continued in the imperial regime (1941-1974). However, despite three urban plans were prepared during 1956-1966 none of these plans were taken into effect due to financial and technical constraints. Later in the downfall of the imperial regime and the introduction of Socialism as a major ideology to guide the economic and social development of the nation by the Dergue Era (1974-1991), the Dergue regime also attempted to develop master plan twice for Addis Ababa city; however, failure of regime to timely effect the master plan had contributed urban sprawl (UN-Habitat, 2017). Back then since 1991 Ethiopian People's Revolutionary Democratic Front (EPRDF) government undertook improvement measures in inner-city and outskirts of the city.

As part of this improvement measures so as to guide, regulate its growth and improve the quality of life of urban residents two master plans were prepared in 1984 a comprehensive development plan (CDP) with a great focus on transport and the 1994 master plan. Thereupon huge public investments have been made to improve water supply, housing, sanitation, waste collection, drainage and road networks (Eshete, 2015; UN-Habitat, 2017). Consequently, it is an observable fact that Addis Ababa has experienced unprecedented development especially with in past two decades aside with population growth demanding more basic infrastructure expansions. To address this the tenth master plan was prepared by **AACGPC** (AddisBiz, 2017) and has been unanimously endorsed as the city's 10 Master Plan (EBC, 2017). The new plan as Mayor of the city Direba Kuma spoke out at council of city will enable to use existing land and give attention to vertical expansions (EBC, 2017).

2.6.3. Demographics and population

Population censuses that were conducted in several African countries in the pre-independence era, all of them could not be considered scientific undertakings. Unfortunately, Ethiopia, on the other hand, is one of those countries that did not have long history of census taking. So far, only three national population and housing census were conducted: in 1984, 1994 and 2007 (CSA, 2012). Hence there is no reliable statistical data to show Addis Ababa's population tendencies since its establishment except the first census in 1961. However, as (UN-Habitat, 2017) argues several researchers have provided estimated population numbers for the city since 1889. Further (UN-Habitat, 2017) cited (World Bank, 2015) and (CSA July 2015), Ethiopia total population is estimated about 90 million people. Of the total population 19.5% (17.5 million people) live in urban areas. This number is rising fast due to an annual urban population growth of 4.89%. Ethiopia's urban population is projected to triple by 2037 Addis Ababa hosts an estimated 3.238 million people, which is a 17% share of Ethiopia's total urban population. Further according to (UN-Habitat, 2017) currently, Addis Ababa is experiencing an annual growth rate of 3.8% and is estimated to reach 4.7 million inhabitants by 2030. (See Table 2-6).

Table 2-6 Addis Ababa estimated population (1889-2010)

Source: (UN-Habitat, 2017, p. 11)

Year	Population (estimated)
1889	15,000
1910	65,000
1930	80,000
1935	140,000
1961	455,490
1967	683,530
1979	1.27 million
1984	1.42 million
1994	2.11 million
2007	2.7milion
2010	3.3 million

2.6.4. Public transportation

Despite the fact Addis Ababa is unofficial capital city of Africa, because it hosts numerous international organizations such as the former Organization of African Unity (OAU) the current African Union (AU), the United Nations (UN), Economic Commission of Africa (ECA), Common Market for Eastern and South Africa (COMESA) and so on (Eshete, 2015). However, the first public transportation Anbesa City Bus Service Enterprise started its operation in 1942 with 10 Autobuses and four routes at a rate of 0.15 birr with a name Public transportation service (ACBSE, 2009). Since then several reforms were taken to enhance service through allocation of different bus models namely Mercedes (in 1963), Volvo, Fiat, DAF and domestically assembled Bishoftu buses, changed its name into "Anbesa City Bus Service Enterprise" by the proclamation number 187/1994, altered its color from green and yellow (used in 1951) to the current red and yellow color and its fare to flexible fare (ACBSE, 2009; Eshete, 2015). While this is the case currently ACBSE is operating in mixed traffic conditions which is the most common setup in Addis Abba. It operates with standard and articulated Bishoftu buses to 124 routes fixed route services to suit changing needs. See Appendix A for ACBSE service routes

However, critical financial constraints have made the state owned ACBSE unable to replace the old buses with new ones which in turn, has restricted its service quality and coverage (FDREMT, 2011). As a result ACBSE's monopoly of mass transit sector for the past decades is changing to competitive market following the introduction Star Alliance Bus Share Company and Sheger Public Transport Enterprise into the market since 2009 and 2016 respectively, despite ACBSE is still subsidized by the city administration (AATA, 2016; Eshete, 2015). Besides, due to lack of organized effort bus stop design guidelines have not yet developed; though it is under way at the time of the study. Further despite researches had been made during the past decade most of the recommendations and implementation strategies proposed by these researches were not fully realized due to various problems most importantly in public transit area. Thus, it's an observable that so far, no intense advances are made.

Together with that despite the 2001 revised master plan acknowledged improvement measures to enhance the efficiency of public transportation of Addis Ababa through providing appropriate bus stops (MoFED, 2010), most of the currently available bus stop shades and signage are still sub-standard and inconsistently distributed. Hence, it's common to see passengers asking for service information and queuing in the streets waiting for the transportation services in an open air (See Figure 2-4).

Figure 2-4 Passengers queue in streets of Addis

Source:(AATA, 2016)

In a related recent study conducted by (UN-Habitat, 2017), to examine the state of Addis Abba's historical, demographic and urbanization process based on extensive researches involving a survey of 1,315 individuals, interviews of key officials and secondary data from city government departments and CSA. UN-Habitat's report tried to capture the challenges and opportunities in managing rapid pace of urbanization in Addis Ababa. Specifically, transportation, the report witnesses that despite Addis Ababa city administration is undertaking a continuous measure to promote better transportation services, access to efficient and affordable transportation and mobility remains problematic mostly for those who relocated to peri-urban zones under the urban renewal program.

However, the size and complexity of Addis Ababa’s public transportation problem, the city administration have gradually expanded and considerably increased the types of services availed to the public over the past two decades. As a result, it is a clearly noticeable and all-out effort by associated stakeholders to attend the ever changing and growing needs of the population is gaining momentum from time to time as the administration is hard pressed to satisfy the fast-growing needs for good quality services. Despite the inadequacies were inviting situations for establishment private mass transit firms, several concurrent actions are being taken by the city administration to deal with the current transportation related problems for instance to entertain the private sector especially for Star Alliance Share Enterprise, by putting duty free and loan measures in place for 200 buses to alleviate the acute public transportation problems for city of Addis Ababa (Berhane, 2017). Besides according (AATA, 2016) the city administration have established Sheger Mass Transportation Service Enterprise with a view in addressing a shortage of transport service at a cost of two billion Birr. The remarkable features being implemented in Sheger are of two kinds: (1) service features ease of access for elderly, physically challenged, pregnant woman and children, air conditioning, limited stop service, and flexible fare initiatives (2) technological features like GPS, LED displays and next stop orientations.

Likewise according to (AACTA, 2017; AATA, 2016), to solve Addis Ababa city civil servants transportation problem which caused an intense stress to report at their offices on time and provide services to clients waiting for them, transportation service for federal and Addis Ababa city civil servants was launched with 410 buses on 263 routes, which transport servants to and from work. Besides it provides a paid service for the general public during the rest of the day (morning and evening time). In general, the public service is giving services for 61,000 passengers per day.

Furthermore a major and eye catching step that had been taken by the government in this respect include the enactment of proclamation No 43/2014 directive for the re-amendment of the Addis Ababa city government executive and municipal service organs re-establishment Proclamation No. 35/2012 to tailor the future economic, social and good governance development plans of Ethiopia by organizing executive organs of city government in line with federal government executive organs specially AACRTB, AACRA and AATA. This proclamation gives responsibilities related to mass transportation system and infrastructure of the city to AATA and AACRA respectively. Whereas AARTPO is aligned with conducting, developing and implementing strategic studies while superiorly directing, administering and controlling AATA and AACRA.

With regard to mass transport proclamation No 43/2014 also lists the key responsibilities of AATA include: (1) to develop appropriate data regarding mass and freight transport in the city (2) to superiorly control, direct, issue or suspend license and operation system of mass transport service rendering bodies (3) cause formation of centralized mass transport system of the city; prepare deployment schedule; study and submit tariff to the concerned body; work towards implementation of the same upon approval; install technological system that help for execution (4) build bus stations and bus stops with in the city government that are to be used by vehicles; administer stores and depots (5) issue directives on the general mass transport system and implement the same upon permission and (6) study supply and demand of mass transport of the city.

To this end AATA had made and is making an effort to improve public transportation some of the remarkable studies conducted regarding public transportation which were accessible at the time of the study include: Feasibility and Operational Planning Study of Bus Rapid Transit (DIMTS, 2015) and Bus Network Design and Assignment (AATA, 2016). Further, a detailed design study of Rapid Bus Transit is in the pipe line and facility provision of 500 modern bus stop stations is underway by AATA at the time of the study (AddisBiz, 2017). The newly constructed shelters are also being far more attractive and safer as compared to the old ACBSE constructed shelters. Despite these shelters are tuned for maximum safety, it is unfortunate fact that they are prone to crime. Hence, they should be supplemented with technological tools like CCTV cameras which will also help in counting passengers boarded and alighted in each stop while enhancing the security of the stop.

However, it is currently an observable fact that population growth is putting continued challenges on the city administration despite the government is currently attempting to include state of the art low floor buses, accessible bus stops characterized by fair pedestrian facilities which makes trip to the stop enjoyable, safe, and convenient and the provision of light rail transit (LRT). On the other hand, the new 10th master plan had devised integrated plans in terms of public transport, with planned extension of the Addis Ababa Light railway routes. Also a new Rapid Bus Transit lane exclusive to public transport will also be developed, alongside the manufacture of dedicated buses to enhance the types, quality and reliability of cities mass transportation system (AddisBiz, 2017). Additionally, Autobus depot foundation stone for Shegole and Kality is put in place by the mayor of the city administration Direba kuma. In his statement at the ceremony Direba said that despite there are numerous works done under mass transportation system, to make the service accessible and modern standard autobuses should also be provided along with constructing a centralized state of the art world class facilities and tools, to foster this the city administration had budgeted 1.4 billion birr.

Furthermore AACRTB head Dr. Solomon Kidane in his side added the new depots (i.e. Shegole and Qality) will accommodate 200 to 350 buses in cooperating modern garages and car wash technology that washes and dries within two minutes (TPMO, 2017). From these two projects the construction of Shegole depot with a budget of 500 million birr with 52 thousand square meters is underway. TMPO magazine add-ons that the depot is expected to reduce the acute shortage of terminals, lessen traffic congestion resulted from boarding and a lightening passengers and improves ease of access to different alternatives for passengers (TPMO, 2017). Notwithstanding all those aforementioned efforts, however, it still remains to be true that a lot needs to be done in the public transit by way of diversifying service types and improving service quality together with detailed economic investigations. If we now turn now to the next section, the next section of the chapter is concerned with research method.

CHAPTER 3
RESEARCH METHDOLOGY

An economic impact is any change in the amount flow and/or distribution of money due to changes in the production, distribution, and consumption of goods and services. Analysis of economic impact is done to support decision making, to determine the value of a policy, project or program, and to measure the magnitude and duration of the economic effects (Litman, 2006). In this regard transportation is an essential part of the economy and changes are likely to impact the economy in some way. Taking this fact many studies claim that transportation funds are life blood of the economy and see transport as engines that fuel economic growth. Consequently, determining whether a given transportation investment or policy makes enough of an impact to earn the description of "economic engine" requires a careful data collection and analysis.

3.1. Impact characterization

Public bus transit is notable to its uniqueness with its frequent interface with commuters at bus stops which necessities the need for achieving a maximal coverage of given demand points with a minimal number of bus stops. Thus, periodic audits simultaneous with economic evaluation should be made to ensure overall transit compatibility with quality of service expected by commuters, objectives set by planners and for continuous improvement of industry practices. Unfortunately, it has been found out there is often a tradeoff between equity and efficiency objectives. To evaluate these perceived compromise between equity and efficiency with in local setting; which is likely to promote increased utilization of public transit, economic impact analysis (EIA) in context of this paper is done to unveil how bus stop will impact the primary recipients of public transit, community and agency in selected major routes; the impacts characterized and investigated in the course of service are direct impacts related with the service accessibility and road user effects; indirect impacts include the environmental effects on the community at large.

Taking the lessons from evaluation approaches cited in the literature, pertinent documents at the time of the study were identified to assess bus stop design practices as they exist today, the anticipated data to be collected were: road network, land use, stop locations, hourly passenger demand, population density, improvement plans, passenger per trips, fare per passenger, passengers per kilometer, route level minimum costs and revenue per route. Yet, acquisition of data was only possible to limited data's, to find best-possible answers for:

- How bus stop locations are spatially distributed in the route considered?
- How many passengers are served in the case study routes per trip?
- How much population could easily access stations within 700m walkway?
- Where is the best location for bus stop along the existing routes of interest?
- Do existing bus stops located in suitable areas resulted suitability model?
- What should be the proposed change to spatial distribution of stations?
- What are the direct and indirectly induced impacts in the course of service?
- What will the net result of alternative scenario in delivering the service?

Prior studies have also underlined the importance of identifying areas with employment and population densities which are likely to generate considerable transit use; some of the noticeable CBD in Addis Ababa city include Hayahulet, Kazanchis, Mexico, Aratkillo, Piazza and condominium housing sites like Yeka-abado, Ayat-tafo, Semit and Jemo (to name a few). And yet, the 10th master plan recognizes city centers across eight locations, including the National Theatre, Cherqos, Filwoeha-Mesqel square, Lagare, Kazanchis and Churchill with a total of 335ha dedicated to the plan which will be finalized over the coming five years (AddisBiz, 2017). Since the case study is based on ACBSE fixed stop bus service routes which link densely populated suburbs located in the outskirts of the city with the inner city central business districts (CBD) like Aratkillo, Piazza, Lagare, Megenagna, Kotebe and Ayat, monthly financial and ridership performance reports compiled by ACBSE is used to evaluate the routes efficiency and identify major routes for the year 2008 and 2009EC.

The criteria to select these routes were as follows: first intra-city service routes were identified and routes were then organized by revenue generated. Yet, ACBSE bus performance reports compiled based on ticket sales data appears to support the assumption that there may be situations allocated buses may not provide service. Thus, three routes operating along the commonly known and specified central business districts in the 10^{th} master plan which serve a noticeable yearly passenger were selected based on the ridership performance of ACBSE (See detailed data in Appendix A). The identified routes of interest for this study are route number 10, 31 and 101 which play a great role in the provision of public bus transit to peoples resettled in condominium buildings, central business districts and densely populated areas in various sub cities namely Guelele, Yeka, Bole, Arada, and Kiros. See Figure 3-1 for study area location in Ethiopia, Addis Ababa

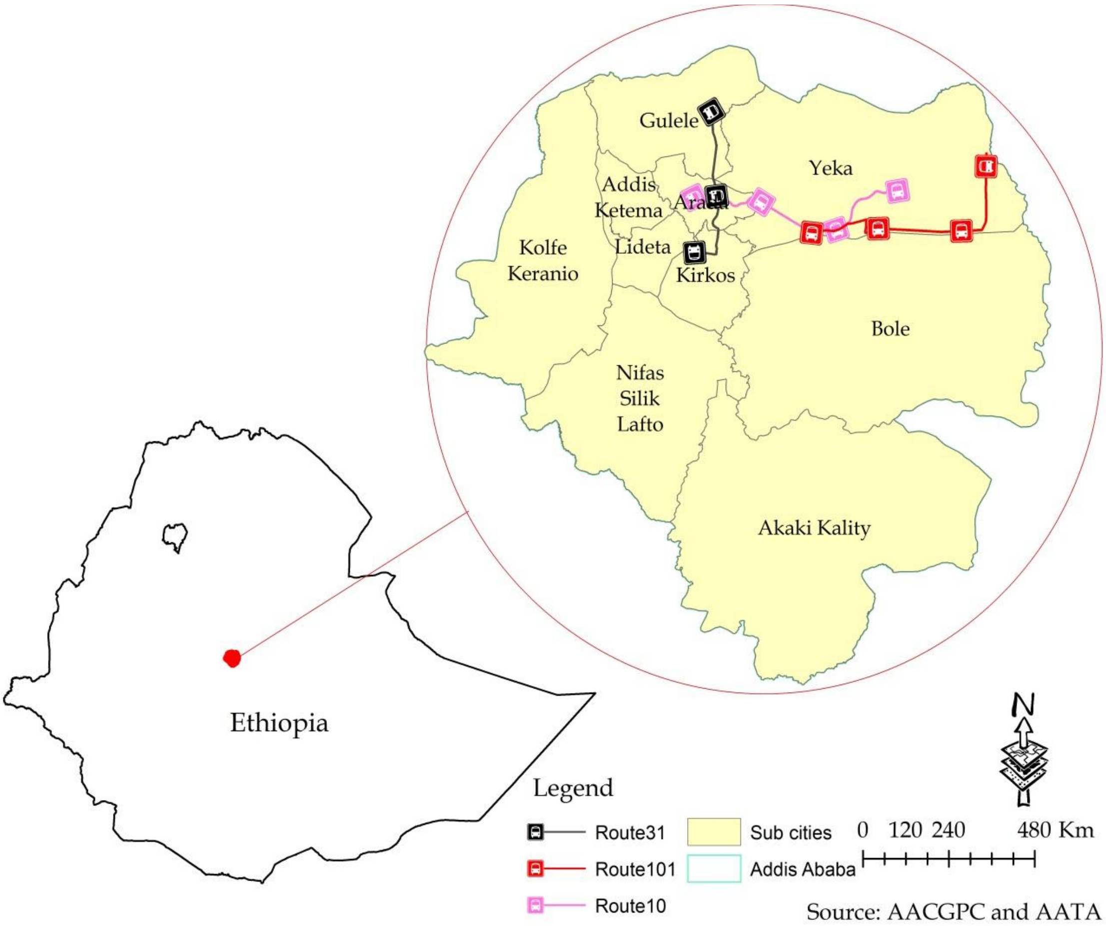


Figure 3-1 Study area location in Ethiopia, Addis Ababa

Source: AACGPC and AATA

Thereby for the purpose of economic evaluation, two analysis scenarios are defined as (1) base line (i.e. existing condition) and (2) Alternative (i.e. proposed change). Then relative and absolute assessment of benefits, magnitude and value of particular alternative scenario is compared in relation to the base line scenario to identify the savings and/or costs and select the best possible scenario that can be considered good. See Figure 3-2 for the evaluation framework

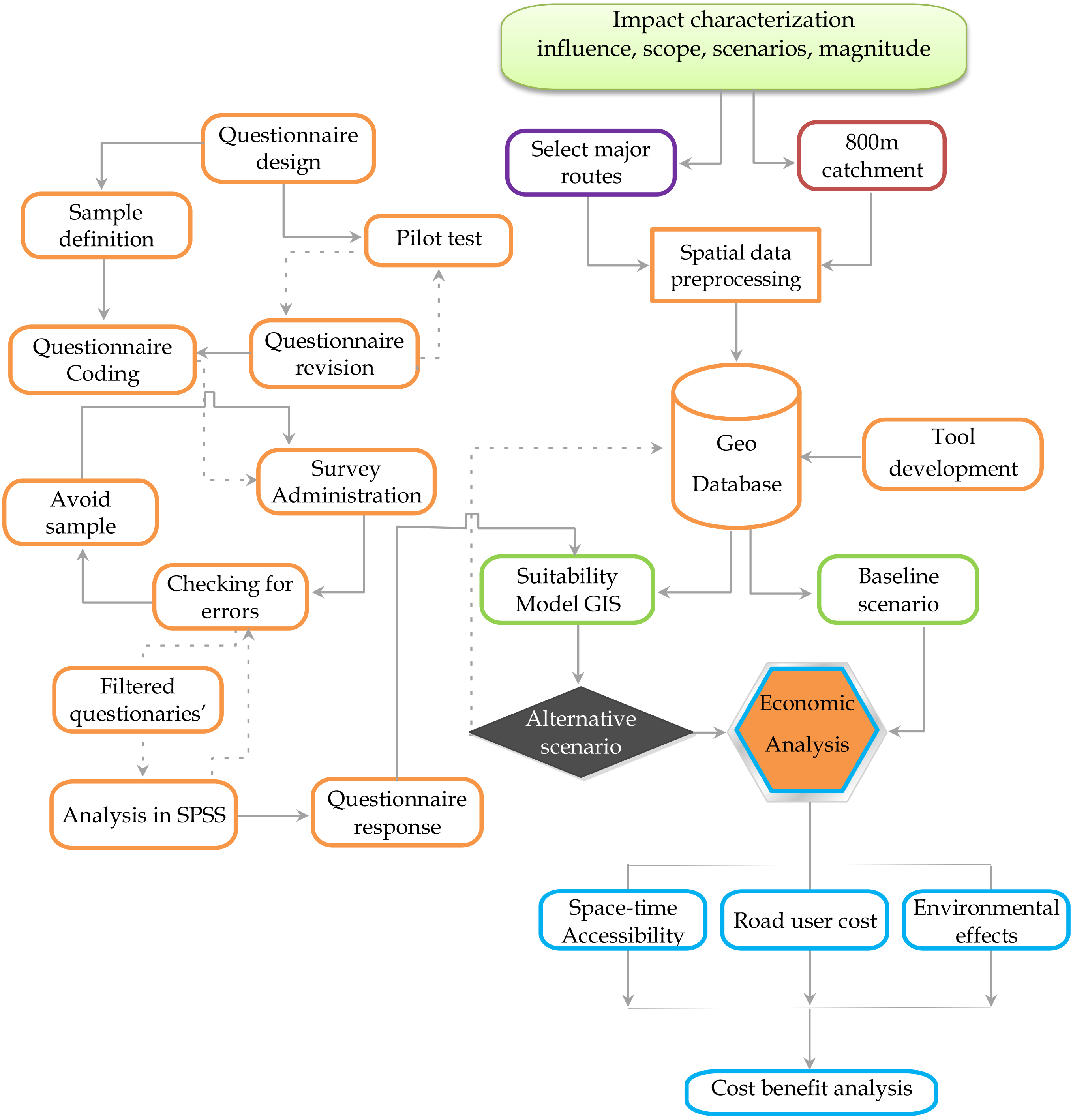


Figure 3-2 Research framework

3.2. Questionnaire survey

It is obvious that demand for transit service is elastic implying service quality determines ridership which ultimately determines revenue (Spasovic, Boile, & Bladikas, 1993). So as to recognizing these interactions between demand and supply this research used a mixture of structured closed and open-ended questionaries' set to assess the current public transit from commuter's point of view (complete details included in Appendix B). However, of all the concerns with questionnaire design, sample size, instrument quality and optimal combination of survey instrument quality and sample size were the critical ones.

Thus, firstly a questionnaire is developed in Amharic language that is convenient for most of the willing respondents using self-explanatory words limited to fill in the blank and multiple-choice questions that encouraged a higher response rate and minimum cost of response. Plus, to avoid confusions ten pilot test questionnaires were administered to find out how participants will understand questions and how long it takes to complete single questionnaire; then revision is made based on the lessons learnt to attain objectives.

Following that, sample size is determined using the z-distribution table and using values from Student two tailed t-distribution. Thus, the value of sample proportion was fixed to 0.5 to fully ensure the specified degree of confidence interval of 90% with margin error being 6.5% of the true proportion. Consequently, the minimum sample size identified is 160 estimated using Equation 3-1 shown below. Instead, to avoid measurement and non-response error the sample size is adjusted to 200 questionnaires.

$$n = \frac{\mathrm{pq}\left(\frac{Z_{\alpha/2}}{E}\right)^2}{1 + \mathrm{pq}\left(\frac{Z_{\alpha/2}}{E}\right)^2 * N}$$

Equation 3-1

Where:

n sample size required | Confidence interval

E maximum error of the estimate value for n | p and q sample proportion

N Projected population density

Then, the revised questionnaire was duplicated and each questionnaire was uniquely numbered and distributed to willing respondents who were randomly selected who use, might use and not use bus transit but at least familiar with mass transportation in spite of frequency of use. Further to avoid future analysis errors among respondent's orientation has been made to create an awareness that respondents are taking the first step to express envision and proposals for public transportation service.

Next the questionnaires are forwarded to willing respondents in order to identify how participants perceive transit waiting setting and riding process through the following set of questions:

- What is the sex, age, work and transportation mode of the respondent?
- Why the respondents selected specific transit mode over other?
- How much they spent for transportation per day?
- How much time and distance they spend to access transportation?
- How frequent you will use public bus transportation in weekly basis?
- Who do you perceive the most users of public bus transportation?
- What is their rating for the current public bus transit?
- Rank what discourages them not to use public bus transportation?
- What did they lose because of the current quality of bus transit?
- What improvement measures should be taken to enhance the service?

Though secondary data by no way equates primary data and the reviewed literature noted equity is commonly gauged from qualitative data's, every possible effort was made to maintain quality of data during questionnaire administration. Thereafter, precursor to analysis responded questionnaires were checked for errors subsequently erroneous samples were avoided. Then filtered questionnaires were analyzed using SPSS version 20.0. The results of analysis are presented in tables at Appendix B where each row represents a 'case', i.e. a specific respondent and their data whereas each column represents a specific measurement variable. Further public opinion's response is checked using Cronbach's alpha test.

3.3. Analysis scenario's

Extensive literature has shown that ACBSE is established with the intention to provide public transit service with great responsibility to serve the public and improve/upgrade its service to satisfy its passengers' need as well as to cut costs at large (ACBSE, 2009; Berhan, Beshah, & Kitaw, 2013). To do so provision of optimum bus stop spacing is a stimulus that provides a step forward to that goal by maintaining the tradeoff between operating agency costs and public welfare. In spite of the fact that all conflicting interests may not be fully satisfied, this paper seeks to characterization of the existing impacts versus the predicted impacts of an alternative being considered as a good balance of possible concerns and feasible courses of action. With this in mind a baseline analysis scenario is defined as the existing spatial distribution of stops, to measure the net changes that would have occurred in the absence of the change.

Still further, the literature suggests that removing and/or consolidating stations that are not with in certain spacing threshold will offer improvement in operations, coverage and emissions. Indeed as it has been noted in (Alam, 2015; Shrestha & Zolnik, 2013) spacing bus stops at rigidly regular intervals will result in introduction of accessibility improvements but it will inevitably result in inconvenient positions which makes itself insufficient to balance all opposing issues. Therefore, it is appropriate to consider various factors like transfer opportunities, accessibility and safety when placing bus stations. Yet, considering all this will often create multiple objectives, in response to identify suitable locations a suitability analysis which can reflect particular set of human reasoning characteristics is done using the multiple criteria decisions making (MCDM) approach called Analytic Hierarchy Process (AHP). The wide acceptance of AHP by various organizations, and countries all over the world for instance a review in online database like science direct reveals more than 21,289 publications is made on AHP to date (2019, May 24) and practical application of AHP in a previous research by (Taye, 2016) is the motivation for this study to use it for GIS based suitability modeling of an alternative scenario.

Besides AHP uses one to one qualitative and quantitative comparison which is clear and easy to digest by decision maker by a preference scale for pairwise comparisons with a numeric value as shown in Table 3-1 below

Table 3-1 Preference scale for pairwise comparisons

Source: (Bernard, p. 423)

Preference level	Numeric value
Equally preferred	1
Equally to moderately preferred	2
Moderately preferred	3
Moderately to strongly preferred	4
Strongly preferred	5
Strongly to very strongly preferred	6
Very strongly preferred	7
Very strongly to extremely preferred	8
Extremely preferred	9

The application of AHP in this paper is structured in to five steps as follows:

Step 1) **<u>Define the decision goal, factor, and sub-criteria's,</u>**

As long as optimum bus stop locations are considered most of the literature reviewed showed it is a circumstantial decision. Given this subjectivity of professionals in the context, AHP & Likert scale are integrated with GIS to assist in organizing thoughts and judgments to make more effective suitability model that answers the question, "Where is the best location for bus stops along the route of interest?" taking into consideration of various objectives such as those local objectives set by AACGPC which is "to reduce distance to public transit to 500 meters" thereby, based on the literature review, discussions with transport experts and available data at first hierarchal level, two objectives are identified to locate stations so as to meet the following objectives:

1. To safely integrate bus stop with built-in environment
2. To maximize the total accessible population in the service area

Therefore, the following parameters were used to better address the objectives:

- Safely integrate bus stop with built-in environment:

A key aspect of integrating bus stops with built-in environment is to identify recognize events that might have negative impacts upon safety; of all the concerns addressed include to locate stations in relatively flat lands with farside stop configuration to steer riders to safe street crossings, minimize impacts in the following traffic and allow signal treatments work effectively whenever possible.

- Maximize the total accessible population in the service area

Most passengers enter a public transit to reach their desired destination but there might be in-accessible areas. So as to lessen these accessibility problem stations need to be placed in proximity to densely populated areas and railway stations to facilitate potential transfer opportunities to better serve the demand.

Thereby factors shown in Table 3-2 are identified as indicators of suitability

Table 3-2 AHP criteria and sub-criteria's

ID	Criteria	Range	Dataset
1	Slope (C1)	Less than 4%	Elevation
		4- 6%	
		6-8%	
		8-10%	
		Greater than 10%	
2	Vicinity to rail stations (C2)	0-100m	AALRT stations
		100-200m	
3	Far from traffic accident black spots (C3)	0-100m	Accident Black spot
		100-150m	
		150-200m	
4	Land use (C4)	Residential	Land use
		Industrial	
		Commercial	
		Community service	

Subsequently, a questionnaire survey (see Appendix C) is used that target transport professionals serving in the city government offices are asked to compare pair of factors from most important to least important by a numeric preference scale developed by Saaty which ranges from 9 to 1 to 9 to derive weights of identified factors.

Step 2) <u>Rate the criteria's through pairwise comparisons</u>

In order to prioritize the decision alternatives with in each criterion, pairwise comparisons of factors are displayed in ordered matrixes where only half of the matrix has to be filled in, as the other half is obtained from the reciprocal weights in ratio form is given by Equation 3-2.

$$\boldsymbol{A} = \begin{matrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{matrix} = \begin{matrix} 1 & z_1\ z_2 & \cdots & z_1\ z_n \\ z_2\ z_1 & 1 & \cdots & z_2\ z_n \\ \vdots & \vdots & \ddots & \vdots \\ z_n\ z_1 & z_n\ z_2 & \cdots & 1 \end{matrix}$$ **Equation 3-2**

Since the study involves multiple decision makers where most of the participants selected are being an expert in the transit field, individual judgements are aggregated to find the geometric mean of the judgement matrix with element's given by Equation 3-3

$$c_{ij} = c_{ij}^{1} * c_{ij}^{2} * c_{ij}^{3} * c_{ij}^{4} \cdots c_{ij}^{h} \ {}^{1}\ {}^{h}$$ **Equation 3-3**

Where

c_{ij}^{k} the pairwise comparison value of criteria i and j given by decision maker

k the number of decision maker k = 1, 2, …, h.

c_{ij} geometric mean of the pairwise comparison conducted by each decision maker (judgement matrix)

Step 3) <u>Developing Preferences within factors</u>

The next step in AHP is to prioritize the decision alternatives within each criterion Eigenvector method is used; which comprise;

- Sum the values in each column of the pair-wise comparison matrices, divide each value in each column of the pairwise comparison matrices by the corresponding column sum to obtain normalized matrices

$$A' = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{bmatrix} = \begin{bmatrix} \frac{c_{11}}{\sum_{i=1}^{n} c_{i1}} & \frac{c_{12}}{\sum_{i=1}^{n} c_{i1}} & \cdots & \frac{c_{1n}}{\sum_{i=1}^{n} c_{i1}} \\ \frac{c_{21}}{\sum_{i=1}^{n} c_{i1}} & \frac{c_{22}}{\sum_{i=1}^{n} c_{i1}} & \cdots & \frac{c_{2n}}{\sum_{i=1}^{n} c_{i1}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{c_{n1}}{\sum_{i=1}^{n} c_{i1}} & \frac{c_{n2}}{\sum_{i=1}^{n} c_{i1}} & \cdots & \frac{c_{nn}}{\sum_{i=1}^{n} c_{i1}} \end{bmatrix}$$

  - Sum up each row of normalized matrix A′ to get weight vector V.

$$PV = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{n} c_{1j'} \\ \sum_{j=1}^{n} c_{2j'} \\ \vdots \\ \sum_{j=1}^{n} c_{1j'} \end{bmatrix}$$

- Average the values in each row of the normalized matrices to get preference vectors and summarize the relative priority for each criterion in relation to their parent criterion

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} \frac{v_1}{\sum_{i=1}^{n} v_i} \\ \frac{v_2}{\sum_{i=1}^{n} v_i} \\ \vdots \\ \frac{v_n}{\sum_{i=1}^{n} v_i} \end{bmatrix}$$

Step 4) **Measure degree of inconsistency**

Further to rely on result the uniformity of respondent's answers to establish preferences between decision alternatives for different criteria's is measured using consistency ratio as follows:

1. Multiply each column of the pair wise comparison matrix by the corresponding weight. (consistency vector)

$$CV = \begin{matrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{matrix} * \begin{matrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{matrix} = \begin{matrix} CV_1 \\ CV_2 \\ \vdots \\ CV_n \end{matrix} \quad \begin{matrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{matrix}$$

2. Divide of sum of the row entries by the corresponding weight.

$$CV_{11}{}' = \frac{1}{w1} \quad \begin{matrix} w1 * c_{11} & + & w2 * c_{12} & + & w3 * c_{13} \\ w1 * c_{21} & + & w2 * c_{22} & + & w3 * c_{23} \\ & & \vdots & & \\ w1 * c_{n1} & + & w2 * c_{n2} & + & wn * c_{n3} \end{matrix}$$

$$CV_{21}{}' = \frac{1}{w2} \quad \begin{matrix} w1 * c_{11} & + & w2 * c_{12} & + & w3 * c_{13} \\ w1 * c_{21} & + & w2 * c_{22} & + & w3 * c_{23} \\ & & \vdots & & \\ w1 * c_{n1} & + & w2 * c_{n2} & + & wn * c_{n3} \end{matrix}$$

$$CV_{31}{}' = \frac{1}{w3} \quad \begin{matrix} w1 * c_{11} & + & w2 * c_{12} & + & w3 * c_{13} \\ w1 * c_{21} & + & w2 * c_{22} & + & w3 * c_{23} \\ & & \vdots & & \\ w1 * c_{n1} & + & w2 * c_{n2} & + & wn * c_{n3} \end{matrix}$$

3. Compute the average of the values from step 2, denote it by λmax

$$\lambda\text{max} = \sum_{i=1}^{n} CV_{ij} \; n$$

4. Then the consistency index is computed using the numbers of items that are compared in this case are four criterions. Henceforth, average of these values is obtained by summing them and dividing by four by Equation 3-4

$$\boldsymbol{CI = \frac{\lambda\text{max} - n}{n - 1}}$$ **Equation 3-4**

Where:

λ_{max} the approximate n Order of matrix

5. Consistency Ratio (CR) is calculated by dividing Consistency Index (CI) by Random index (RI) which is based on the order of matrix as shown below.

Table 3-3 Random index (RI) based on order of matrix

Source: Saaty, 1980

n	1	2	3	4	5	6	7	8
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.35	1.41

In general, the degree of consistency is satisfactory if CR is less than 0.1. Thereby a single set of weights extracted that represent a consensus view which aspects of the criteria's considered will decide either being suitable or unsuitable.

Step 5) **<u>Pairwise comparison for sub-criteria scoring</u>**

To standardize the scores of sub-criteria's a five point scale for pair wise comparison of sub-criteria similar to Likert-type scale which is a bipolar scaling method is used to measure either positive or negative response to sub-criteria's being suitable for locating a bus station and to prioritize importance of each criterion in the overall context of the factor; as shown in Table 3-4.

Table 3-4 Five-point scale for sub-criteria scoring

Suitability Class	More suitable	Highly suitable	Moderately suitable	Suitable	Less suitable
Score	5	4	3	2	1

Step 6) **Suitability model**

A suitability analysis tool is developed in ArcGIS model builder to fast-track the analysis by linking datasets with tools & corresponding relative weight of factors and enables ease of identifying suitable locations for bus stop. The overall process is includes mapping selected datasets along the route of interest, then linking datasets from the folder connections established as input parameters (to make them show up when the model is executed) in the model with spatial analyst tools as shown in the figure below to create raster's (i.e. rasterizing) followed by reclassification of output data in to sub-criteria's as per the classification's made in AHP analysis finally the reclassified data's are combined to identify surfaces with possibility of being suitable for all the preferred constraints. See Figure 3-3 for workflow

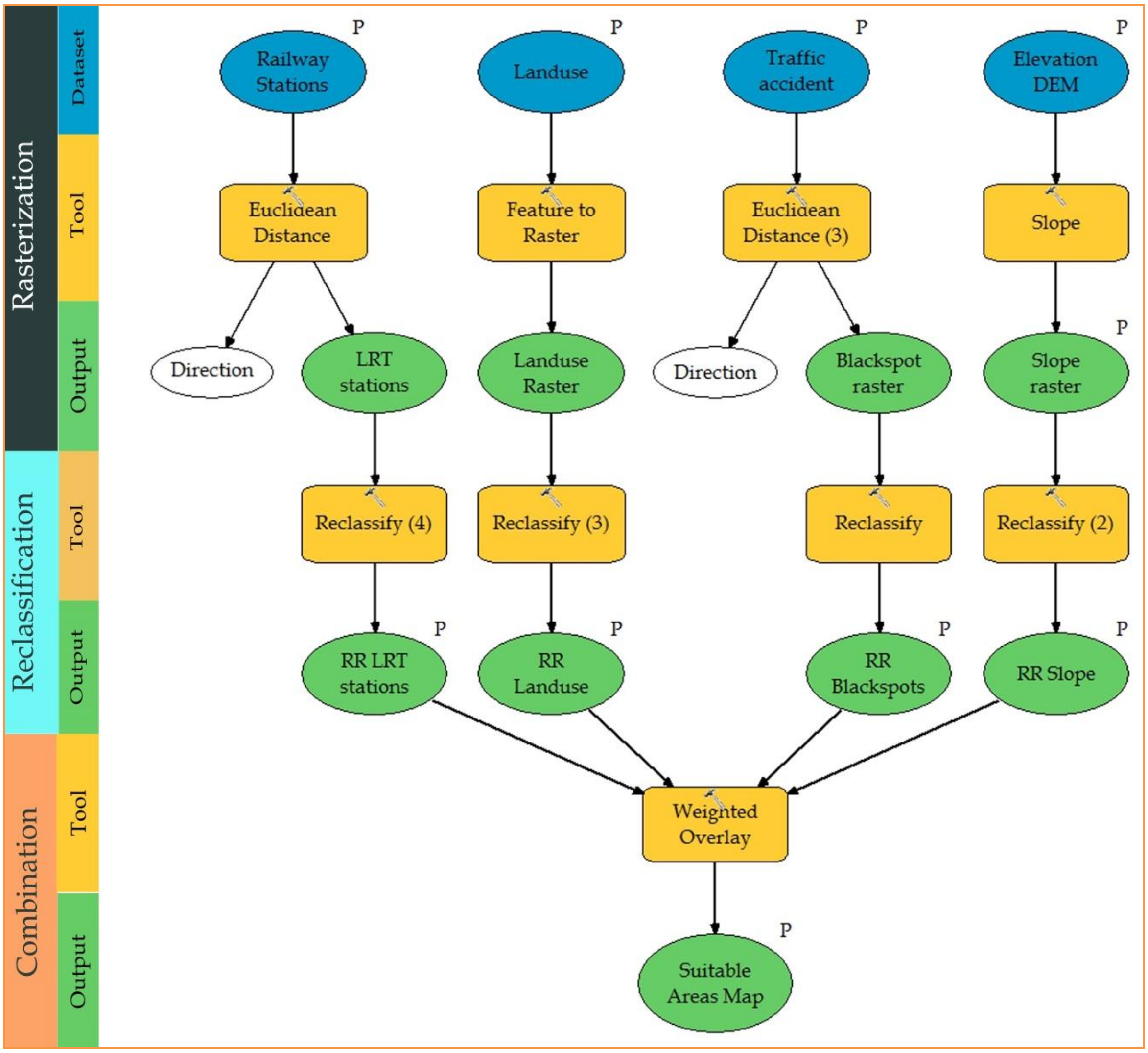


Figure 3-3 Suitability model workflow

1. Raster data preparation and classification

For the case of these paper proximity to railway stations and distance from traffic accident spots is created using 'Euclidian distance' command available in spatial analyst for the purpose of indicating the space that exists from a certain these locations to another locations, until a maximum distance value of 800 meters by specifying input source data's which are point files and proceeding with default settings for the remaining parameters as shown in Figure 3-4 below.

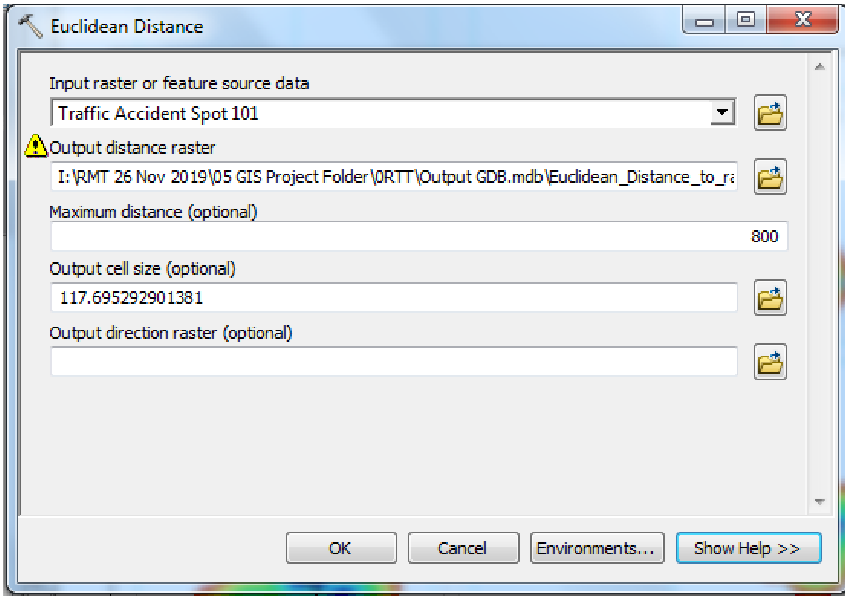


Figure 3-4 Euclidian distance

Besides to create land use raster, rivers were buffered to 0.1km both sides to avoid the search to areas for suitable locations in these areas. Then using "feature to raster" polygons were converted to raster datasets while using their land code as a field to assist succeeding activities as shown in Figure 3-5

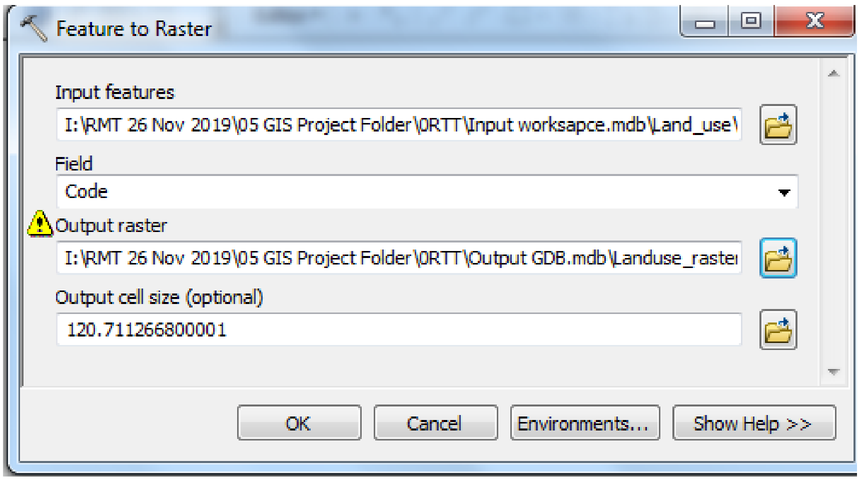


Figure 3-5 Feature to raster conversion

Further to identify the slope from each cell of raster surface data "Slope" tool from a spatial analyst tool is used, where the input raster is a DEM data and the output raster is slope with a percent rise as shown in Figure 3-6 below.

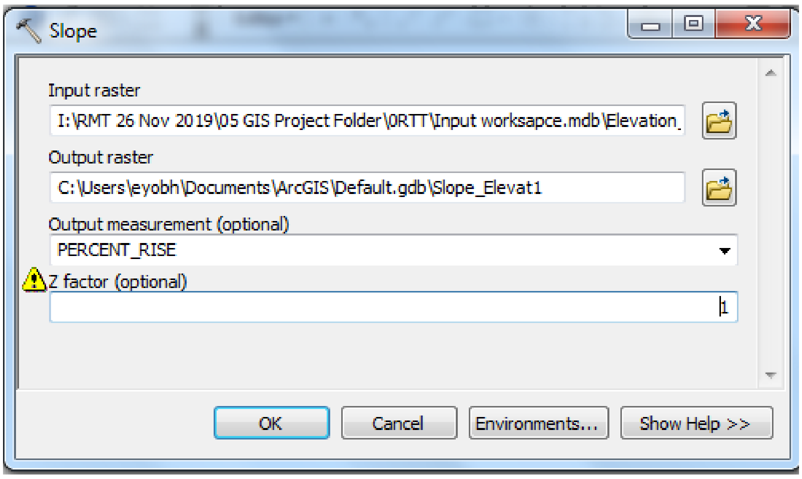


Figure 3-6 Slope raster

Afterwards the resulted rasterized data is further reclassified using "Reclassify" to assign weights to each distance range, far regions being more suitable gets a score of 5 whereas less favorable gets a score of 1. To do so input raster is selected using the folder connection created and classification field for ranking the raster cells is selected in the case of slope percentile rise, whereas proximity to in accident & LRT stations distance and in case of land-use classification code is used accordingly See Figure 3-7 for reclassification window.

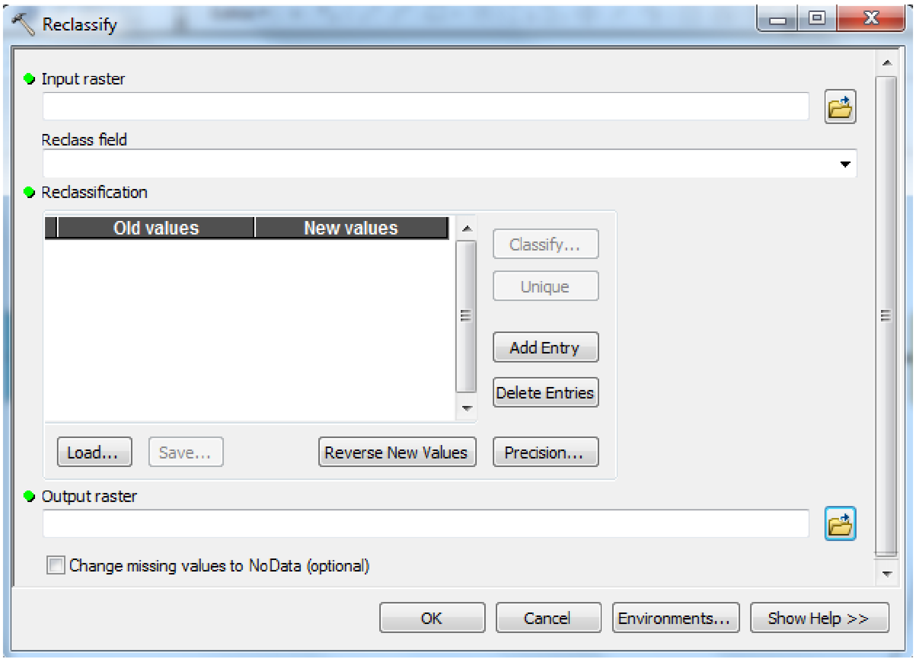


Figure 3-7 Raster reclassification

2. Combine reclassified outputs

To create a suitability map for bus stop, a linear combination of the reclassified outputs using 'weighted overlay' of the layers (i.e. land use, distance from traffic accident black spot, proximity to railway station, and slope) based on standardized factor weights ranging from 0(least suitable) to 1(most suitable) for each criteria's attribute values involved which are obtained by AHP is used to determine the total suitability score 'Si" for each raster in the map using (3-6).

$$S = \sum_{i=1}^{n} w_i \times r_i$$ **Equation 3-5**

Where:

"n" is the number of factors,
"W_i" is the weights of the "i_{th}" factor
"Ri" is a rating given for the defined class of the "i_{th}" factor found on the assessed land unit

3. Produce a suitability map

Then, the total suitability score from each factor was bring together to create suitability map for bus stop using "Weighted Overlay" which overlays several raster's using a common measurement scale and weights each according to its importance (i.e. weights obtained in AHP shown in Appendix C) give the final suitability map for bus stop location. The final suitability map is classified into four suitability classes that reflect various degrees of suitability as shown below:

- Unsuitable (S4): lands that are severe suitable at the current condition
- Poor (S3): lands that are marginally suitable and have major limitations
- Moderately suitable (S2): lands that are moderately applicable for given use but have minor limitations
- Highly suitable (S1): lands with no major limitations and ready for applicable use at their current condition

4. Classifying existing stations and evaluate existing stations suitability

Similar with Huang and Liu (2014) Existing stops are classified as follows:

1) Ordinary stops: stops that area at the lowest level located to ensure appropriate spatial coverage of bus stops.
2) Key stops: topologically important stops that may serve as transfer centers of bus trips.
3) Connection stops: stops that link bus transit to other transport mode, such as rail stations and road intercity transport, and major activity sites.

To validate whether existing stations are on which suitable classes and their accessibility existing stops were overlaid on the results of suitability map to validate their location suitability and overlaid on accessibility maps to identify stations which have either overlapped zone of influence or gaps respectively.

5. Formulate alternative spatial distribution of stations

Location is important factor leading to the success of public sector organization by enabling public sector facilities to provide a high-quality service to the community at low cost (i.e. time or distance) when good location is chosen. Given bus stop facilities provide access to transportation and a set of demand points consume them, the goal of location-allocation is to locate facilities in a way that the supplies the demand points most efficiently. There are so many types of location-allocation problem types, which offer different problem types to answer specific questions for the case of these research the problem type is to maximize coverage within certain walking distance. In cases of connection stops they are maintained to provide access when there is a need for transfer opportunities between inter-city and intra city transportation modes. Thereupon stations with following conditions was identified and red flagged to be removed/consolidated from the existing spatial distribution:

a) When there are service overlap stations are consolidated or removed
a) When existing stations are located in S4 suitability class

To do so Distance Constrained P-Median Problem (DCPMP) is selected. A major advantage of DCPMP is that it reduces the current number of bus stops in order to promote faster transit speeds and greater geographic coverage ensures that all areas that are provided suitable access by the current location of bus stops continue to receive suitable access (Challuri, 2006). The p-median problem involves the location of a fixed number of facilities in such a manner that the total weighted distance of all users assigning to their closest facility is minimized. By minimizing weighted distance, accessibility is maximized; which was first defined by (Hakimi 1965) according to (Challuri, 2006).

According to (Challuri, 2006), Hakimi defined the p-median problem on a network of nodes as a place of demand & potential facility location and arcs which represent transportation or accessibility linkages. Thereupon Hakimi proved that there existed at least one optimal solution to a network p-median problem that consisted entirely of nodes of the network with no restrictions on the distance that a user (demand) has to travel to a facility. In reality users travel to facilities decays as the distance to facility increases so p-median problem should be constrained by limiting the possible assignment of user (demand) to only those facilities that are within certain distance from the demand points.

Thereupon the distance constrained p-median problem, proposed in Murray and Wu (2003) cited by (Challuri, 2006) is used. The model is formulated as follows:

$$Minimize\ Zi = \underset{i}{}\ \underset{j\in N_i}{}\ a_i d_{ij} z_{ij} \qquad \textbf{Equation 3-6}$$

Subject to:

- $\underset{j\in N_i}{}\ z_{ij} = 1 \quad \forall i$
- $z_{ij} \leq X \quad \forall i\,, j$
- $x_j = p$
- $x_j = \ 0{,}1 \quad \forall j$
- $z_{ij} = \ 0{,}1 \quad \forall i, j$

Decision Variables:

$$x_j = \begin{matrix} 1\, if\ transit\ stop\ j\ selected\ to\ remain\ on\ the\ route \\ 0\ other\ wise \end{matrix}$$

$$Z_{ij} = \begin{matrix} 1\, if\ transit\ stop\ i\ assigned\ to\ transit\ stop\ j \\ 0\ other\ wise \end{matrix}$$

Where:

Z = total weighted distance of route 1

i = index of ridership service areas;

j = index of potential transit stops (entire set denoted j);

p = number of stops to be maintained;

a_i total weighted distance of route i;

d_{ij} = potential ridership demand in service area i to stop j

S = suitable access distance standard;

$\{N\ j\ |\ d_{ij} \leq S\}$ i = set of bus stops that are within a distance S

The objective of the DCPMP, Equation 3-6 is to minimize the total weighted assignment of potential demand to its nearest sited transit stop. The use of d_{ij} enables the model to account for differing levels of local accessibility to stops. Constraint (2) requires potential ridership demand in each area to be assigned to a transit stop within the suitable coverage standard. This constraint ensures that all potential demand for service is located within the acceptable access standard. Constraint (3) prohibits assignment to a stop unless that stop is sited. Constraint (4) stipulates that p stops are to be located. Finally, integer restrictions are stipulated in constraint (5).

Immediately to propose appropriate and feasible improvement measures (i.e. consolidate, remove or add), it is assumed that potential demand is equal to the total population of a census block. Further to limit possible assignment to stops that are within the access standard, governmental goals put forward by AACGPC which is "to reduce distance to public transit to 500 meters" (i.e. Ni).

To define the demand points, parcel polyline was converted to polygon using 'feature to polygon' route catchment then parcels with in 500m catchment area from the route of interest are extracted using 'clip' tool and intersected with census data, followed by calculations for respective areas and parcel populations in the attribute table. Then using 'feature to point' parcel centres were obtained; the overall geo-processing chain of commands is shown below in Figure 3-8.

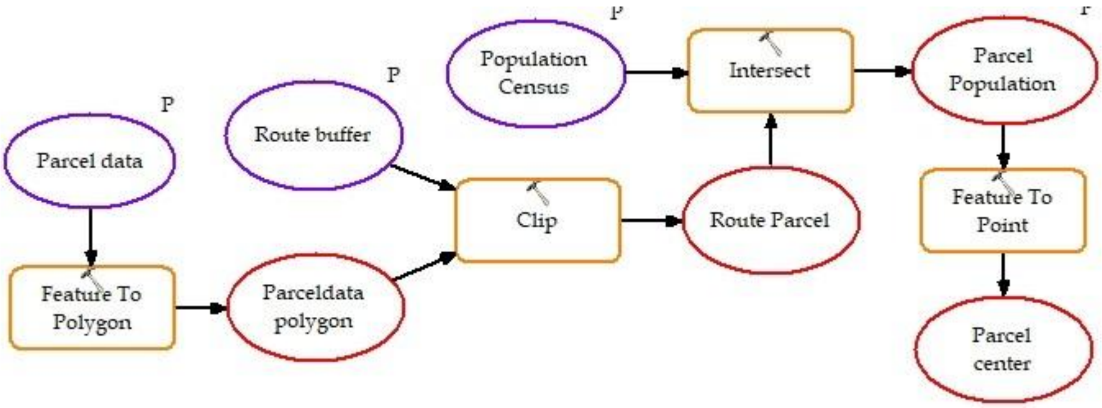


Figure 3-8 Parcel population centroid model

Then DCPMP analysis is made on ArcGIS 10.5 to do so location-allocation layer is created that stores the inputs, parameters, and results for a given location-allocation problem using respective route network dataset in Network Analyst toolbar as shown in the figure below.

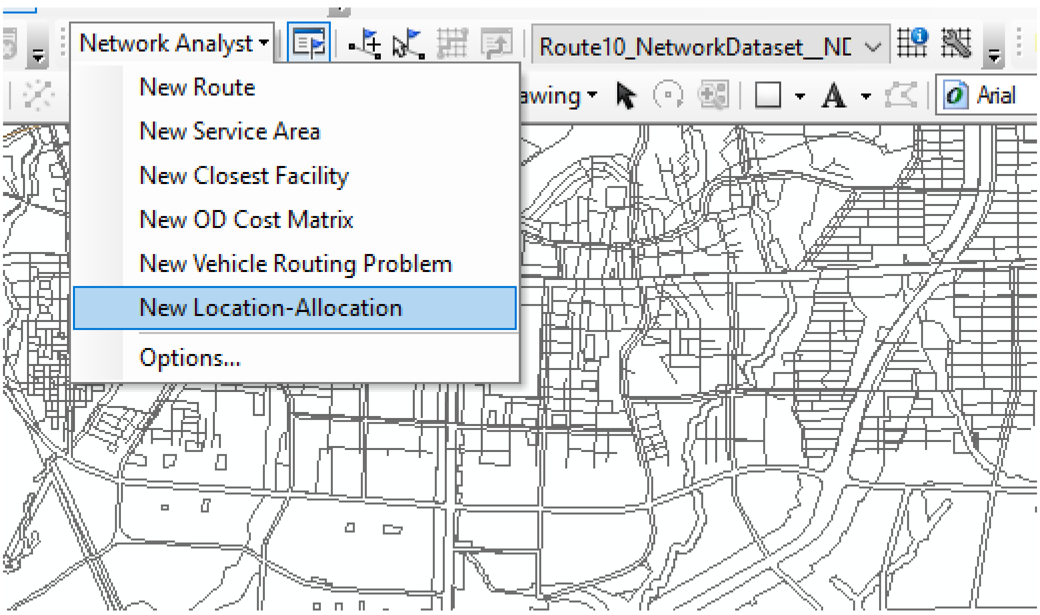


Figure 3-9 Creating location-allocation layer

When a location-allocation analysis layer is created, it shows up in the Network Analyst window along with its six network analysis classes Facilities, Demand Points, Lines, Point Barriers, Line Barriers, and Polygon Barriers. Subsequently the following datasets were loaded:

- Bus stop as facilities with different scenarios
- Catchment area parcel centres as demand points

<u>Scenario 1: Base case facilities as 'candidate' p unconstrained</u>

So as to validate station removals which do exist on lower suitability class and have a service area problem (i.e. gaps and overlaps) and determine facilities that may be part of the solution the existing spatial distribution of stations have been analysed by use of the parameter p.

<u>Scenario 2: Modified base case & candidate facilities with p constrained</u>

In reality passengers are sensitive to elimination of service (i.e. bus stops) where as the number of stops (i.e. p) increases, the average travel distance to one's closest stop decreases, henceforth to balance the trading off travel distance and geographic coverage which could minimize the adverse impact of elimination the optimum number of stops to maintain service efficiency through fewer stops for respective route is determined by dividing route by 600m spacing and rounded down to the lowest number, which resulted in route 10 (12.6/0.6=21 stops), 31 (8.6/0.6=14 stops) and 101(13.7/0.6= 22 stops) for analysing base case. After the removal of redundant stations, the resultant stops are defined as a 'modified base case'. In the meantime, candidate bus stop locations are generated using a bus stop spacing of 600m which is compliant with international and developing world practice for iterating the analysis in different scenario and introduce stations when there is service gap from the candidate sites. For the case of these existing stations which are maintained are defined as 'required' facilities where are the generated candidate sites are defined as 'candidates'.

Supplementary, to maintain access within 10 minutes (i.e. which is about 540m) to a bus stop 'demand to facility' is selected with traversal cost along the elements of the network as length. Furthermore, the problem type is selected as 'Minimize Impedance', though 'Minimize Impedance' reduces the overall distance the public needs to travel to reach the chosen facilities, the minimize impedance problem without an impedance cut-off is ordinarily regarded as more equitable but in-efficient for locating bus stop. Thus, to maximize access and geographical coverage while maintaining operator efficiency impedance cut-off is defined as 500meters, with a limit on number of facilities and a linear transformation with an impedance parameter of 1 is used as seen in Figure 3-10.

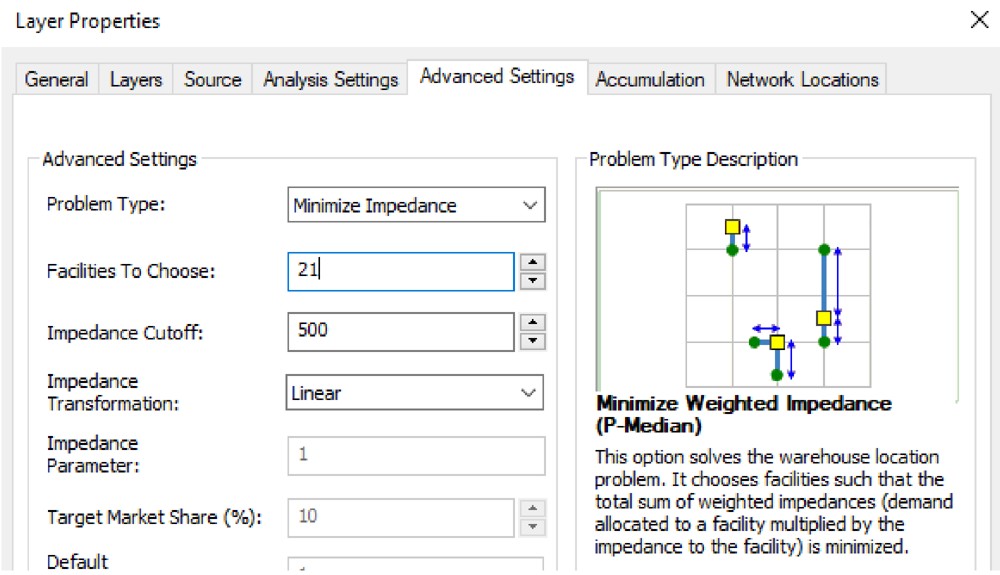


Figure 3-10 Location-allocation analysis setting

After creating a location-allocation analysis layer, the required network analysis objects are populated, and setting appropriate analysis properties shown above, the solution for the location-allocation problem is determined by solving a location-allocation problem, that results in the appropriate output fields of the network analysis objects. Subsequently the results are inspected by looking at the properties of the facilities and lines in order to verify station removal decisions. Then all solution facilities for the problem are exported to geodatabase as 'optimal facilities' classified in to ordinary, key and connection to determine the accessible population and make comparisons against the baseline scenario, overlaid on the results of suitability model and determine improvements.

3.4. Economic indicators

The key economic indicators that are addressed in EIA of bus stops that directly impact the service are road user effects (i.e. Vehicle operating cost) and space–time accessibility is regarded as the "direct" effects. In addition, there is the spinoff effects on the community from emission which is indirectly induced impact resulted from providing the public transit. Thus, in estimating the said direct and indirectly induced impacts various inputs were retrieved, including: road surface types, roughness indices, terrain of roads and speed limit. Thereafter calculations are made for the following economic indicators:

- Environmental effects
- Road user effects
- Space-time accessibility of bus stop's

3.4.1. Environmental and road user effects

Environmental and road user effects are key component of EIA analysis and they are required to be valued for different operating conditions and vehicle characteristics. In this regard one of the indirectly induced impacts introduced as a result of public transportation are Green House Gas (GHG) emissions that are released directly from vehicle exhaust pipes which have numerous damages, including human health, ecological and esthetic degradation. However, as it is noted in the literature, the uniqueness of public transit is its higher emission rates due to operation of heavy-duty vehicles in a higher combustion pressure, consequently the major expenses of operators are direct vehicle operating cost. In spite of the said fact, ACBSE neither have organized record of per-kilometer operating cost estimations nor factors usable for calculations of emission rates. Thus, in order to quantify the vehicle operation costs (VOCs) and inseparable outputs of public transit Highway Development Management system (HDM) 4 version 1.0 software is used to quantify vehicle fleet emission based on acquired vehicle characteristics data from WT Consult (i.e. technical details, financial and economic prices of vehicles and associated items).

The decision to use this standalone program is based on three reasons. First it is developed by World Bank aiming to facilitate the analysis of road management and investigation of alternatives in investing urban road infrastructure for developing countries. Secondly, it is equipped to investigate the economic viability of road projects and to optimize economic benefits to road users under different level of expenditures. As such it provides road investment analysis tools with broad applications in diverse climate and conditions. Moreover, it is one of the widely used tools by the Ethiopian government as a comprehensive way of decision making. Thirdly, its capability to simulate vehicle operating costs as a function of vehicle characteristics, vehicle utilization, congestion, vehicle unit costs and the road characteristics. The overall process is as follows:

Step 1) **Define program details**

First, HDM4 analytical framework which is based on pavement cycle analysis is applied to predict the environmental and road user effects. Thereby data's that characterize vehicle attributes, utilization, value of time, and road characteristics retrieved from state offices are incorporated in the software. First, the normal working hours of ACBSE per year expended to provide transportation service is 14 hours which is from morning 12:00 AM to 2:00PM with no private use. For the purpose of defining vehicle type bus heavy (i.e. diesel vehicles) with cost details shown in Table 3-5 is used with 15 years estimated average life.

Table 3-5 Vehicle attributes

Source: WT consult 2017

Vehicle Type	Large bus (IVECO)
Engine Size	150E 18
One New Vehicle (USD)	116,740.088
One Tire (USD)	669.604
One Liter Fuel (USD)	0.764
Fuel Type	diesel
One Liter Lubricant (USD)	3.225
One Working Hour in Work Shop (USD)	2.377
One Working Hour for Crew (USD)	2.740

Furthermore to identify road characteristics in the route of interest associated data's are extracted from AACRA road network are tabulated in Table 3-6 below are supplied to the software to define the road section's characteristics.

Table 3-6 Road sections characteristics for route of interest

Source: AACRA 2017

Route 10				
Road Section	From	Arat Killo	Kara	Megenagna
	To	Piazza	Megenagna	Arat Killo
Link ID		ROUTE10AP	Route10KM	Route10MA
Drainage		Fair	Poor	Excellent
Speed flow type		Two lanes standard	Two lanes narrow	Four lanes
Road class		Secondary	Secondary	Primary
Length (km)		1.724	7.175	5.202
Carriageway width		18	18	30
No of lanes		4	2	8
Route 31				
Road Section	From	Arat killo	ECA	Sheromeda
	To	ECA	Lagare	Arat Killo
Link ID		Route 31AGHE	Route31EML	Route31SA
Drainage		Fair	Fair	Fair
Speed flow type		Four lanes	Four lanes	Four lanes
Road class		Primary (trunk)	Primary (trunk)	Primary
Length (km)		2.484	1.373	1.982
Carriageway width		40	20	16
No of lanes		6	6	4
Route 101				
Road Section	From	Ayat	Megenagna	
	To	Tafo	Ayat	
Link ID		ROUTE10AP	R101MA	
Drainage		Excellent	Excellent	
Speed flow type		Two lanes standard	Four lanes	
Road class		Secondary	Primary	
Length (km)		3.07	8.2	
Carriageway width		12	30	
No of lanes		2	4	
Note: All road sections surfacing is asphalt with two-way traffic flow				

Thereafter, ACBSE vehicle utilization shown in Table 3-7 (i.e. annual average kilometers driven per year and average passengers per trip per route) along with value of time shown in Appendix K, is inserted to HDM software.

Table 3-7 ACBSE Vehicle utilization and loading

Source: ACBSE 2008-2009 performance

ACBSE Vehicle Utilization and Loading	
Average kilometers Driven per Year (km)	272,173.15
Time Driven per Year (hr)	5,110
Service Life (years)	15
Percent of Time for Private Use (%)	0%
Gross Vehicle Weight (tons)	1.2

Step 2) **Generate program**

Thereafter, analysis is run in the HDM4 with economic analysis before budget optimization since there was no budget options considered in the analysis. To further account for road effects three HDM models were included in the analysis specifically "Energy Balance", "Emission" and "Model acceleration effects"; on the other hand, "Annual vehicle data & period" and "Accident costs" were excluded from analysis setup as shown in figure below.

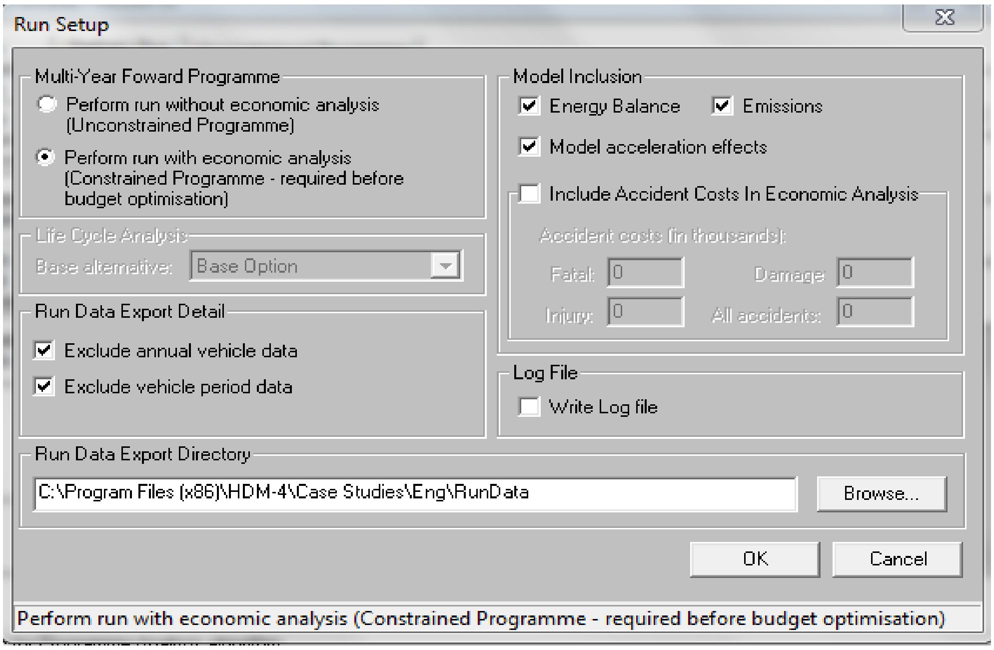


Figure 3-11 HDM4 run setup window

Step 3) Produce report

Then, reports are made on the "Start" button that executes generated program with the inputs and analysis settings specified shown in Figure 3-12.

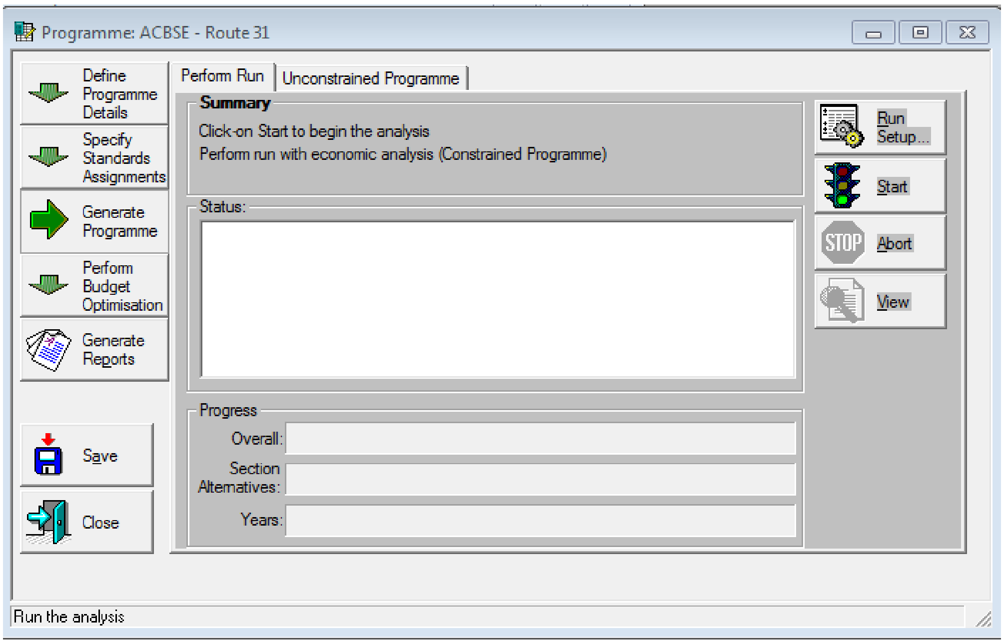


Figure 3-12 Run the program

Once the program is run, reports are generated in "Generate reports" section. Yet, environmental and road user effects shown in Appendix D are only consumed for the purpose of this study (see Figure 3-13).

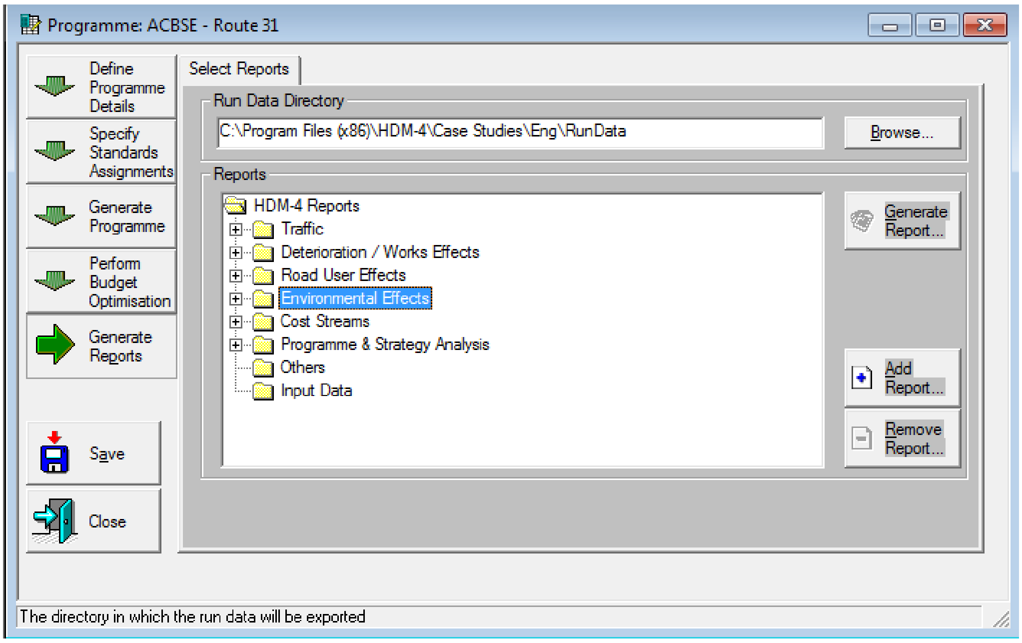


Figure 3-13 Generated reports by HDM4

Step 4) <u>Estimation of annual idling emission</u>

As HDM4 estimates only the emissions when vehicle is in motion not the idling emissions it is important to duly incorporate the associated emissions because of high frequency of idle at loading areas. Among these emissions carbon dioxide (CO2) is classified as GHGs that contribute to the changing of the world's climate by its adverse effects thereby CO2 estimation is done as follows; first stations in respective routes are categorized into three categories with a similar classification used by (Huang & Liu, 2014) as Ordinary stops Key stops and Connection stops as shown in Appendix E. Way forward dwell time values is adopted from (TRB, 2013) which suggests 60 seconds at a downtown stop, transit center, major on-line transfer point, or major park-and-ride stop (key stops); 30 seconds at a major outlying stop (connection stop); and 15 seconds at a typical outlying stop (ordinary stop) respectively. Next, to account for portion of fuel that is not oxidized in to CO_2 an oxidation factor 0.99 is used (i.e. 99 % of the carbon in the fuel is eventually oxidized, while 1 % remains un-oxidized) as specified in IPCC 2005 guideline. Furthermore idle engine fuel consumption of transit bus obtained from https://www.anl.gov accessed on 13 April 2020 is consumed (i.e. 0.97 Gallon/hr). Finally, to calculate the idle CO2 emissions per hour, the carbon footprint from a gallon of diesel is multiplied by the ratio of the molecular weight of CO2 to the molecular weight of carbon with oxidation factor of 0.99, idle fuel consumption rate and CO2 emissions from a gallon of diesel fuel as shown in Equation 3-7 similar as used by (Kirti Bhandaria, Purnima Parida, & Singh, 2013); see Appendix G for details.

$$\boldsymbol{IER} = \boldsymbol{R} * \boldsymbol{Ifc} * \boldsymbol{Rmw} * \mathbf{O} * \mathbf{T} \qquad \textbf{Equation 3-7}$$

Where

IER	Idle emission rate per hour
R	CO2 emissions from a gallon of diesel fuel (2,778 gram/gallon);
Ifc	Idle engine fuel consumption (0.97gallon/hour);
Rmw	Ratio of the molecular weight of CO2 to carbon (44/12);
O	Oxidation factor (99%)
T	Total idle time in a year (hour)

Step 5) **Calculate yearly direct operating costs in idling (dwell time)**

Idling of vehicles is a frequent scenario in public bus transit which does not only result Green House Gas (GHG) emission but it also incurs additional cost of running a vehicle's engine without actually moving the vehicle which is relatively pronounced in diesel engines that is the actual scenario for ACBSE. Following these IVECO 150e18 vehicle technical characteristics is used since it actually simulates the actual vehicles used by ACBSE. Thus, for the purpose of accounting the real monetary cost behind the effects of dwell time https:// https://www.vcalc.com accessed on 15 April 2020 is used to calculate the annual idling costs using few dominant variables like engine size, idle time, static engine revolution per minute (rpm) and operating days per year, and fuel cost per gallon are filled considering actual operating scenarios.

Step 6) **Quantifying emission control costs**

In spite of the possibility of estimates the vehicle fleet emissions and idling emissions, it appeared that monetizing the economic losses of emission (i.e. the damage costs such as crop losses, ecological degradation, lost productivity when people are ill, the increase in mortality rate, plus any non-market costs such as pain, suffering and grief) is is a complex undertaking, though a consistent emphases issued by different researchers have raised the need to consider air quality as criterion in evaluation of transportation projects.. Therefore, as argued by (Shrestha & Zolnik, 2013), standard cost-benefit analysis may not provide an accurate estimate of the tradeoffs related to social costs. Hence, more emphasis is given to Carbon Dioxide since it plays a significant role in the depletion of Ozone layer. Thereby the local emissions for analysis are assumed relatively similar across the scenarios considered for analysis; this is because fuel consumption when the vehicle is idle with running engine is minimal. One way to account such costs according to (Gebru, 2016) is through quantifying control costs (i.e. prevention, control or mitigation expenses like medical services, clearing polluted air using forest plantation and etc.).

As described in (IPCC, 2005) sequestering CO2 over afforestation play a significant role in the stabilization of the atmosphere by capturing and storing CO2 form the atmosphere. Hence in this study, control costs of Carbon Dioxide emission is monetized using costs of planting Eucalyptus Saligan tress quantified based on the cost of clearing polluted air using tree plantation in Ethiopian context as shown in Equation 3-8 similar as proposed by (Gebru, 2016) is used to compute the mitigation cost of Carbon Dioxide for the quantities of gross emission (i.e. fleet and idle emission) and expense for plantation of said trees that clear CO_2 from atmosphere, see further details in Appendix F.

$$MC = QE * NT * PE \qquad \textbf{Equation 3-8}$$

Where

MC: mitigation costs of Carbon Dioxide emission in ETB/Year;

QE: gross quantity of CO_2released to the environment in Kg /year;

NT: No of trees need for sequestering CO_2 emission; and

PE: total expense for tree plantation to clear Carbon Dioxide

Step 7) **<u>Direct operating cost recovery ratio</u>**

In order to understand the financial efficiency of ACBSE the total operating cost required to provide service in the specified routes is assessed unfortunately ACBSE have no prior organized record on vehicle operating cost (i.e. fuel, oil, tire wear) for each vehicles used which have retarded the calculation of per-kilometer operating costs, thus expense of a firm per kilometer (i.e. VOC/km) is calculated based on HDM 4 which is estimated considering direct operating costs such as operator wages and variable maintenance costs such as fuel and consumables (oil, tires) that are required to put buses into service. Aside with these, because of high frequency of idling relative to other transportation modes, there up on idling costs are estimated by the designated vehicle type engine which characterizes ACBSE buses and expected operating scenario in bus stations. Thereby the total operating cost is computed based on the actual number of trip and distance covered by vehicles and revenue collected is compiled for the year under consideration in Appendix A.

Thereupon for the purpose of analysis it has been assumed that VOC and idling costs are the same across all other vehicle types ACBSE is using. Following that the route level direct operating cost recovery ratio is calculated as the ratio of revenue collected for respective routes to the total vehicle operating cost as shown in equation below. In order to maintain the transit agency in service the fare recovered should be at least equal to the total direct vehicle operating cost.

$$\boldsymbol{DOCFR} = \boldsymbol{R}/(\boldsymbol{VOC} + \boldsymbol{IC}) \qquad \textbf{Equation 3-9}$$

Where

DOCFR Fare recovery ratio (%)
R revenue collected in ETB/Year;
VOC direct vehicle operating cost in ETB/Year;
IC idling cost in ETB/Year;

3.4.2. Space-time accessibility analysis in GIS

It has been noted in literature that, GIS have a great reputation to organize and visualize spatially-oriented database containing multiuse information's collected from various sources with different themes to support answering questions in terms of location, condition, trends, patterns, modeling, quantities, densities and proximity (Eck, Collura, & Aultman-Hall, 2004; Gabre, 2016). As a result several researchers have also utilized GIS to evaluate bus stop design in particular include (Adebola & Enosko, 2012; Furth & Mekuria, 2005; Furth & Rahbee, 2000; Huang & Liu, 2014; Pulugurtha & Vanapalli, 2008; Xuebin, 2010). According to many scholars the major advantage of GIS is it makes possible to develop interrelated maps, organize geographic information and identify spatial relationship between datasets. Therefore, despite there are so many GIS tools out there ArcGIS 10.5 was selected due to its availability and analytical capability of emulating the widest range of 'what if' scenarios with easy interface. As Table 3-8 shows the acquisition of data involves collection of various data's

Table 3-8 Dataset features

Datasets	Data Source	Characteristics	Feature class
Existing land use	AACGPC	Shapefile	Polygon
Road network	AACRA	Shapefile	Line
ACBSE Service routes	ACBSE	Excel Worksheets	Line
ACBSE stop locations	AATA	Excel Worksheets	Point
Transport facilities	AATA	AutoCAD file	Polygon
Population census	CSA	PDF file	Table

Unluckily, the datasets collected need significant cleaning before they can be used. Thus, the spatial data collected in multiple setups is converted into a format that can be used by ArcGIS which involved the extraction of information from online base maps and printed records (such as demographic reports and route information's) and the recording of that information is made within the scope of route buffer to fill the missing attributes of data retrieved from AACRA and ACGPC.

To perform the task a GIS framework is structured as follows:

A. Data preparation

The following pre-processing actions are done: first the projection system for the spatial data is defined as Adindan_UTM_Zone_37N. Then to work with a single window some of the AutoCAD files collected in ".dwg" format is converted to a shapefile in order to be used by ArcGIS. In doing so to extract data's quickly some of the necessary data's outside the study area are removed. In some cases, the projection system used by different offices do vary hence a necessary adjustment is made by Rubber sheeted (i.e. overlaid and matched) edges of feature datasets and adjustment is made through "topology" tool. Finally, the attribute information for each dataset is updated for ease of analysis.

B. Import data to personal geodatabase

Following a serious examination of data's pertinent to the study routes and a significant cleaning, pre-processed data's were are kept under a personal geodatabase as feature datasets, grouped together with related feature classes for instance case study routes and, bus stations are grouped under ACBSE routes and bus stops respectively to bridge data exchange when geo processing tools or in-house built models require input or to store output spatial and non-spatial data generated within a separate container.

C. Tool development

Then, for the purpose of analysis ArcGIS 10.5 is used, in fact some of repeated GIS operations take considerable processing time which necessitates the need for automating geo-processing. Henceforth, these batch jobs are programmed through ArcMap as a gateway to build re-usable and self-documenting models that systematize and create efficient geo-processing workflow. The decision to use model builder is based on its easy-to-use feature to automate, iterate and/or show the sequence of complex tools chained together, perform analysis alongside with managing dataset and producing accurate outputs as a result.

a) Area of interest

To accurately define the geographic boundaries of the study area and extract associated features a route line buffer is created by extending a zone around the route of interest 800m radially. While doing so it has been learnt that some zones are not be inside the city, as a result "Route buffer" is intersected with city boundary polygon using "Intersect" tool. Ultimately, to extract the datasets in buffer zones (i.e. "Area of Interest") all datasets were clipped iteratively through "Iterate feature" tool is integrated with "Clip" and store them in geodatabase as shown in Figure 3-14. As shown in the figure below when the model is executed a wizard shows up asking the necessary model parameters which are colored in red and purple colors to successfully run the model.

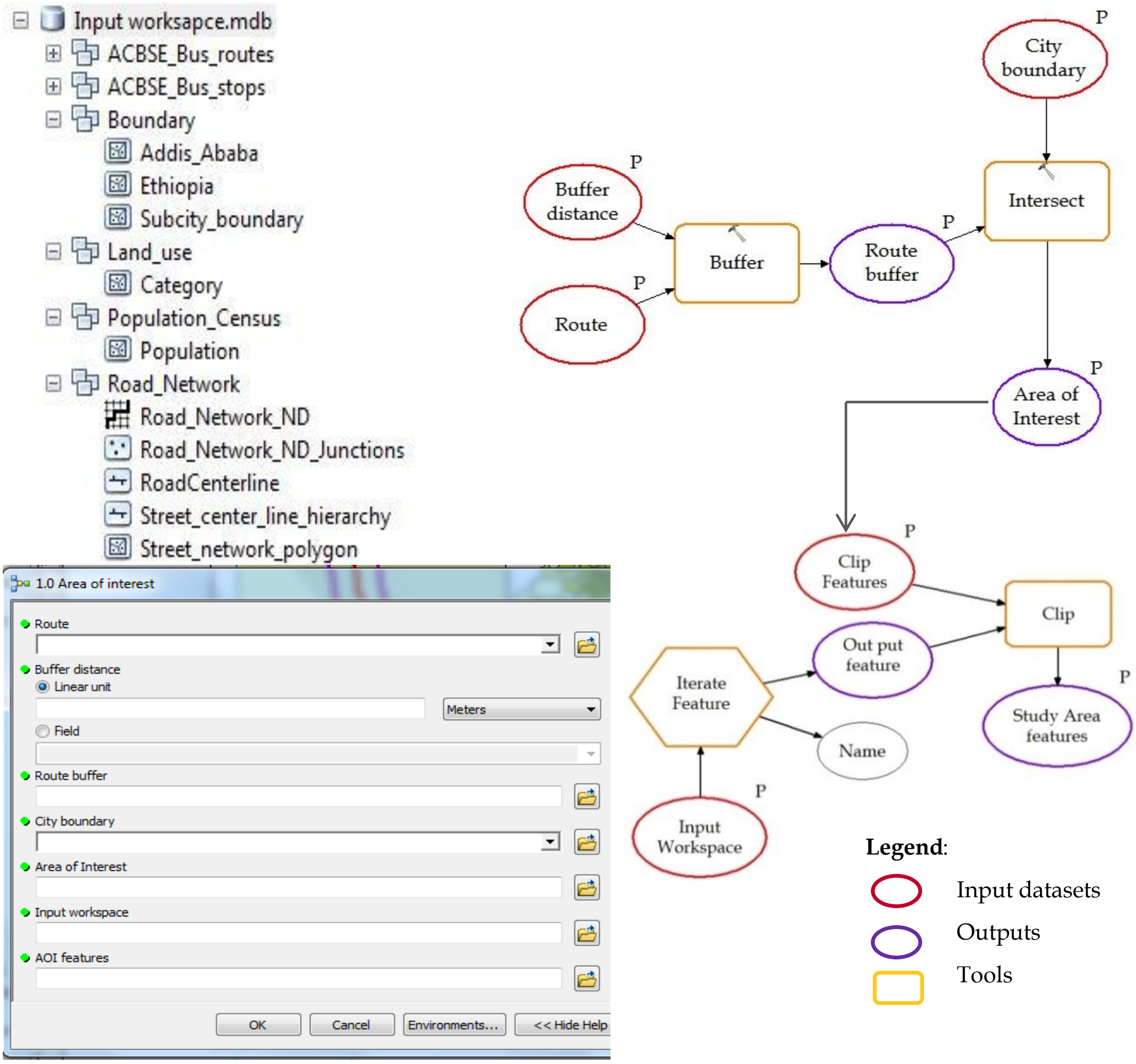


Figure 3-14 Area of interest model

b) Service area

One of the most well-known approaches for assessing service area is using buffer distance from facilities which is like buffering a point (i.e. circular buffer). Since using fixed route transit typically involves walking for access to and egress from bus stops into a person's daily routine, it plays a pivotal role in increasing physical activity and reduce overweight, blood pressure, diabetes and obesity which are the growing health concerns in Addis Ababa and the nation. Thereby proximity operation "Buffer" 500meters buffer is tested to answer what areas are covered with 10-minute walk from facilities considering CDC recommendation for a moderate physical activity which roughly matches 500meters at 0.9m/s. See Figure 3-15 for circular polygon(s) showing the catchment area accessible within 10-minute walk radius in the area of interest.

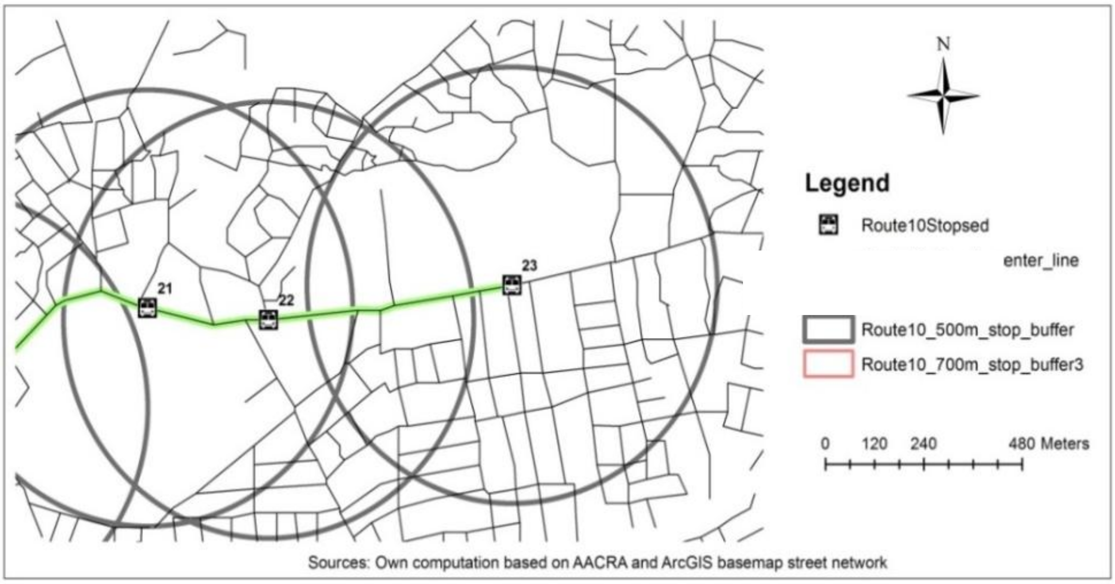


Figure 3-15 Sample service area using 500m buffer

The limitation of buffering is it doesn't take into consideration of geographic obstacles and access to walk which make the operation's unable to pinpoint the coverage reachable in the actual street network rather evaluate service area with a predefined radius. Thus, buffering clearly is not valid for analyzing the actual service area in the road network. To overcome this short coming, a recent advance in GIS ArcGIS network analyst tools that consider street network and geographic obstacles is used to capture the representative of real catchment area.

To do so the road network is processed to create a network dataset that models the street network form source features, which include lines and points. Then ArcGIS Network analyst extensions are used to evaluate accessibility with concentric area with specified impendence (i.e. walking distance) as follows:

i. Prepare feature dataset and sources.

As discussed earlier all datasets are stored in the geodatabase and the network datasets created is based on the said geodatabase, hence all feature classes (i.e. road center line) are arranged to in one feature dataset (i.e. Road Network) as shown in the Figure 3-16 below.

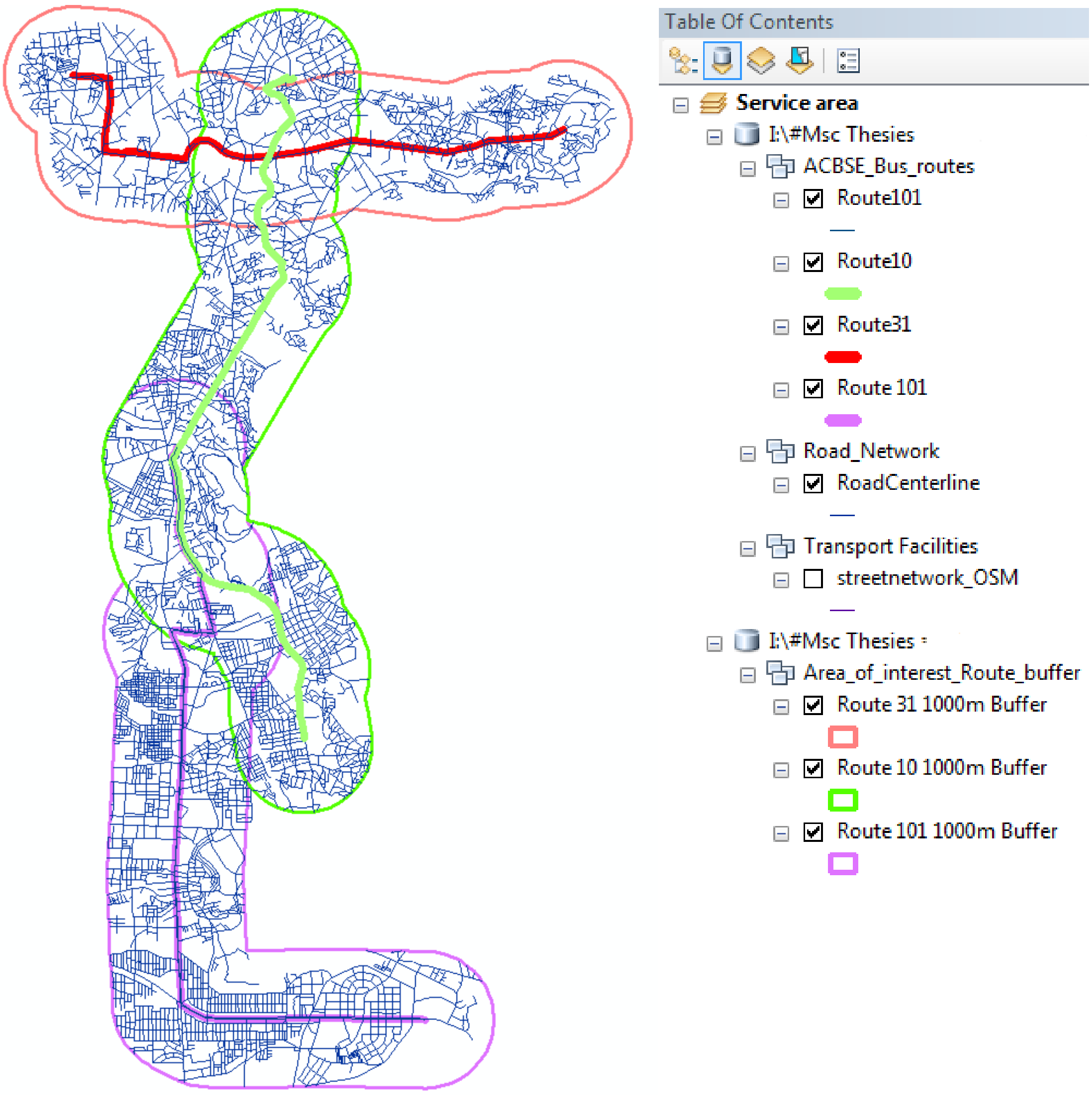


Figure 3-16 Feature dataset for network dataset

ii. Create the network dataset

The dataset "Road network" that contains road centerline features is selected in the catalog tree and a new network dataset is created by choosing the drop-down menus from 'New' as shown Figure 3-17. Then to identify the roles inside the network dataset distance is selected as the units of impedance value. Since most streets permit travel in either direction no changes have been made.

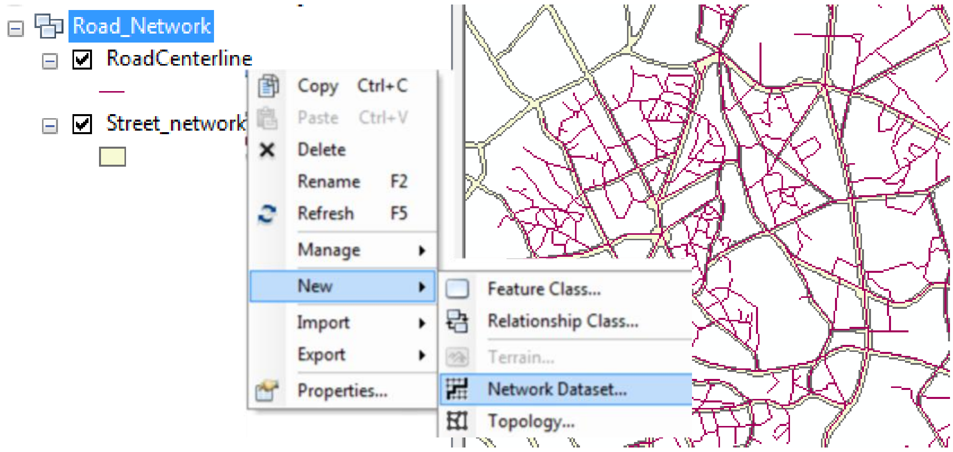


Figure 3-17 Create and build network dataset

iii. Build the network dataset.

Finally, network elements are created, connections are established and attributes are modified that resulted in a network dataset shown in Figure 3-18 which store the relationship and connectivity between elements (i.e. edges and junctions).

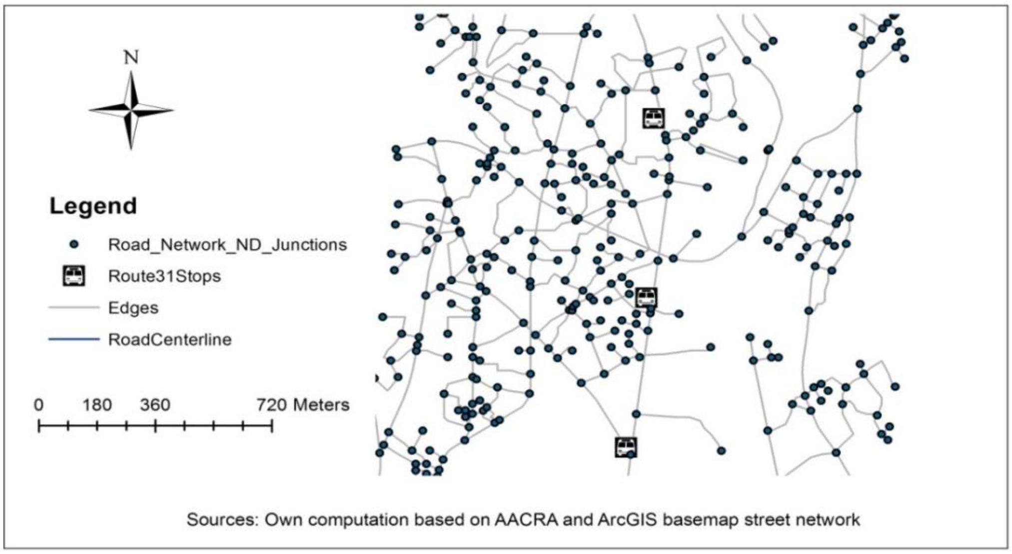


Figure 3-18 Sample service route network dataset

iv. Adding data's

Data's extracted in the prior analysis are consumed for this analysis, specifically "Bus stops" and "Network Dataset. Once data are identified the said data are dragged into a new "Service area analysis" model from the "Input Workspace" geodatabase as shown in Figure 3-19 below

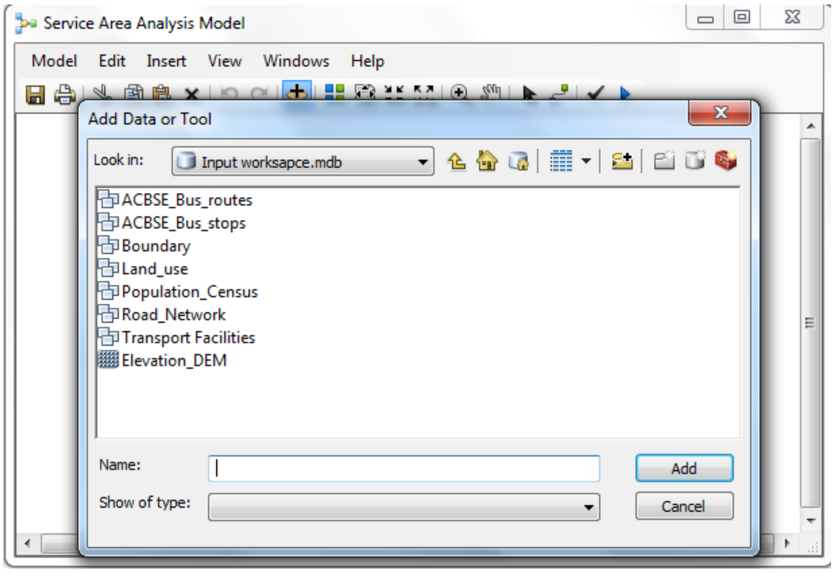


Figure 3-19 Adding datasets to service area analysis model

v. Adding geo-processing tools to model:

Prior to creating the model, the geo-processing tools necessary for the analysis is identified as "Make service area layer", "Add locations", "Solve" and "Buffer". Further refer Table 3-9 for a comprehensive detail of the tools.

Table 3-9 Description of tools used for Service Area Model

Tool	Description
Make service area layer	To determine the area of accessibility within a given cutoff cost from a bus stop.
Add locations	To add bus stop facilities to a network analysis layer.
Solve	To solve the network analysis layer problem a based-on network dataset and bus stop locations and given impedance
Buffer	To create buffer polygons around bus stop with given radius.

vi. Defining model parameters

The inputs and outputs of the model are defined as model parameters to make them show up when the model is executed and define their associated datasets from the folder connections established. See Table 3-10 for parameters

Table 3-10 Description of Make service area tool parameters

Parameters	Description
Tool: Make service area layer	
Impedance	
Break values	These are values indicating the extent of the service area to be calculated.
Network dataset	It stores the symbology of edges, junctions, system junctions, turns and traffic.
Tool: Add locations	
Facilities	This network analysis class stores the bus stop locations which are used as the starting points in service area analysis.
Network Analysis layer	It contains feature classes referenced by the network dataset rather than the data itself; so as to be added to where it can be solved and appear in the contents of the map.
Tool: Solve	
Network service area	A region that encompasses all accessible streets those are within specified impedance (i.e. distance).
Tool: Buffer	
Distance	The distance used to create buffer zones around input coverage features.
Facilities	The input features to be buffered (i.e. Bus stops)

vii. Add network analysis objects and create the workflow

First the analysis layer is created with "Make service area layer", and then network objects are added to it using the Add Locations tool. Next the resulting outputs "Network Analyst Layer" are used to solve the service area problem at the specified impedance. When all these tools are connected together they form a workflow as shown in Figure 3-20 and the models were saved so that they can be re-used and updated. Finally, model parameters were defined.

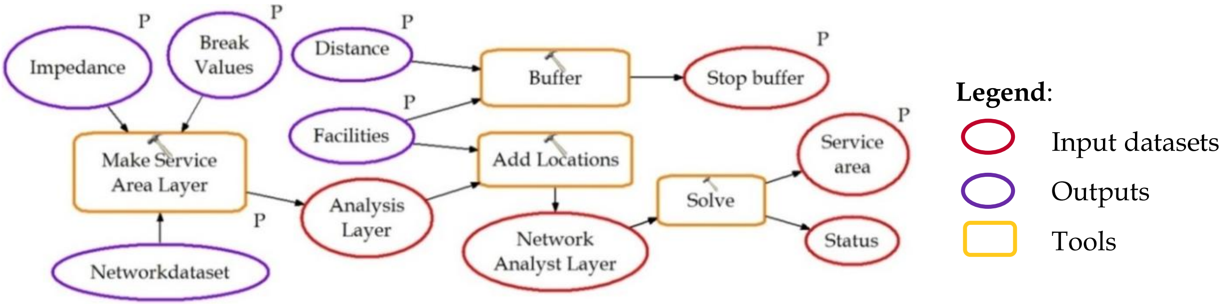


Figure 3-20 Service area model workflow

viii. Solve

To solve the analysis using the Solve tool, break values are set for multiple polygons breaks to create concentric service areas to find 300, 500, and 700-meter service areas for the same facility in the shortest street path for a perfect simulation of walking distance in the street network. For the case of these paper, a service area for a point on a network includes all the streets that can be reached within 500 meters is considered for further details; as shown in Figure 3-21

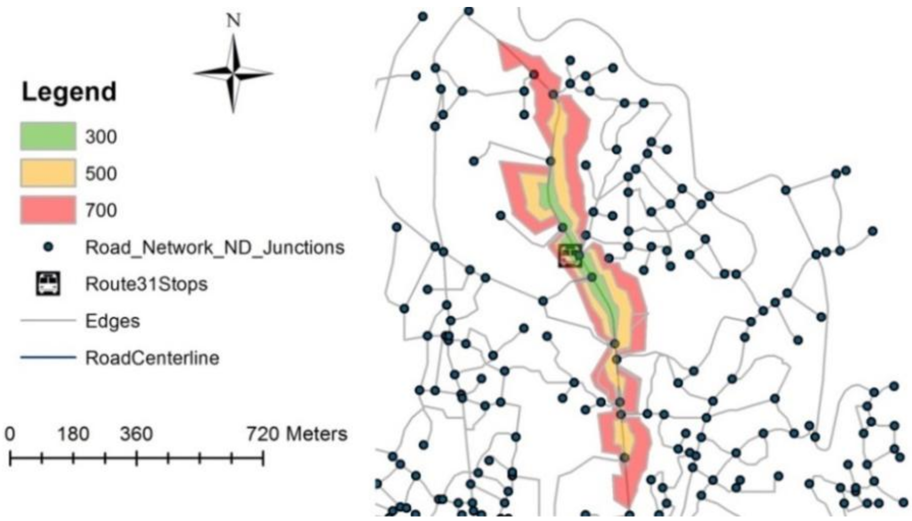


Figure 3-21 Sample service area using Network analyst

c) Population in the service area

As it is further shown in Figure 3-22 the projected population is provided at Kebele level as provided by the Ethiopian Central Statistical Agency in 2007 growth rate of 3.2% and thematically mapped in the route of interest with buffer radius of 800m.

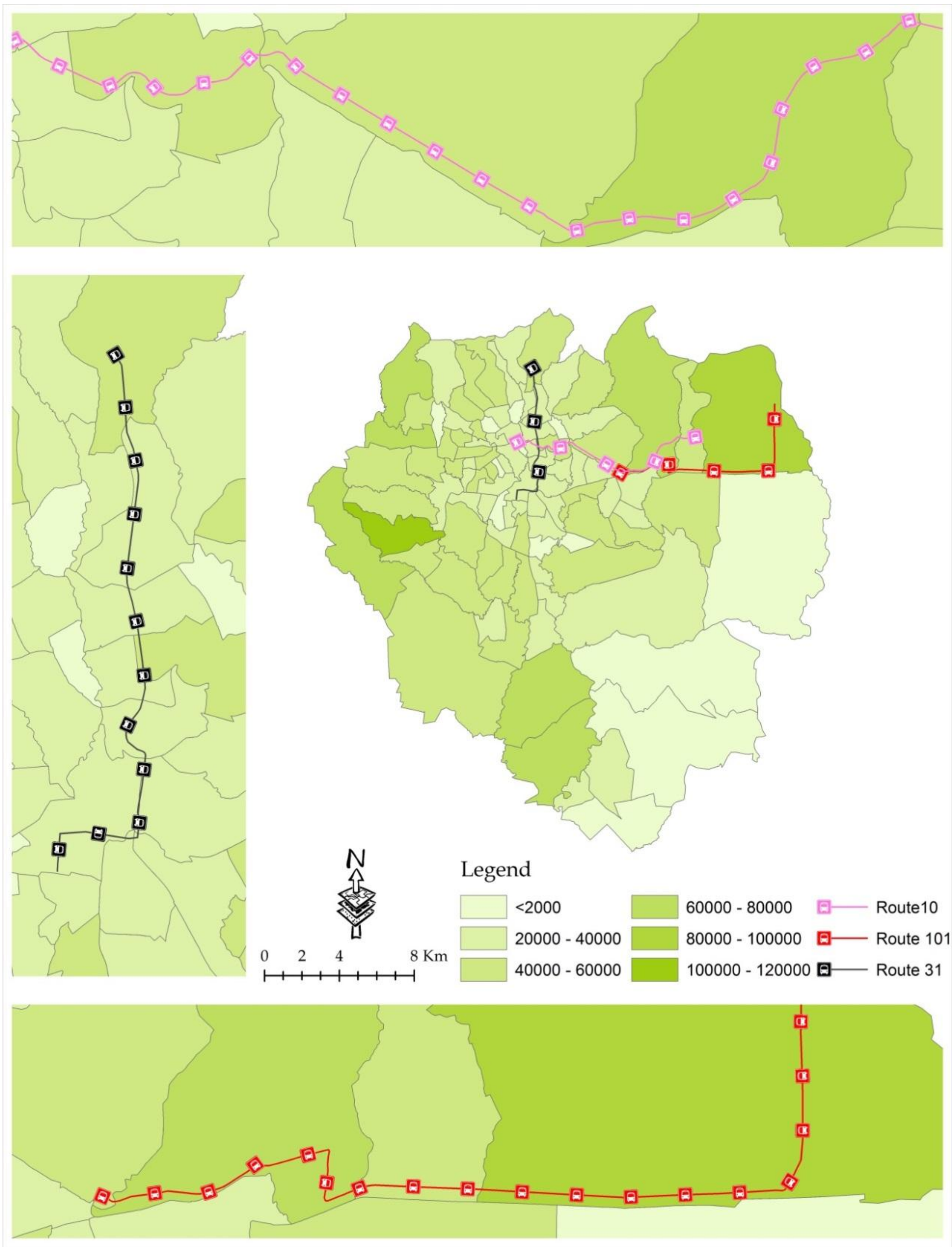


Figure 3-22 Study area projected population
Source: Based on CSA 2007 report

To get effective insight to accessible population that are considered to be "Near" or "Served" by the existing bus stops the process involved following procedures:

1. Service area polygons representing the area accessible within 500-meters from bus stations on a network were extracted using "feature to polygon" command as shown in Figure 3-23 below.

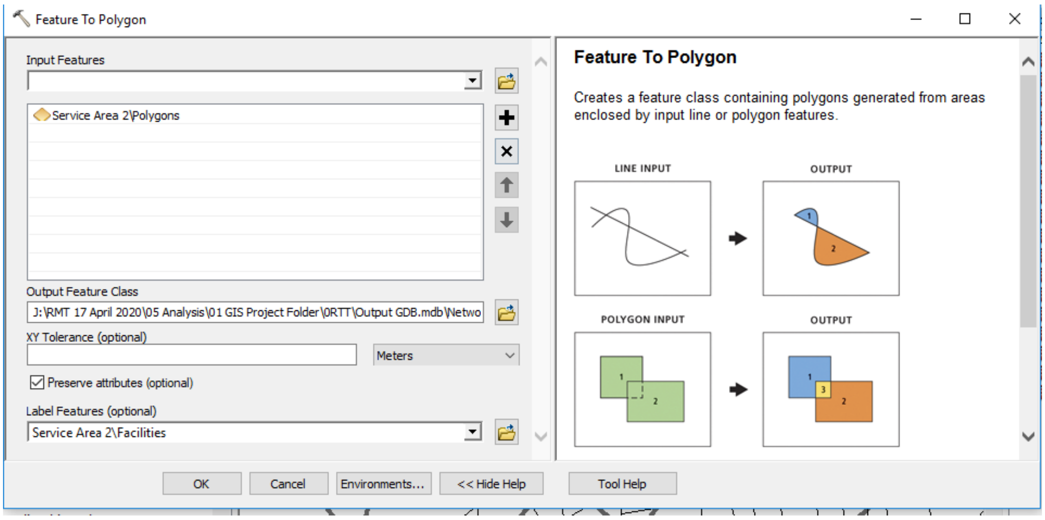


Figure 3-23 Service area polygon extraction

2. A spatial intersection of the service area and census data polygons is conducted using "Intersect" tool to answer "How many people live within 10 minutes of proximity from bus stops? "as shown below

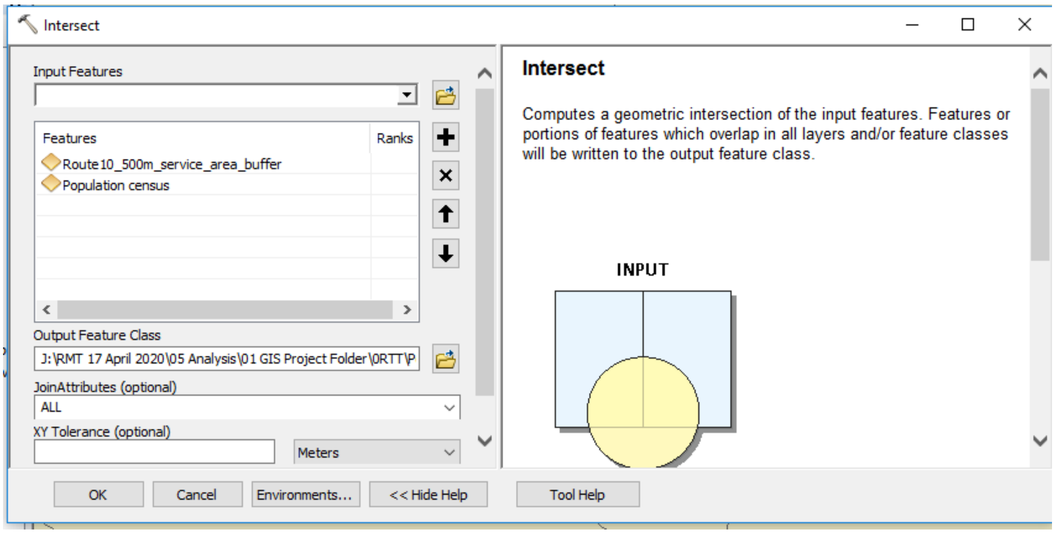


Figure 3-24 Intersect tool

3. Then "area "and "population" fields are added to dataset attributes to compute geometry of the polygons by "calculate geometry" tool.

4. Finally, population figures are derived from multiplying the service area and the population density per square kilometers since the data are joined spatially for each service areas, sample computation window for buffer service area looks like as shown in Figure 3-25.

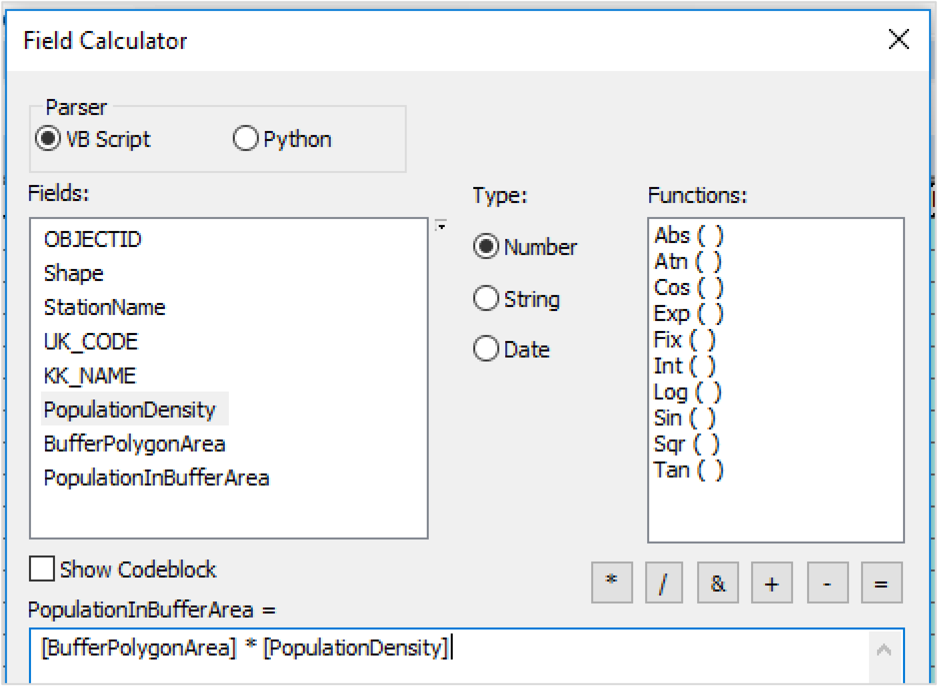


Figure 3-25 Population in the service area computation

5. The results of the data in the attribute table are further exported to excel using "table to excel" tool for further summarizing the total population served in the route of interest as shown in Figure 3-26 below.

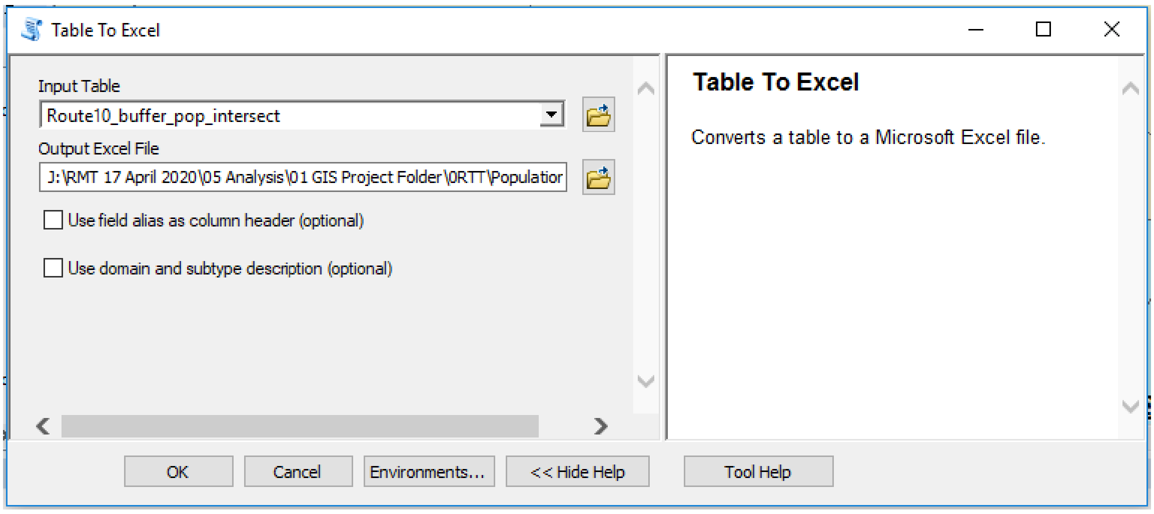


Figure 3-26 Exporting attribute table to Excel

3.5. Economic evaluation

After alternatives have been screened for their economic impacts on the basis of efficiency and equity relative economic merits of pursuing alternatives are evaluated to evaluate the anticipated changes from project implementation. One of the ways for in-cooperating such impact in public transportation is through benefit–cost analysis; the appraisal process involves monetized benefits and costs as well as other benefits and costs to provide a reliable picture of savings and other benefits could be associated with in the absence of the change and proposed course of action as follows:

i. Present value of benefits and costs of each option were computed for:
   - User costs / benefits associated with operation –time
   - Externalities (non-user impacts) emission
   - Agency costs related with operation: vehicle operating costs
ii. Then present values of net benefit and costs (i.e. benefits less costs) are assembled to determine viability of options
iii. Finally, comparison of net benefits with net costs is made.

CHAPTER 4
RESULTS AND DISCUSSIONS

This chapter enumerates the results and discusses the main findings. It starts by discussing the questionnaire survey conducted to collect public opinion. Thereby the paper continues to discuss the spatial distribution of stops, vehicle operating cost accessible area, emission rate and emission control cost along the selected route of interest in the base case and proposed scenario.

4.1 Questionnaire response

To assess the city's current public transportation from customer's point of view and supplement the development of integrated framework for economical evaluation of bus stop design, a sample survey of residents was undertaken in May 2017. The questionnaire survey administered has two parts: the first sets of questions focuses on basic information of respondent to investigate participant's sex, age and job and in the second set of questions are aimed to consider respondent's urban public transportation view in their jurisdiction.

This survey is conducted through interview and distribution of questionaries' to 200 willing individuals who use, might use and not use bus transit without basing their living area. Conversely, by the end of the survey period, properly filled data had been retrieved from 195 persons. From these participants 117 of them were male while the rest were female. Further, most of the participants who take part were office workers and below age 40 that use minibus favoring its speed and ease of access for them (for summary of statistics Table 5-6 in Annex B). Despite the majority of respondents cite their reasons for respective choice cross-tabulation of tables revealed the relationship between transport modal choices, cost, sex and age do exist as shown in Table 5-6. Hence, from these tables it can be understood that choice mostly depends on speed and access of transportation.

It is also evident from literature that performance of the route pertains to the space and time to access service provision. However, not all respondents were able to specify neither how much they are walking nor how much they prefer to walk in terms of both time and space variables. Hence, from those surveyed the numbers of respondents who quantified the distance they are walking were 38% and whereas the majority of participants have indicated in terms of time which may be attributed to most people perceive the public transportation is by the travel time but not on distance travelled. This variation may be due to lack of clear knowledge of relation of distance and time.

In spite of these it is noted that most portion of the trip involve some walking, further from Table 5-8 it can be observed that most walk 300-600m to access transportation. Especially data in Table 5-9 shows 59% percent of respondents spend 5-20 minutes, while the rest 41% of the participants say they spend more than 20 minutes (see Figure 4-1 for more). The results of Cronbach's alpha test indicated the response is reliable since alpha is more than 0.7 see Appendix C.

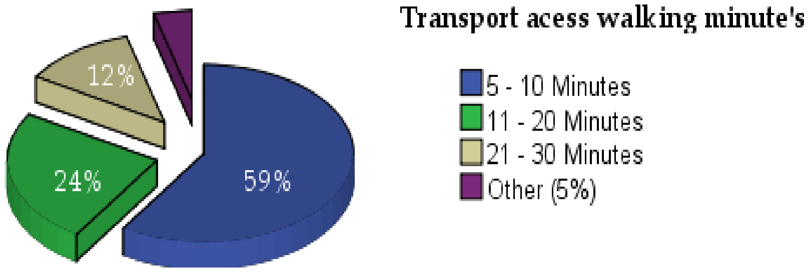


Figure 4-1 Transport access walking minutes

Though, most of the participants preferred to walk with in a range of 10-20 minutes (see Table 5-13), that is about 540-1080m (i.e. assuming percent of elderly pedestrians does not exceed 20% and average pedestrian walking speed of 1.22m/sec obtained from (TRB, 2000, pp. 11-14) however considering moderate percentage of slow pedestrians it is reduced to 0.9m/sec). It is also apparent from Table 4-1 that there is a correlation between transport mode and walking distance that further support the idea of (Agrawal et al., 2008), that walking to public transit depends on availability of alternatives (further for summary of statistics Table 5-13, Table 5-14, and Table 5-15 in Annex B).

Table 4-1 Public Transport mode vs. access distance

Walking distance (m)	Mostly used Transport mode				
	Minibus	Alliance Bus	Higer Bus	Sheger Bus	Anbesa Bus
< 300	32	3	4	5	7
300 - 600	9	1	0	0	1
600 - 900	2	1	1	0	0

In conjunction with walking distance participants of the survey were also asked how frequent they use public transit. However, responses to this question are collected from 59 of respondents that showed 41% of them were frequent users while the rest are infrequent users. Despite over half of respondents were infrequent users they take similar stand with frequent users in perceiving most users as peoples with low income. Besides 66% of the frequent users have disagreed to aforementioned views rather they express their belief that users as peoples who do not have alternatives (further refer Table 5-12 and Figure 4-2)

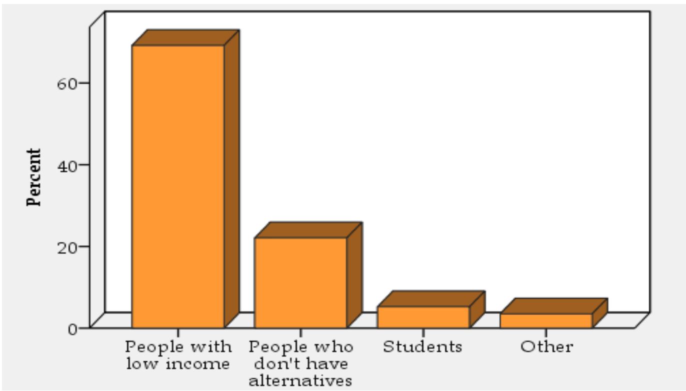


Figure 4-2 Public bus transport perception

In spite of frequency of use data from Table 5-16 disclosed that respondents are not satisfied with the current transit service citing primary problems as absence of shelter, unclean stations, poor schedule information and reliability that had resulted passengers to lose their time and money (See Table 5-17); which could detract passengers. With this regard some participants proposed that proper resource allocation, enhancing sanitation of waiting and riding setting, providing adequate shelters, facilitating schedule information and improving the headway and reliability are the major action plans that should be realized to improve the service quality.

4.2 Baseline scenario

As mentioned in the literature review, ACBSE is the oldest operator that have undergone through a lot of changes despite the financial constraints. However, state owned ACBSE still takes the major share of the market by operating in 124 routes through about 1440 fixed stops distributed in inner city and the surrounding suburbs (AATA, 2016; ACBSE, 2016; Eshete, 2015). Further investigation of stop spacing in the current study showed that it ranges from 100m to 1.2 km. As it is depicted from the chart in Figure 4-3 it is notable that distribution of distance between stops in any route is inconsistent, but in most cases it ranges from 300-600m which may be attributed to a lot of reasons.

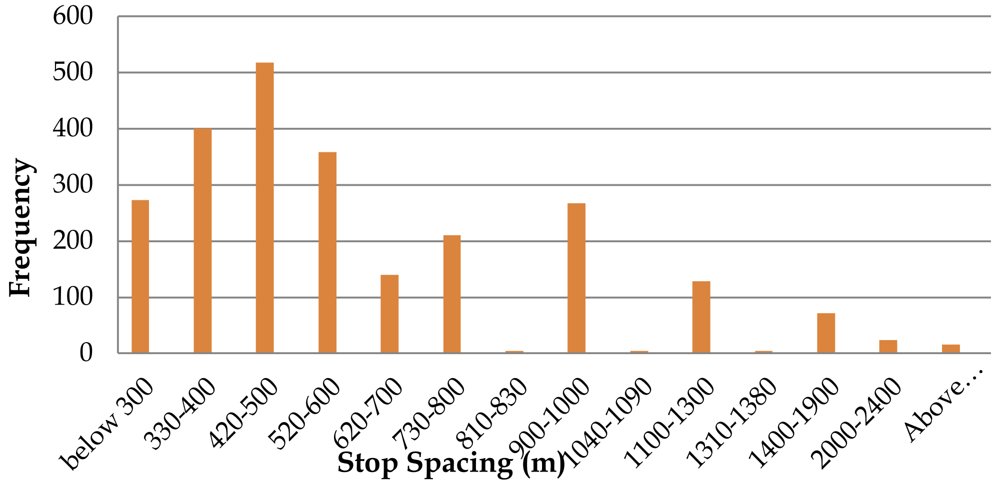


Figure 4-3 Distribution of ACBSE stop spacing

Thus, it was convenient to select main routes from of the many routes which ACBSE operate in the city as discussed in chapter 3. The identified routes of interest for this study are route number 10, 31 and 101. As it is depicted from Table 4-2 the routes have more than 10 stops with the smallest spacing of 200meters, and the highest of 1,400 meters. Further closer inspection of Table 4-2 shows passenger in-vehicle travel time ranges from 35 through 53 minutes which was obtained from ACBSE, however it was observed that they have a reliability problem. Moreover the findings of a research done by AACTA (2017) showed that the average waiting time is 1 hour and 26 minutes, which is consistent with findings (Eshete, 2015). Hence it is possible to hypothesize that ACBSE have a reliability problem which may be attributed to frequency issues.

Table 4-2 Major service routes attributes

Source: AATA and ACBSE data's

Route number		10	31	101
No. of stops		23	12	23
CBD in the route		Aratkillo Megenagna	Aratkillo, Lagare	Megenagna, Ayat
Route length		12.7	8.6	13.7
Service	origin	Kotebe	Lagare	Megenagna
	destination	Piazza	Sheromeda	Aba Kiros
Stop spacing(m)	minimum	200	300	300
	maximum	1,100	1,400	100
	average	552	717	596
average travel time (minutes)		53	35	43

Getting back to the spatial distribution of stops, stop spacing and land use in respective routes is plotted on the digital map (see Appendix E). In spite of the fact that the spatial distribution of bus stop's is mainly linked with the distribution of housing, working, shopping, and other public service activities, the resulted map showed that the distribution of stop's are inconsistently distributed without any formal guideline. Yet, it can be seen that the distribution is tailored to serve high density population areas as origin of trip and central business districts as destination. Moreover, to serve a mixture of land uses which create considerable transit use like social and economic activities along the route contact points to load and unload passengers are placed. Further investigation of the spatial distribution of stops and existing land use is also made however no correlation is found. In the meantime, stops are rubersheeted (i.e. overlaid) on the road network as shown in, to identify the type of stops in the route. Despite there were a total of 58 stations in the s study routes 95% of them are on-street configurations. Further afield visit is made and confirmed that most of the stations are on street except Megenagna, Ginfele and St. Silase College with off street (i.e. closed bus bay) arrangement. The reason behind monopoly spatial distribution of on-street stops is not clear but it may have something to do with lack of consideration of bus stop to the following traffic Besides it can be seen that the road hierarchy along the routes is arterial streets. (See Figure 4-4).

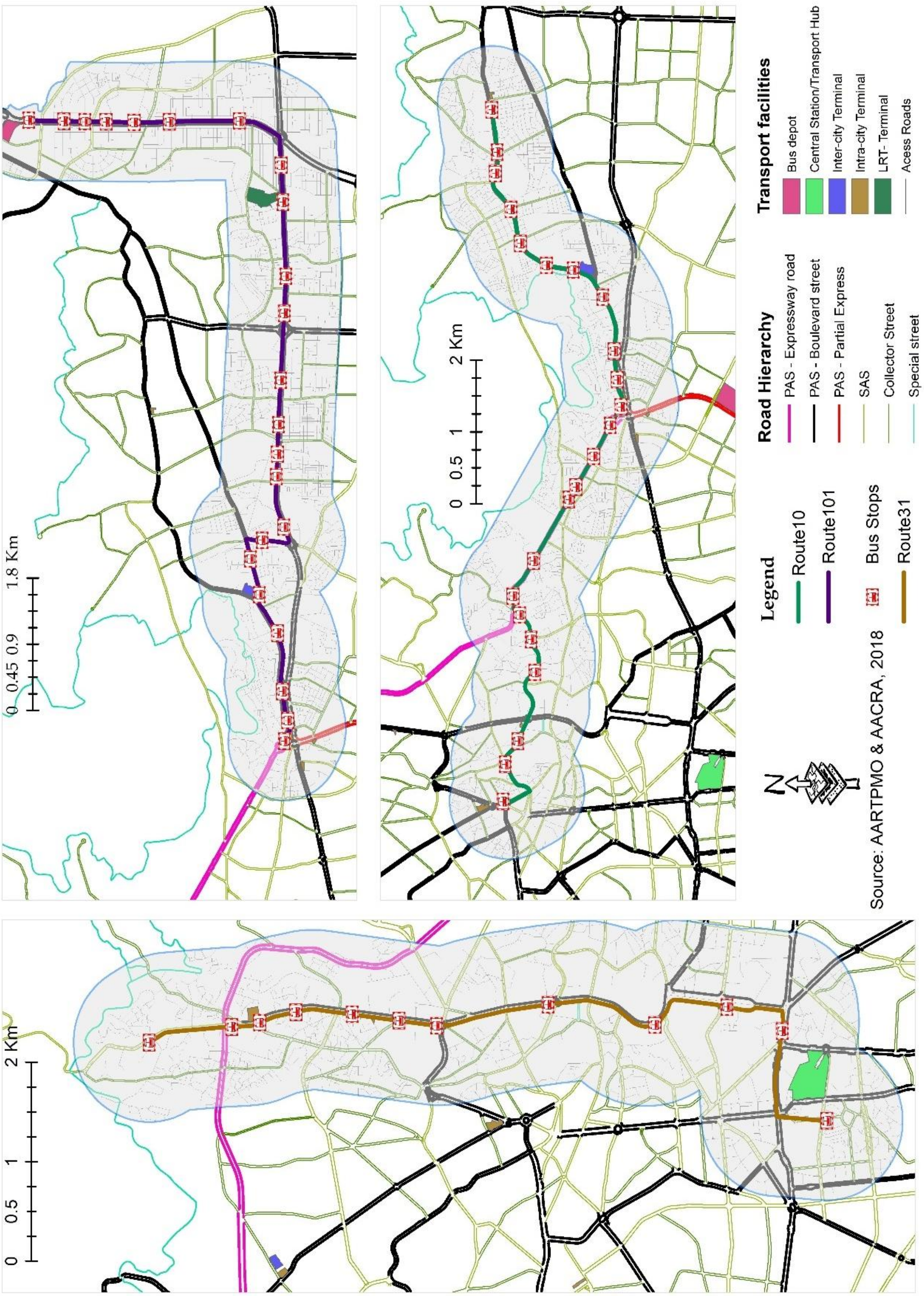


Figure 4-4 Base case spatial distribution of bus stops

Source: AACRA &AARTPMO 2018

4.3 Alternative scenario

The significance of having suitable locations for a bus stop is recognized as a crucial element in the drive to improve the quality of public transit. As doing so to account for the fact that some factors have more importance in the suitability model, the datasets were weighted as they represent different geographical realities and consequently affects the location of the new stops in a different way. In response, determination of potential sites for bus stop locations have been investigated using GIS based on four (4) factors specifically slope, proximity to rail station, distance from accident black spots and existing land use. As noted from AHP results shown in Table 4-3, it can be inferred that the most preferable objective to satisfy is "to locate the stations where there is flat land", and the next is to locate them far from accident black spot areas and near to residential and community service areas (i.e. commercial, educational, and public gathering places) and then close to existing railway stations. See Table 4-3 for AHP-derived weights

Table 4-3 weight influencing factors in bus stop suitability analysis

No	Factor	Weight	Sub-criteria's		Score
1	Slope (C1)	0.4600	C1-1	<6%	5.0
			C1-2	6-10%	3.0
			C1-3	>10%	1.0
2	Vicinity to rail station (C2)	0.0800	C2-1	<100	5.0
			C2-2	100-150	4.0
			C2-3	150-200	3.0
3	Far from traffic accident black spots (C3)	0.2300	C3-1	<100	2.0
			C3-2	100-150	3.0
			C3-3	150-200	4.0
4	Land use (C4)	0.2300	C4-1	Residential	5.0
			C4-2	Industrial	1.0
			C4-3	Commercial	3.0
			C4-4	Community service	3.0

To establish constraint for not locating stations in areas near to traffic accident black spots, concentration map is prepared along routes as shown in Figure 4-5. Looking further in the figure the service routes under consideration pass through notable fatal traffic accident black spots based on 2008-2010 accident record obtained from AATPMO.

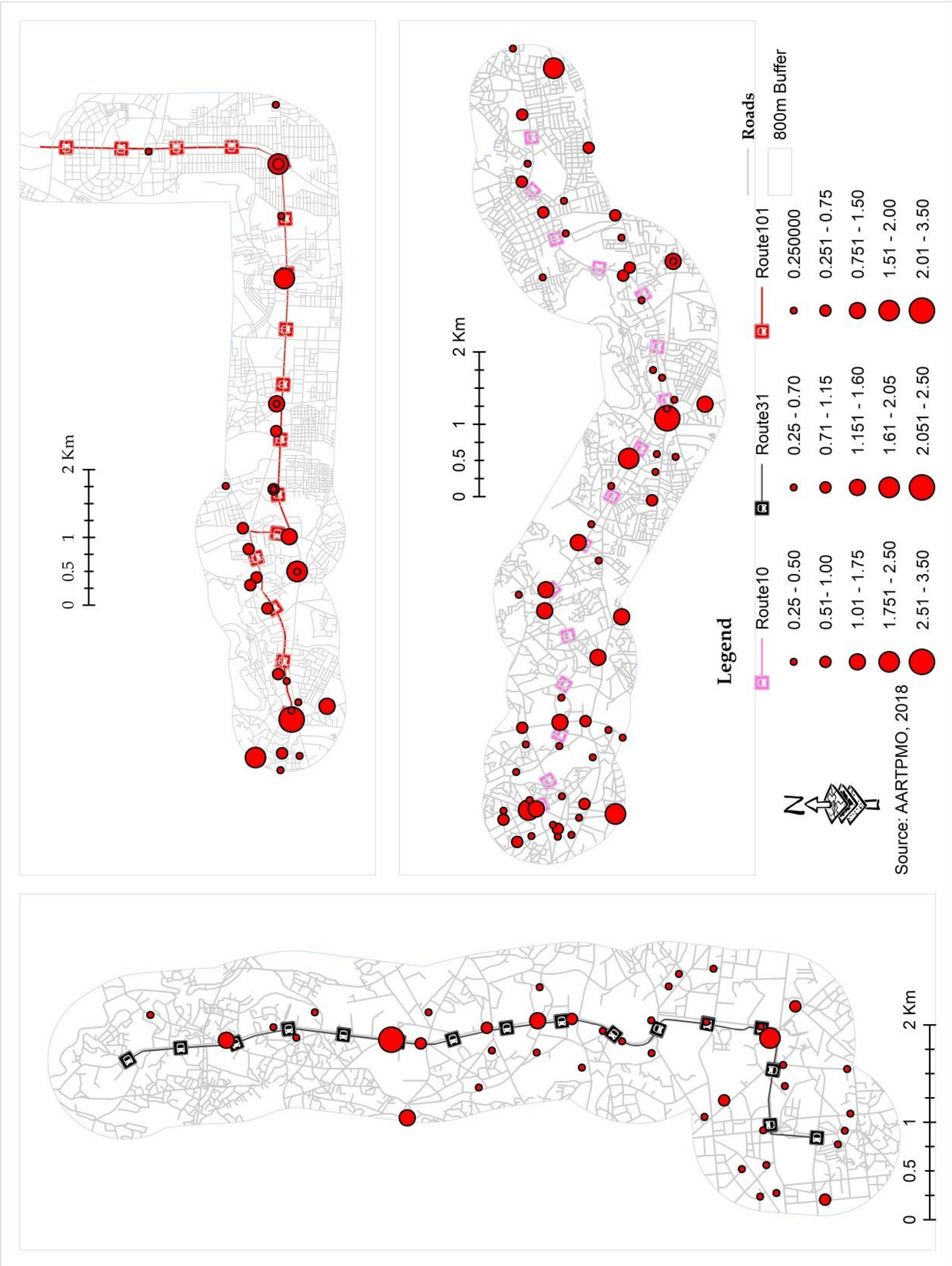


Figure 4-5 Traffic accident concentration along route of interest

Slope is derived from the digital elevation model (DEM) raster is classified in to five classes' (1) <4% which is more suitable, (2) 4-6% which is highly suitable, (3) 6-8% which is moderately suitable (4) 8-10% which is suitable and (5) >10% which is less suitable; as far as bus stops are considered flat slope is favorable most of the places have a slope with in a range of 6-10% which is the expected value Addis Ababa as shown in Figure 4-6.

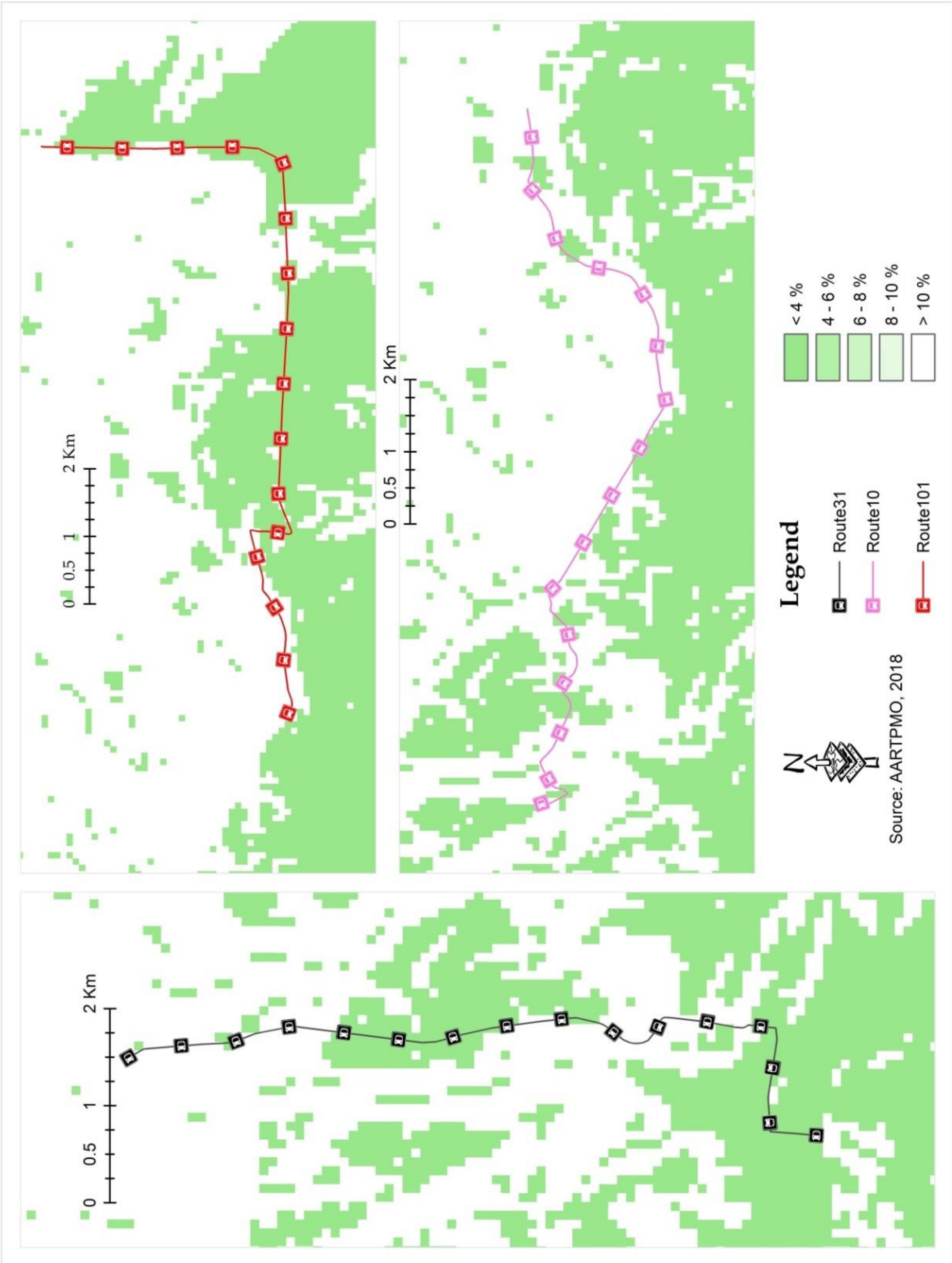


Figure 4-6 Classified slope raster

Then Vicinity to rail stations, the only rail way line adjacent case study route to AALRT railway route is route 101 that share an adjacent distance of five kilometers which is from Megenagna to Ayat roundabout. To investigate locations that facilitate transfer opportunities between the rail and bus transit, railway stations adjacent to route 101 are located as shown in the figure below.

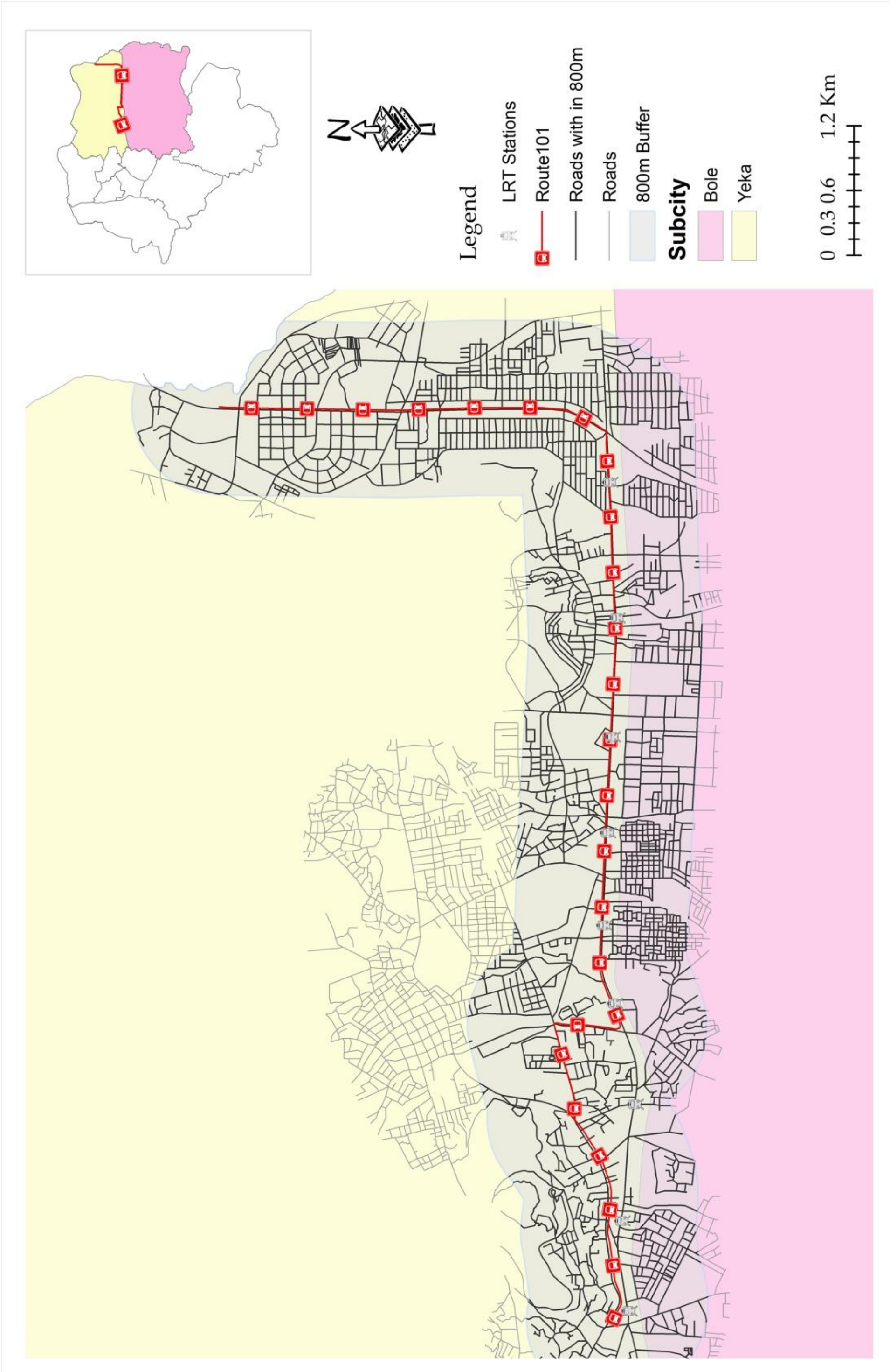


Figure 4-7 Vicinity to rail stations

Land use obtained from AACGPC along the routes of interest is also mapped shown on Figure 4-8 below to identify and generalize land use by types in to four categories to fold specific certain land uses with a single umbrella such as social service as community service, with mixed residence as residential while keeping others unchanged. According to the data along respective routes which mainly connects urban out skirt and densely populated areas with the central business districts pass through mixed residence and commercial areas.

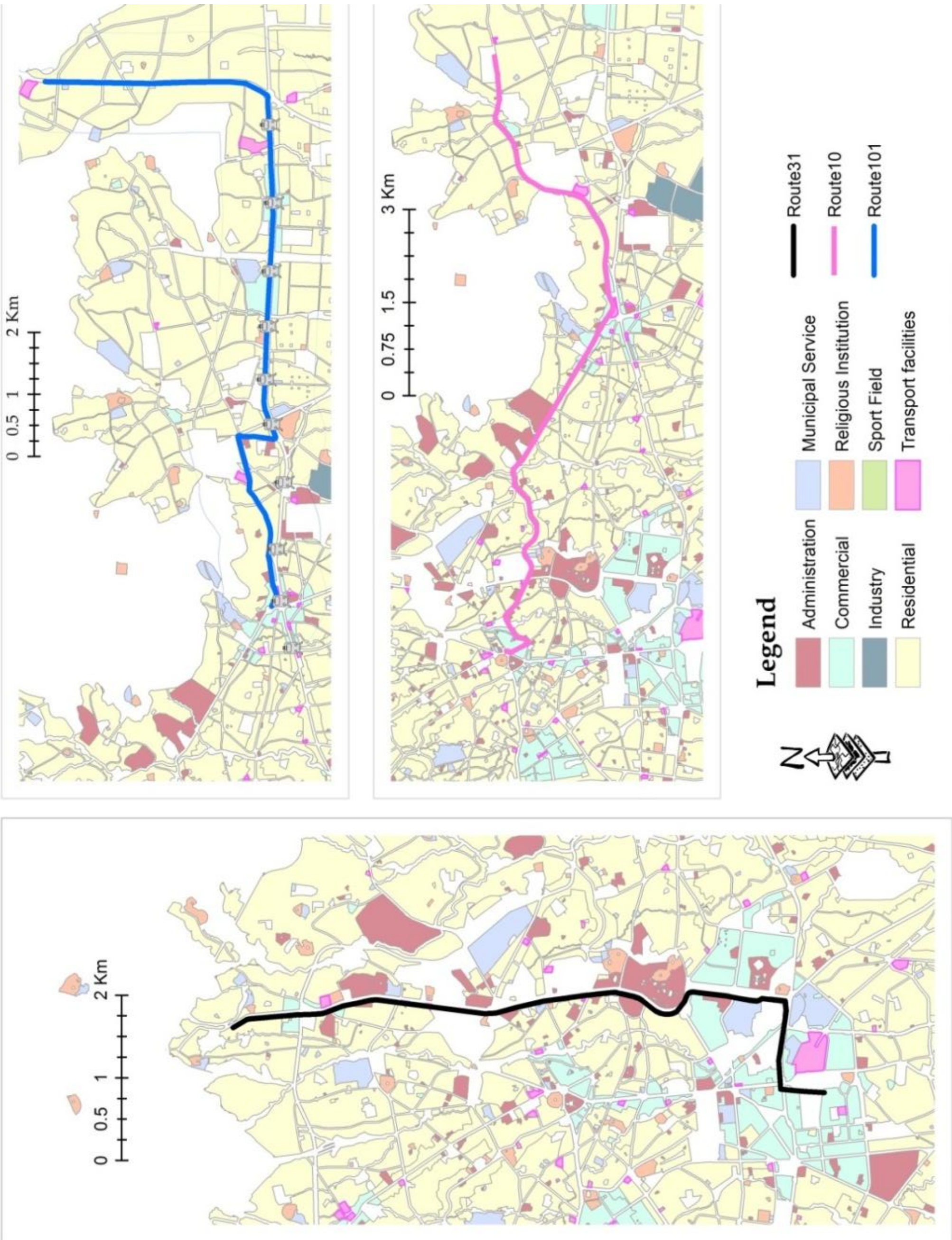


Figure 4-8 Classified land use map in the study routes

Source: AACGPC 2017

The output of accident black spot reclassification is shown below in Figure 4-9 from the results it can be inspected that regions colored with blue are near to black spots in contrary regions colored in red are far from the spots.

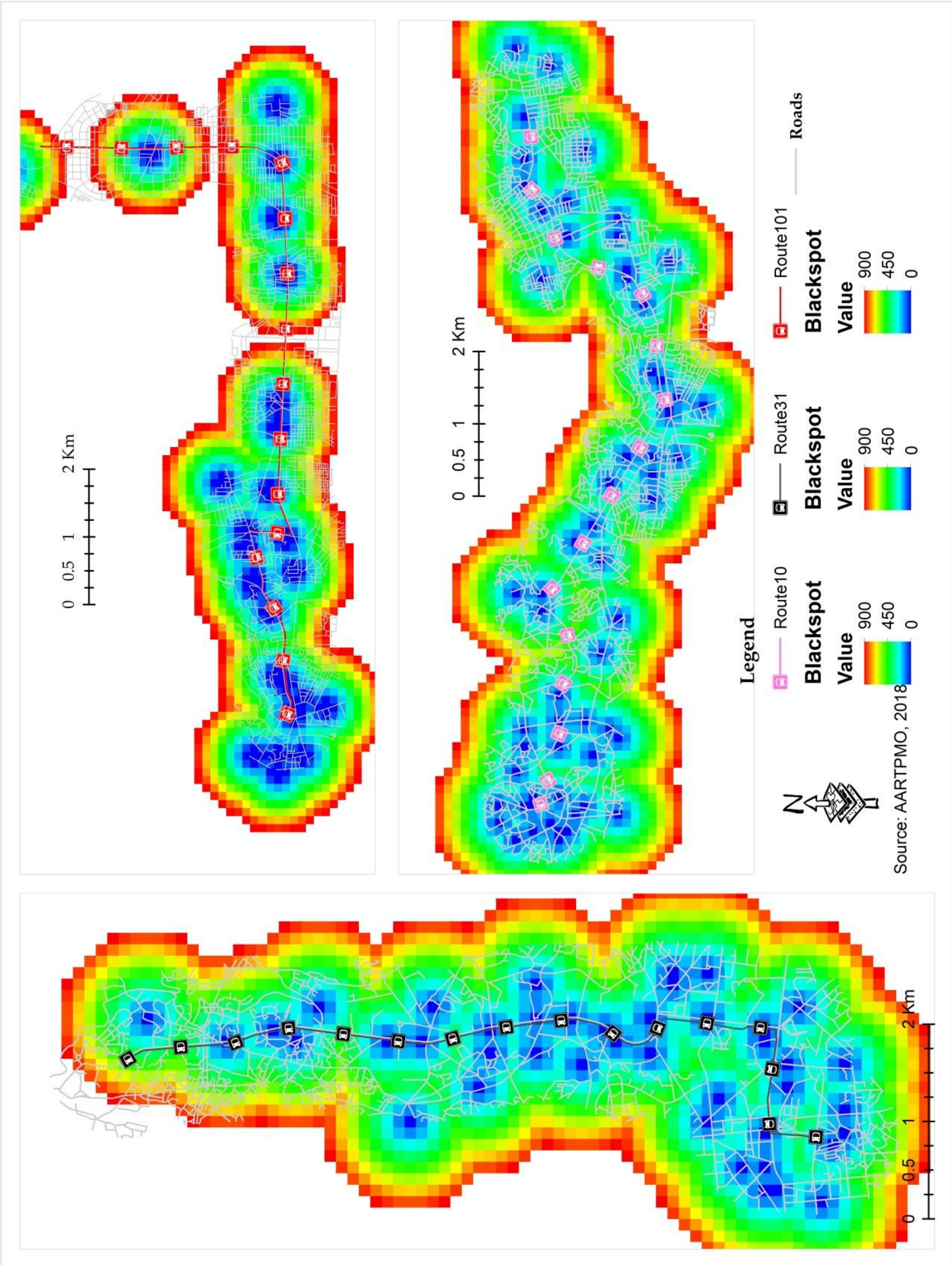


Figure 4-9 Euclidean Distance to traffic accident black spot

Then again reclassification is done to assign scores for slope ranges with regions for being relatively flat get a score of 5 (i.e. with <4%) whereas regions with steep slope is less favorable get a score of 1 (i.e. with >10%). The resulting re-classified slope raster map is shown below on Figure 4-10.

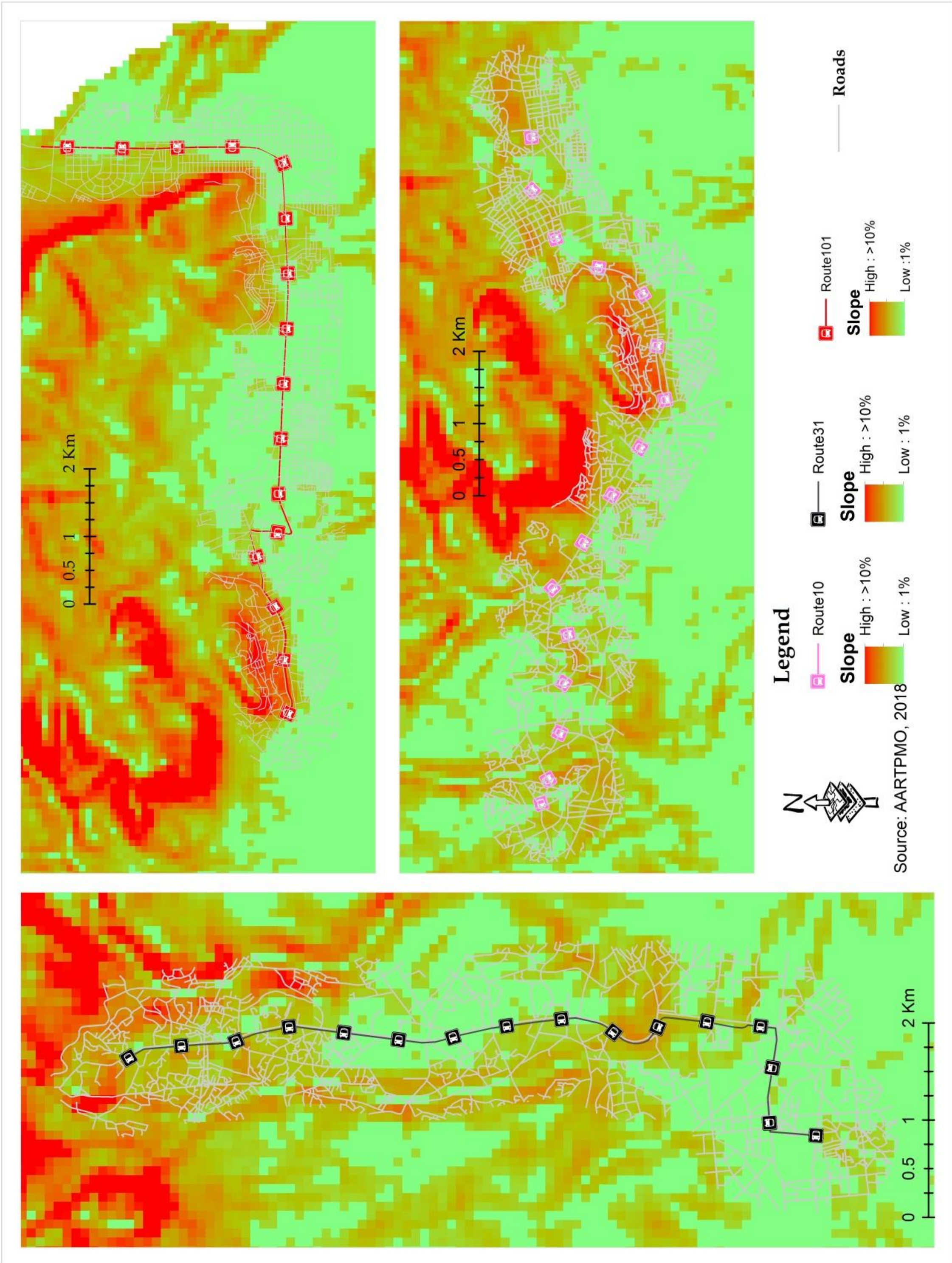


Figure 4-10 Reclassified slope map

Still with "Euclidean distance" tool radial buffer is created taking stations as center, then the raster created is exported to the geodatabase folder under the name 'vicinity_to_rail_stations' as shown in the Figure 4-11 below. , then radial buffer is created with 100 and 200m taking

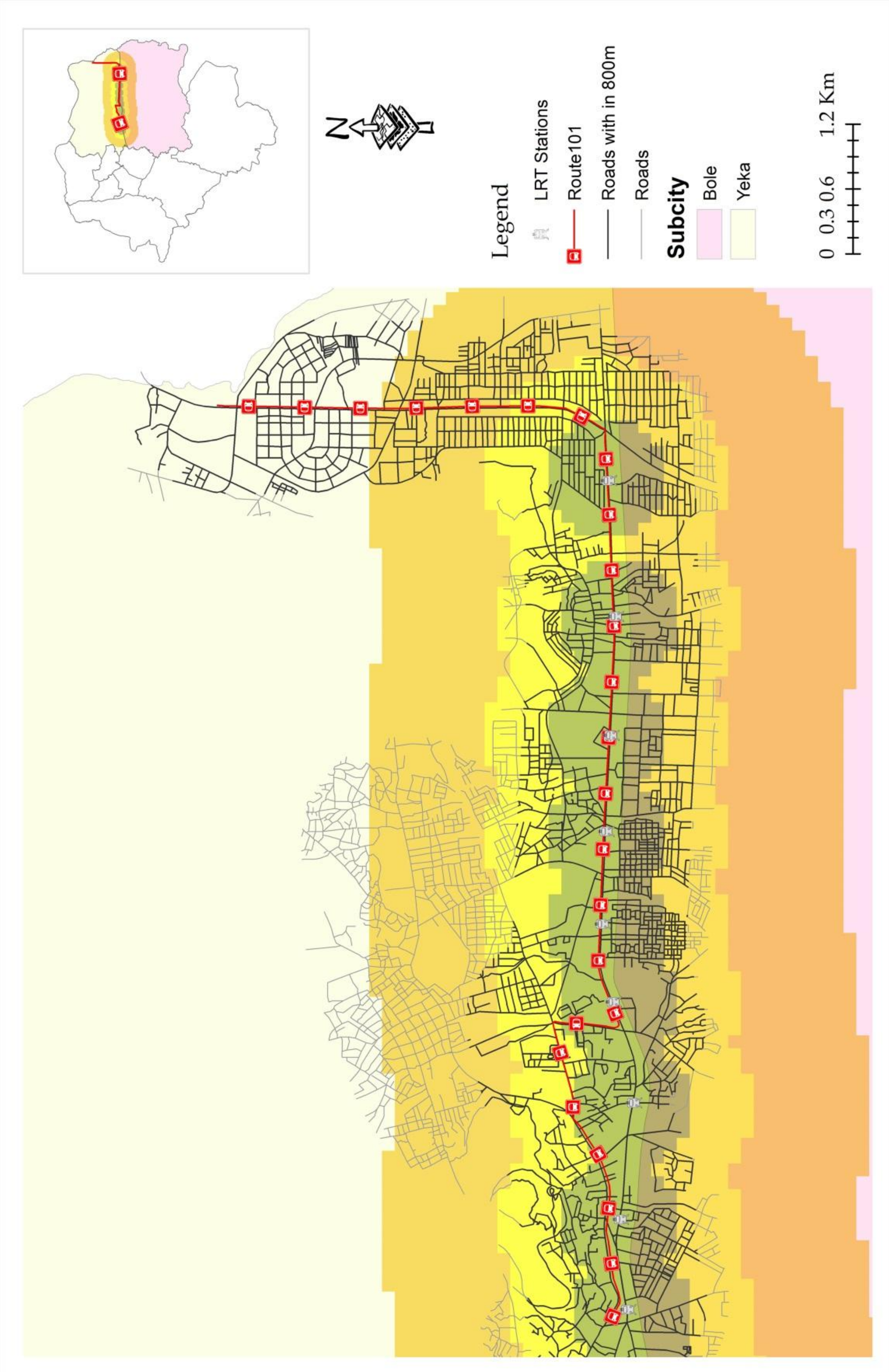


Figure 4-11 Euclidean Distance to railway stations

Further again the land use is and converted to raster using "Feature to Raster" then it is reclassified using "Reclassify" to assign specific suitability sores to certain land use types as shown in Figure 4-12 below.

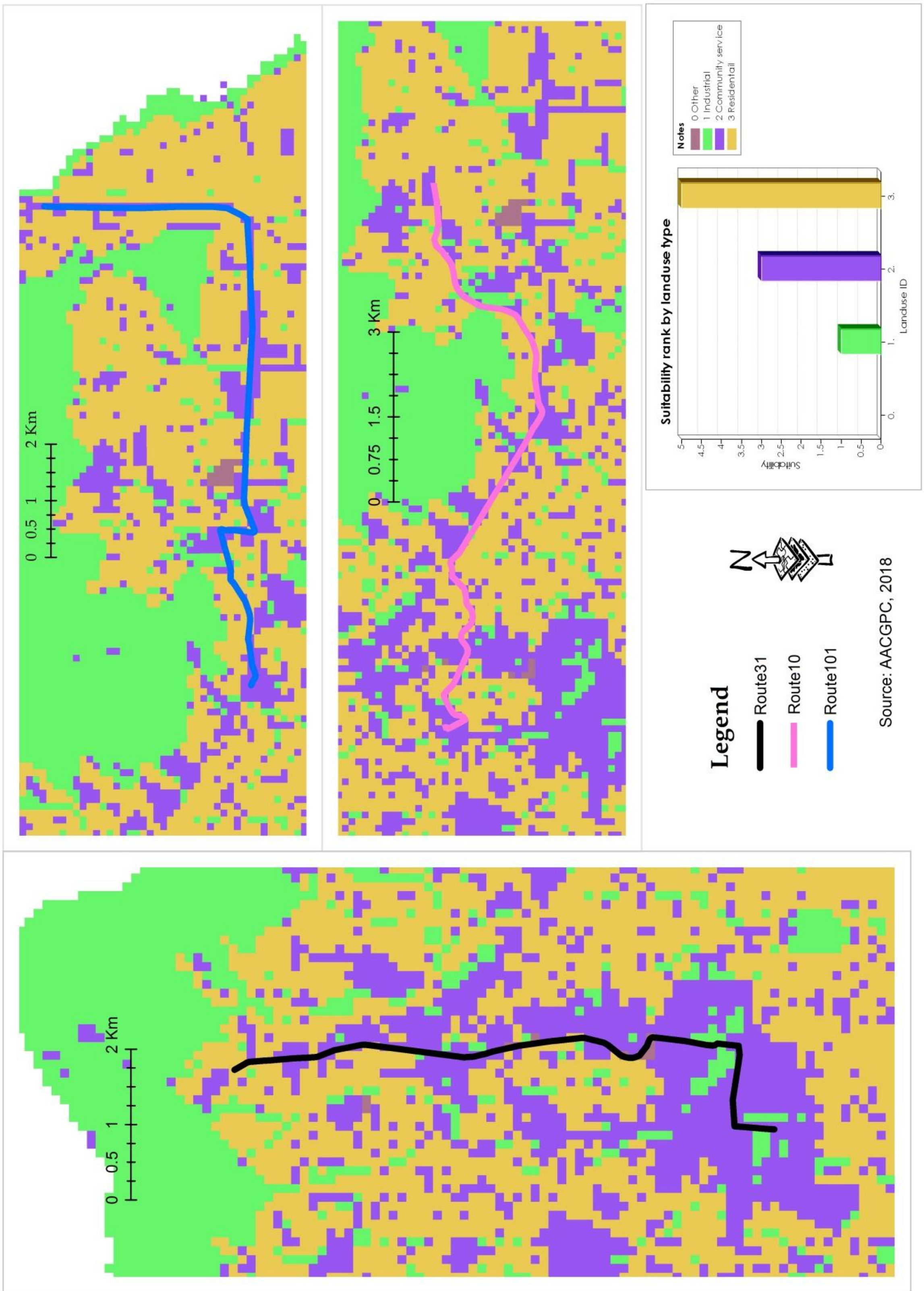


Figure 4-12 Reclassified land use map

The final suitability map is obtained by carrying out 'Reclassification' followed by 'Weighted overlay' to assign AHP-derived weights classes within a map layer and combine layers; see Figure 4-13.

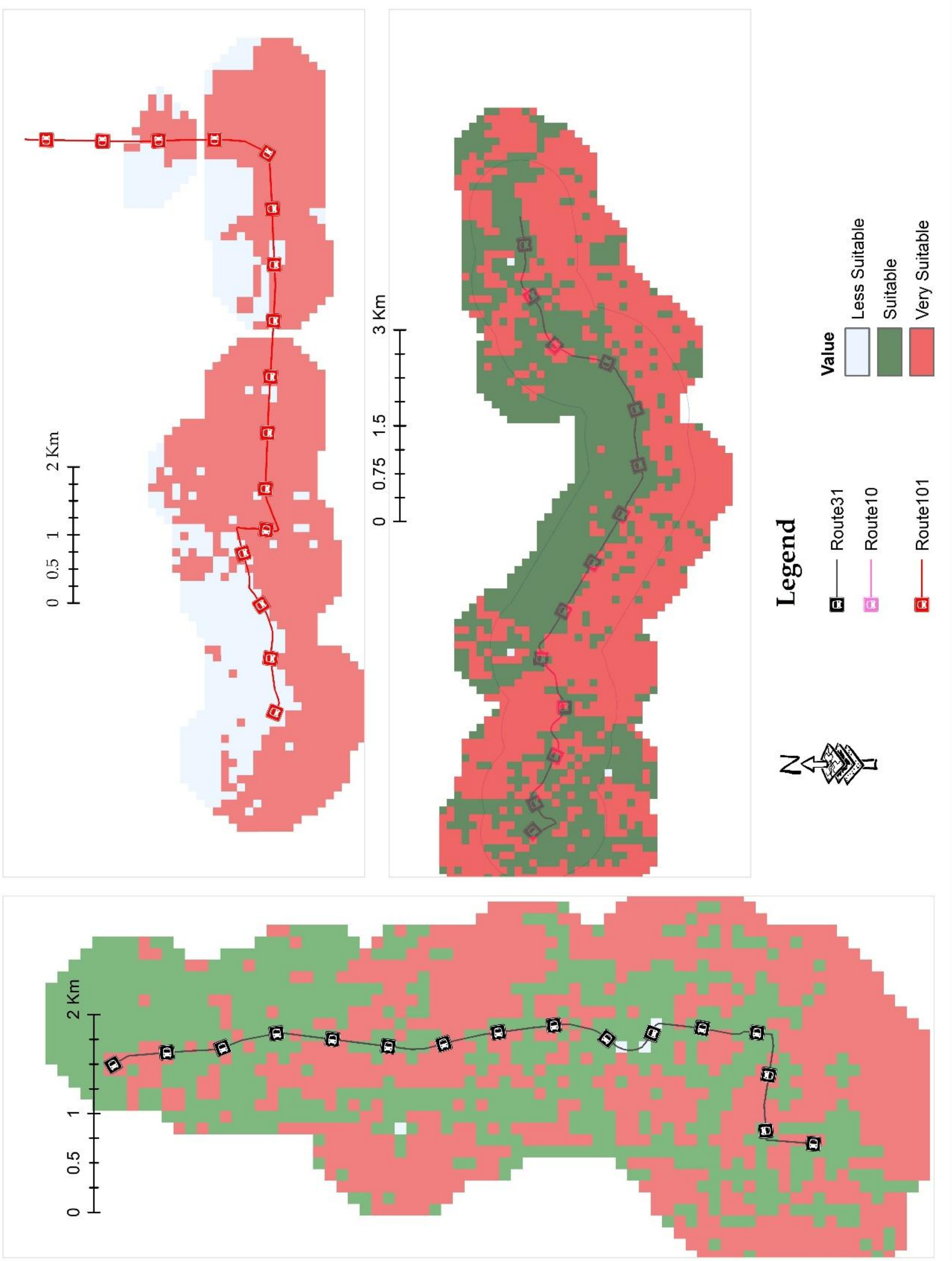


Figure 4-13 Suitability Map

Once the suitability map is created, existing stops overlaid are with resulted suitability map shown on Figure 4-14; which revealed that there is a service area overlap & gaps, besides there are 51 good bus stops located on very suitability surface (value 2) and 7 bus stops located on the less suitability (value 1).

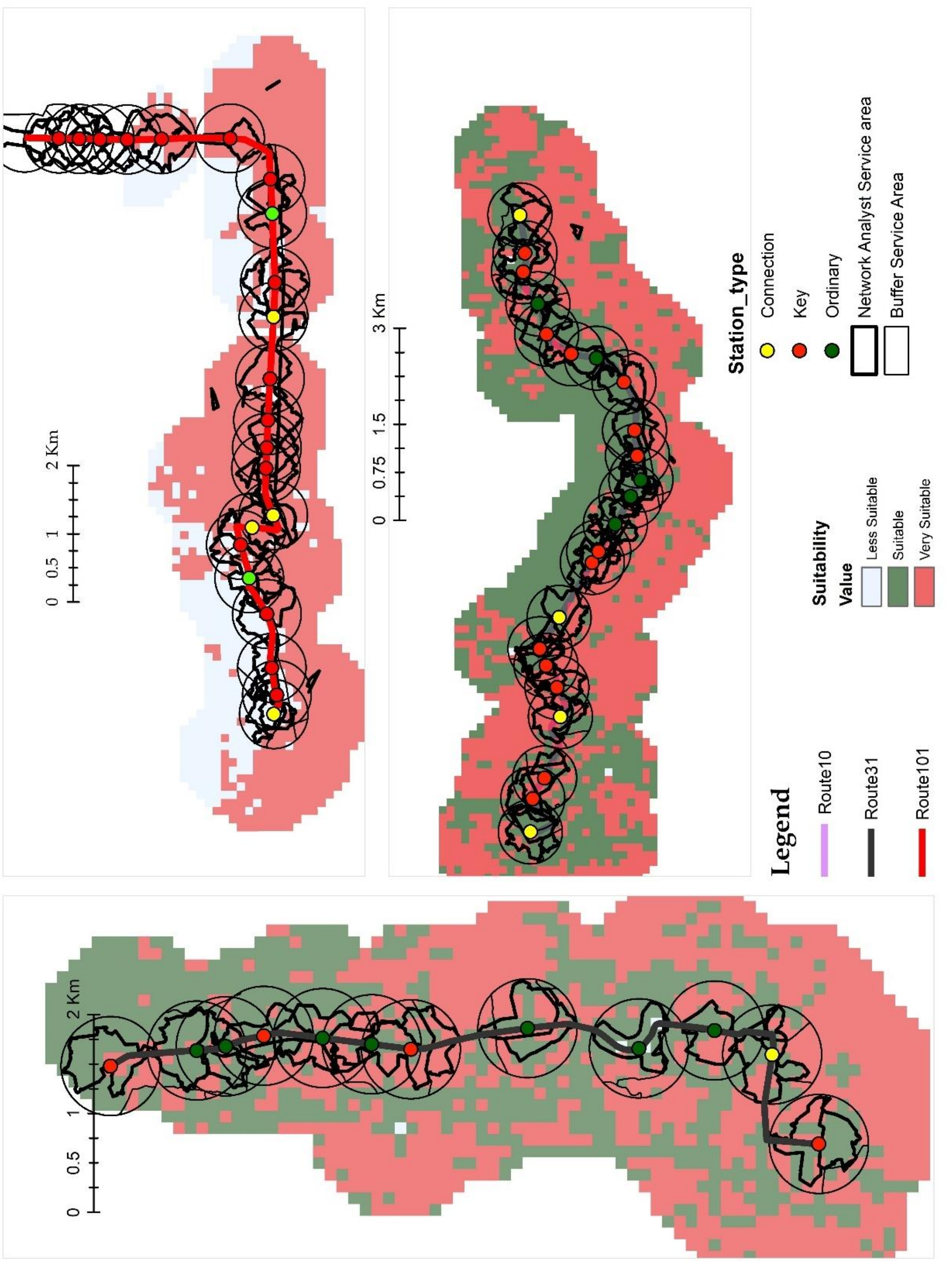


Figure 4-14 Overlay of existing bus stops on a suitability map

In view of the above; there is a definite need to improve spatial distribution of stops. Thereby to formulate an alternative that combines safely integrating with built-in environment and maximize total accessible population in the service area identified stations that are have an accessibility and suitability problems are identified for further investigation. To accomplish this goal imagery data is used to see what actually exists on the ground that might have note been accounted for. In response to this data revealed that the street networks provided steer the flow of commuters to existing stations safely and stations do provide access public facilities which indicates that they were appropriately located considering all the four constraints and the capability of the developed model to identify areas suitable for bus stop.

While this is the case many of the solutions are rooted in the decision of bus stop spacing; this is because spacing plays a pivotal role in enhancing the service area, provision and quality in terms of optimum walking distance and facilitating transfer opportunities. In the meantime, the average bus stop spacing in the routes 10 and 101 fall within the range 400m to 600m which is compliant with international and developing world except route 31 which might stem from the local conditions such as resettlement of people who live there to other areas and lack of public activity centers that necessitate access point. Thereupon location-allocation analysis is made to minimize impedance using P-median constrained problem the results of the analysis witnessed 5, 1 and 4 ordinary stops should be eliminated in route 10, 31 and 101, while this is the case 4, 3 and 3 ordinary stops were newly introduced for route 10, 31 and 101, which make up the small percentage of changes as shown in the Table 4-4 below.

Table 4-4 Summary of changes on the route of interest

Route	Stops Before/After	Stops Removed/Added	Avg. Spacing Before/ After
10	23/22	5/4	552/577
31	12/14	1/3	717/614
101	23/22	4/3	596/623

Further the resulted spatial distribution is mapped as shown in Figure 4-15; which shows the loss of stops means that residents provide a room to walk to the next nearest stop while the introduction of new stops maximizes the service coverage that in-turn reduces the walking distance.

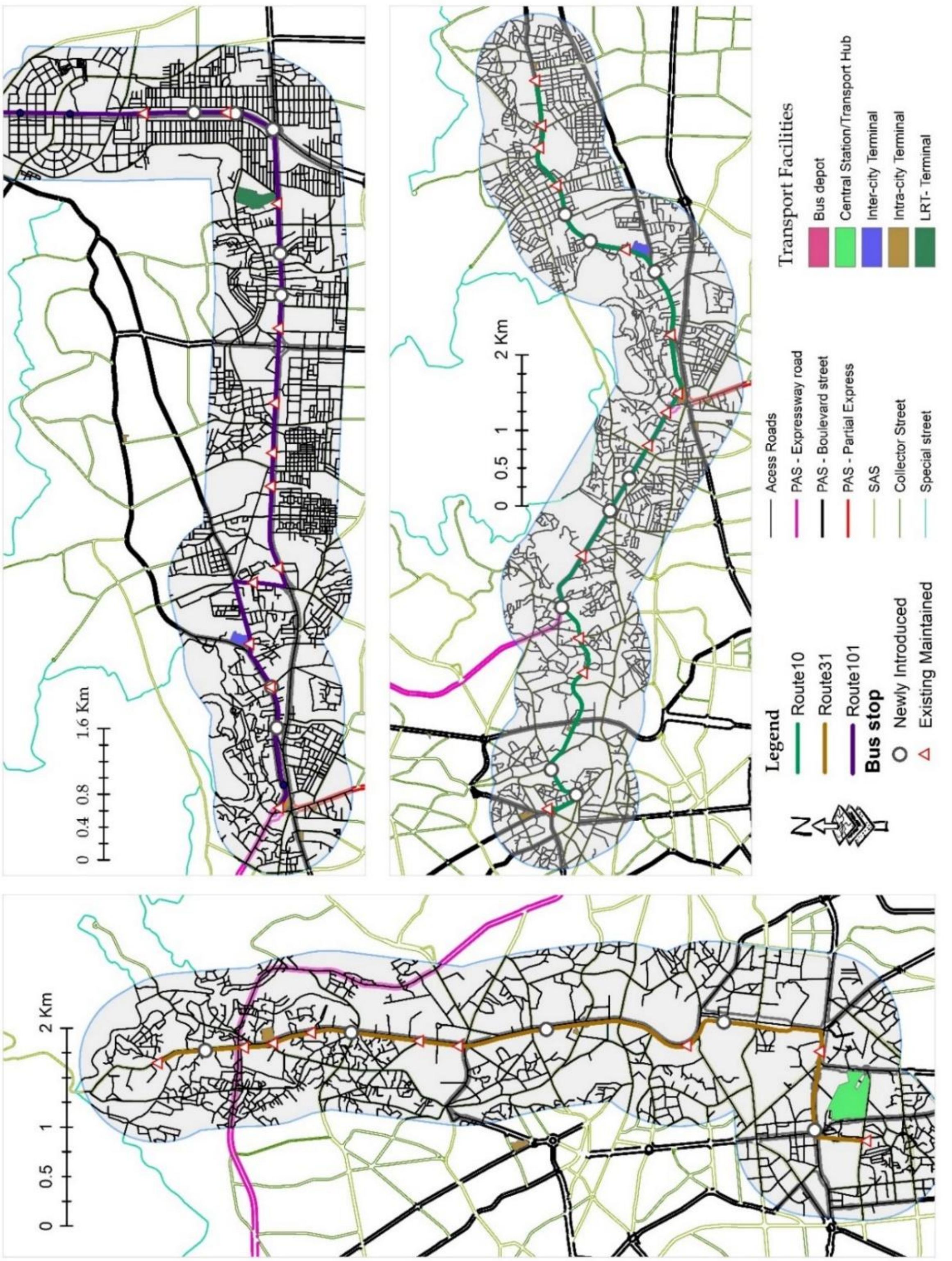


Figure 4-15 P-Median solution set spatial distribution of stops

4.4 Road user effects

The vehicle operating cost have been estimated based on HDM4 with WT consult data's, ACBSE vehicle utilization report and the application of assumptions specifically for the purpose of analysis it has been assumed that (1) VOC is the same across all other vehicle types ACBSE is using (2) cabin, driver and maintenance labor numeration doesn't differ based on bus type that they are driving, operating and maintaining respectively and (3) IVECO 150E 18 represents the vehicle characteristics used by ACBSE in terms of engine size cylinder and revolution per minute. Thereafter, expenses of a firm per kilometer that are required to put buses into service are estimated for roads sections of respective routes are summarized in Table 4-5. As the Table 4-5 shows the average present value vehicle operating cost estimated at 0.628$/veh-km (17.14birr/veh-km) whereas the travel time value is estimated at 1.499$/veh-km (40.90birr/veh-km), the average road user costs to be 2.127$/veh-km (58.04 birr/veh-km). During the years under review, the route performance for route 10, 31 and 101, ACBSE has transported and collected 1,866,568 passengers and birr 2.76 million, 4,111,960 passengers and birr 5.52 million, 2,248,572 passengers and birr 3.84 million birr respectively in 2008 where as in the succeeding year 2,592,427 passengers and birr 4.14million, 2,343,600 passengers and birr 3.17 million, 1,361,550 passengers and birr 2.35 million birr respectively.

Table 4-5 Average cost per vehicle-kilometer per route

Route	Passengers (Million)		VOC ($/veh-km)	Value of travel time	Revenue	
	2008	2009			2008 Ec	2009Ec
10	1,866,568	2,592,427	0.656	1.506	2,760,617.8	4,148,534
31	4,111,960	2,343,60	0.636	1.479	5,525,789	3,173,052
101	2,248,572	1,361,550	0.592	1.512	3,842,424.2	2,352,675
		Average	0.628	1.499	3,633,848.66	

Aside from the operating cost public transportation will also have a frequent idling at bus stations which will incur additional cost is estimated by online tool available in https://www.vcalc.com. From the results shown in Table 4-6 it can be see that the annual idling costs between base case and alternative scenario is estimated to be within a range of 528,811to 340,757 in base case, where as it is 511,184 to 359,012 in alternative scenario. While that of the direct vehicle operating cost per route is a function of the total distance travelled in the year multiplied by respective VOC ($/veh-km), which result in average of 230,353.51, 150,284.76 and 135,611.81Birr for route 10, 31 and 101. While this is the case, as data from table shows the direct operating cost recovery ratio in 2008 is below 1 which means it operates below its breakeven point. When we compare 2009 the ratio with 2008 is declined by 98% & 82% for route 31 and 101 it has increased by 36% for route 10 respectively.

Table 4-6 Total Direct Vehicle Operating Cost

Route number		10	31	101
Average VOC		230,353.51	150,284.76	135,611.81
Annual idling cost (birr)	Base case	528,811	458,037	340,757
	Alt. Scenario	511,184	478,394	359,012
Total VOC (birr)	Base case	759,164.4	608,321.7	476,368.5
	Alt. Scenario	741,537.4	628,678.9	494,623.4
Average Annual Revenue		3,454,575.9	4,349,420.5	3,097,549.6
Fare recovery ratio	Base case	455%	715%	650%
	Alt. Scenario	466%	692%	626%

4.5 Environmental effects

As mentioned in the literature public transit similar to other transit modes it have in-separable "bad" outputs like air pollution, what separates it from other is its higher emission rates are due to their operation in a higher combustion pressures in heavy-duty vehicles (Shrestha & Zolnik, 2013). As a result, several researchers have done optimizations in order to reduce these undesirable outputs. In spite of the fact public transportation produces lower Greenhouse Gas emissions than autos, the results of the analysis are presented in 1 which are summarized in Table 4-7 that shows route wise greenhouse gases (GHG) emissions. Taking Carbon Dioxide (CO2) as a focal point of discussion the results revealed route number 10 generate more CO2 than the other two routes followed by route number 101 and 31.

Table 4-7 Summary of emission quantities per route

Route wise CO_2 Sequestration cost per year	Route		
	10	31	101
Quantity CO_2 released to the environment per 1000 Vehicle-kilometers (g)	1.934	0.783	1.52
ACBSE average Vehicle-kilometers per year	351,148.65	236,296.80	229,074.00
Quantity CO_2 released to the environment per year (Kg)	679.12	185.02	347.73

Although many individual idling events are small which make most people argue idling can be ignored citing the damage caused to the environment is less than some other sources of pollution, the cumulative impacts of idling are large! For instance, route's 10 emits 67.6 kg of CO2 in idling in base case which is 10% of operating emission as shown in Table 4-8 below; see details in Appendix H.

Table 4-8 Idleing emission

	10	31	101
Base case	67.6	58.6	43.6
Alternative scenario	65.4	61.2	45.9
Change over base	-3%	4%	5%

Besides the mitigation costs of CO_2 is calculated for each route depending on the vehicle fleet emission obtained from HDM and idle emission obtained through IPCC guidelines to incorporate the total yearly gross emission characteristics and estimate the plantation costs shown in Appendix F. This result has demonstrated that in order to make afforestation a catalyst in uptake of CO_2 from atmosphere, corresponding quantities of trees need to be planted to stabilize the emitted CO2 in to the environment. Thereby the route wise CO_2 sequestration cost for vehicle fleet emission per year 10, 31 and 101 is 12,226, 3,330.9 and 6,260 birr per year for subsequent 25 years which is less than one percent of the annual revenue; further see Appendix F for details. As it can be seen from the results in Table 4-9, the control cost per year accounts for small percent of the annual direct vehicle operating cost which confirms the cost effectiveness of the option.

Table 4-9 Route wise CO2 Sequestration cost per years (ETB)

Route		10	31	101
Base case	Operating	12,226.2	3,330.9	6,260.2
	idle	1,217.3	1,054.3	784.4
Alt case	idle	1,176.7	1,101.2	826.4

4.6 Space- time accessibility of bus stop's

Most passengers enter a transportation mode with intention of accessing their desired location in vicinity; so, the lesson seems clear mass transit stations need to be placed in a reasonable walking distance. Unfortunately, in reviewing the literature, retrieved researches done in local context have not treated walking distance in much detail. For-example (Taye, 2016) paper which focuses on accessibility of AALRT have been more useful if his research takes into account service area within the actual street network rather than using buffer approach to determine the service extent of stop. Moreover (Mengistu, 2013) will have been more useful if the paper had in cooperated the effect of stop spacing which influences walking distance in his study which might be due to limitations of readily available GIS dataset which was also the challenge of the current study.

Though how to balance an opportunity to increase physical activity of transit user's and maintain accessibility at the same time is a great question. In response to this researches like (Furth & Mekuria, 2005) have explained the usefulness of accessibility analysis with in actual street network. In doing so 500m walking distance from facilities in the street network is used for network analysis; the results of the service area as shown in Figure 4-16 revealed that not all the areas where routes were passing through have access to the bus stops, have service area have overlaps and gaps.

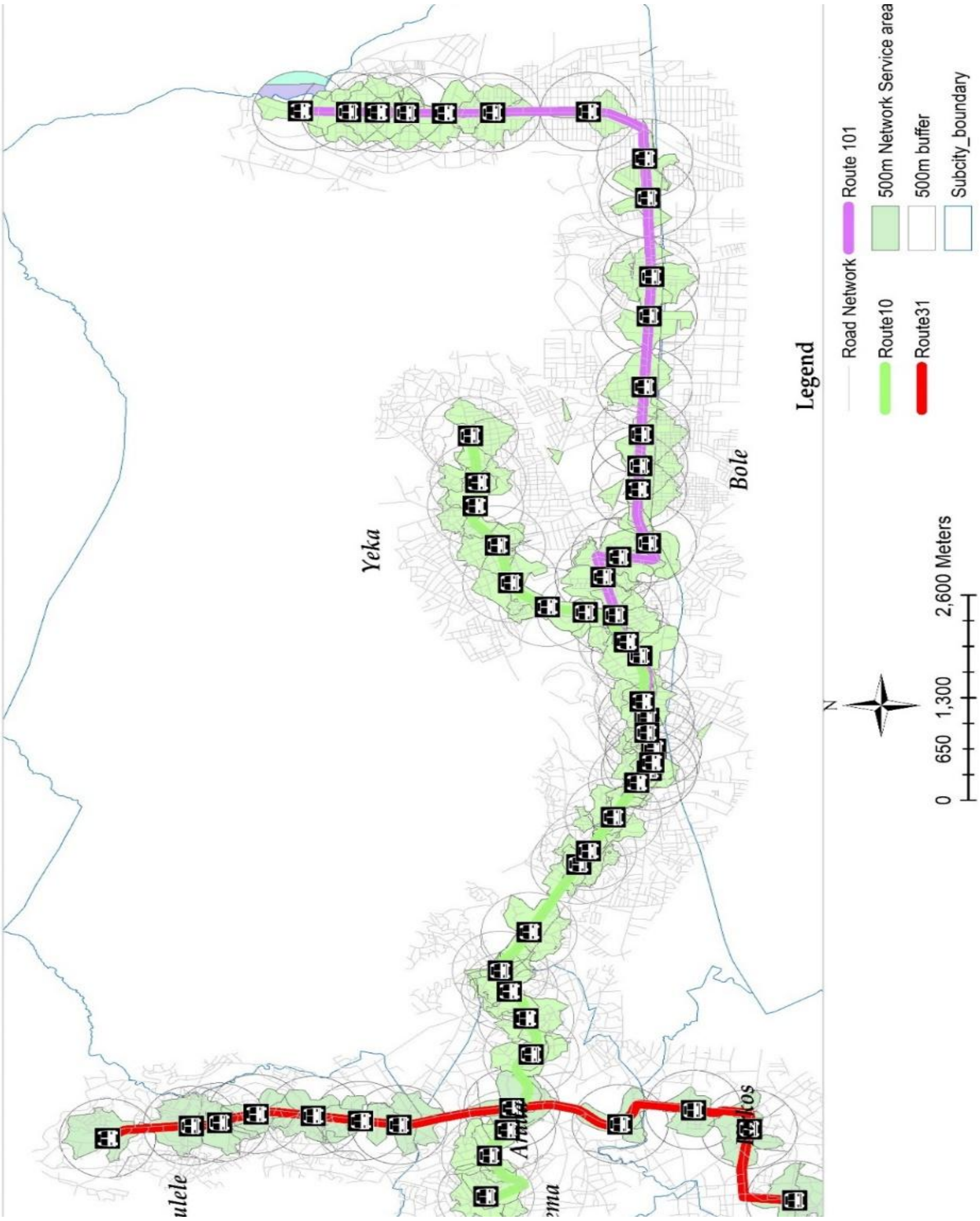


Figure 4-16 500m service area through network analyst and buffer

Results from a query between accessibility map polygons (i.e. resulted from buffer and network analyst) and population census data when the service coverage is within 500m catchment from bus station showed that the accessible population in buffer area is pronounced since it does not consider the actual street network thereby the results of buffer case biased decision if utilized which is one downside of using buffer consequently it is omitted. In the meantime, the total number of accessible populations within 5 and 10-minute walkway along the street network is estimated. As shown in Figure 4-17 the total accessible population for route 10 and 101 with 5-minute threshold on street network with the alternative scenario accounted for a 19% and 9% drop where as 24% increment for route 31 over the base case. Similarly, the accessible population with 10-minute walking threshold for routes 10, 31, and 101 improved by 38% 2% and 32% over the base case scenario. From the results it is evident that, the removal of selected existing stations in the alternative scenario has positive impact on maximizing accessible population.

Figure 4-17 Accessible population in the service area

4.7 Benefits and costs

4.7.1 Total present value of costs of each option

The total estimated present value costs by alternative per each route are summarized in Figure 4-18 shows the present value of costs varies significantly between baseline and alternatives scenario innocuously. In the meantime, the baseline option has a higher cost than alternative scenario due to variables in idling cost accounts more than 70% of the total annual direct VOC cost, while this is the case emission control cost have negligible value.

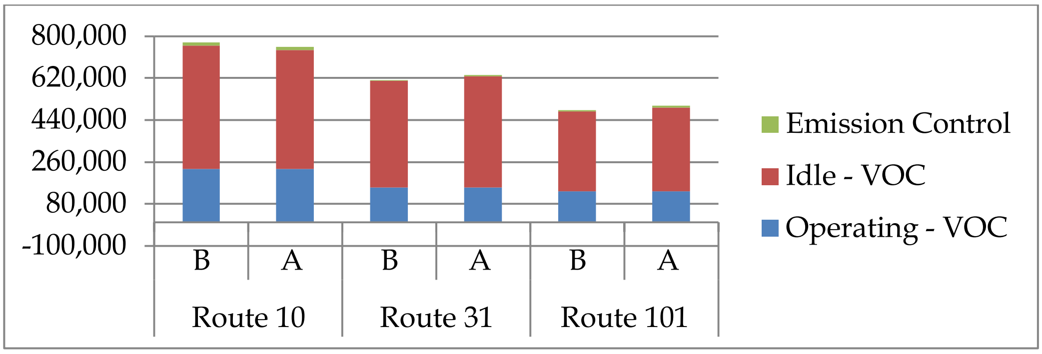


Figure 4-18 Total present value of costs for analysis scenarios

4.7.2 Costs relative to the baseline option

Similar to the approach used to evaluate benefits; the costs of each option have been assessed relative to the baseline option and shown in Figure 4-19. As shown in the figure only route 10 alternative scenario is less costly in present value terms than baseline option due to stop consolidations; in case of route 31 and 101 the baseline option is estimated less expensive than alternative scenario because both routes alternative scenario requires large cumulative dwell time.

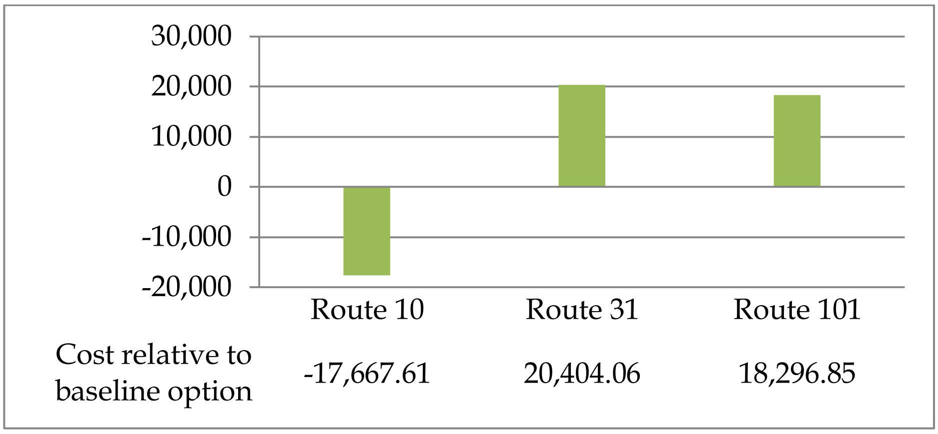


Figure 4-19 Costs relative to baseline option

4.7.3 Net benefits relative to baseline

The net benefits of alternative relative to the baseline option is brought together in Figure 4-20 to demonstrate the overall benefits, costs and net benefits (benefits minus costs) of an initiative based on the net benefit calculations, most evaluated option produce benefits greater than costs relative to the baseline. From the benefits net costs relative to baseline route 10 show positive net benefits. While this is the case the relative net benefits associated with baseline scenario for route 101 and 31 exceed relative costs as compared with the alternative scenario. Though the accessible population in all routes of interest with 10-minute walking threshold for routes 10, 31, and 101 improved by 38% 2% and 32% over the base case scenario, the gain in coverage due to elimination and addition of bus stops is large (7%) of the total population of Addis Ababa. City.

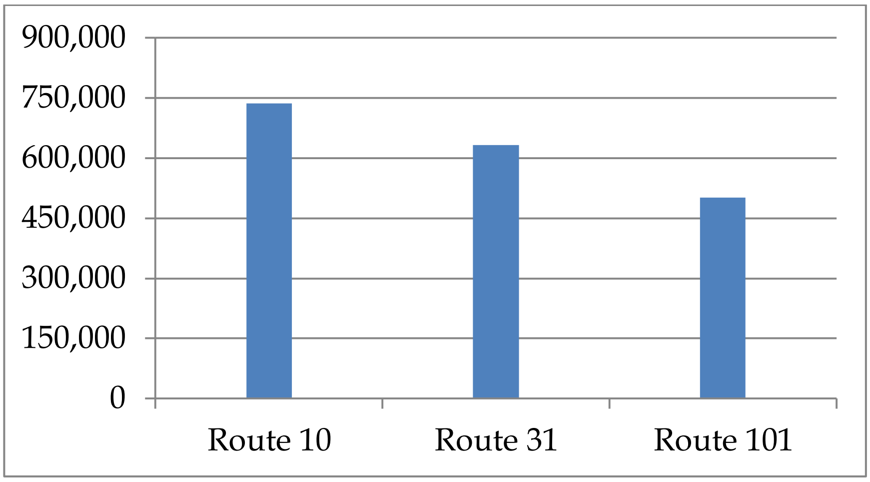


Figure 4-20 Benefits net of costs relative to the baseline option

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This brings us to the conclusion section so far it has been noted that station spacing is subject to multi criteria variables which comprise efficiency and equity issues. In this regard the paper investigated the economic impact of ACBSE bus stop in three routes by formulating two analysis scenarios namely baseline (i.e. existing) and alternative scenario which is expected to represent a good balance of all possible concerns. The results of this investigation revealed the following key points:

- Despite people are comfortable to walk for 10 minutes; most people are likely to walk up to 20 minutes for accessing transportation daily which is about 3.9 to 7.8birr. In this context relative to baseline scenario the proposed scenario maximizes access in actual pedestrian street network favoring 10 minutes that equates to willing walking distance of 540m to and from bus station's the direct user benefits in terms of monetary savings will be 7.8 birr/day/trip.
- In context of efficiency ACBSE fare recovery ratio is good in the route of interest, though these results are in-consistent with previous results reported by (Aimero, 2016) that argues ACBSE operates for no profit; given these findings are based on the limited number of routes the results cannot be used in estimating profit of the agency. Hence, in order ACBSE continues its operation and function properly fare collected should cover overall expense of the agency or else a subsidy should be provided.
- Like any other public transit ACBSE releases undesirable outputs to the environment which can be controlled by plantation. The local Total sapling, land, agency management and conservation work cost and land required for plantation relatively similar with the baseline for instance for route 10 drops by 3% whereas for route 31 & 101 it has grown up by 4% and 5%.

- Average per-kilometer operating cost is estimated at 0.64$/km using this figure and elimination 4% of existing bus stops the savings and costs in annual direct vehicle operating relative to baseline is estimated at 2.3% and (-3.35%) for route 10 & 101; while this is the case the introduction of stations in route 31 increases the total direct vehicle operating cost by 3.35% though it provides additional 2% access coverage as compared to baseline; in the meantime idling imposes 70% of the total annual direct VOC cost.
- Interestingly the resulted modification of spatial distribution stops in alternative scenario were found to provide additional access coverage within acceptable 10-minute walk 38% 2% and 32% over the base case scenario (i.e. the gain in coverage is 7% of the total population of Addis Ababa city).

To sum up the likely implication of this is that significant improvements in system performance are possible if some inefficiencies and redundancies are eliminated along routes the results implicated walking distance and stop spacing are critical components of public transit that must be well articulated; yet, locating a bus stop is a context sensitive issue. For instance, From the benefits net costs relative to baseline route 10 show positive net benefits. While this is the case the relative net benefits associated with baseline scenario for route 101 and 31 exceed relative costs as compared with the alternative scenario. Though the gain in access coverage in alternative scenario is large for all routes of interest which is expected to help in economic reinvestments in the economy from increased efficiency (i.e. time and money savings) which make the proposed option with the greatest positive net benefits. In view of the above there is a great need to improve spatial distribution of stops.

While the findings of this study are encouraging, there are limitations to be addressed in the following research which were resulted from financial resources and data constraints. First investigation of how much distance passengers travelled could not be made since ACBSE buses are not equipped with the state-of-the-art automatic passenger counting technologies. Thus, to evaluate the cost benefit of the turnover relative to the loadings is not made.

Secondly despite ACBSE provides fixed-stop services since 1942, there were no historic archived on-and-off passengers surveys, bus running speed, detailed operating cost and dwell time data's which are crucial in determining the relationship between stop spacing and the said factors. Moreover, continuous streams of data are not readily available in many bureaus; the snapshot nature of data available makes it difficult to analyze specific conditions. For example, the ACBSE datasets consumed is crudely aggregated and only allow to determine performance in weekly, daily and hourly basis only.

5.2 Recommendation's

The issues raised in this paper point to the importance of evaluating accessibility on actual street network that involve commuters some walking to reach the nearest bus stop. Hence, continuous efforts are needed to locate stations by investigating how far people can comfortably walk to access bus stops and placing them at acceptable walking distance that in-turn elevate the attractiveness of mass transit. A reasonable approach to tackle this issue could be via considering multiple variables which play a part in decision making process with a key priority on walking distance to access transit using approaches such as those detailed in this paper.

Since using fixed route transit typically involves walking from and to transit stops, which necessitate the need for walkway connection besides the role of transit in increasing physical activity by the general public on a daily basis is a widely recognized to reduce serious health problem in Addis Ababa. To do so proper walking environment is essential for encouraging the community to walk as a daily routine which in turn have a positive health effect. Meanwhile, despite it is not common in society to pass someone with physical disability, transportation system should be strategically integrated to form an effective pathway with due consideration of peoples with physical disabilities. Besides pathways should not be blocked for purposes they are not intended for, thus AACRA should enforce walkways are used for purposes they are planned.

While this is the case there is often an overlap between efficiency and equity objectives, since benefits to disadvantaged people often provide relatively large increase in social welfare and productivity, (Litman, 2006) therefore service access and mobility determines horizontal equity. In the meantime, it is unfortunate fact that transit routes serving the majority of the population will likely to perform better in cost benefit analysis. Thus, in order changes don't extremely impact riders with mobility challenges such as seniors and physical disabilities from using fixed-route bus services and enquiring additional costs it should be tested and monitored on a small-scale.

Another important implication of the study is that there is a little incentive for peoples to use public transport while the current public transportation is characterized by poor service quality, unattractive waiting environment, and insufficient amenities. Besides, in spite of the fact modern comfy buses are in service during the survey by Sheger Transport Sc., and Alliance S.C, the entire respondents of the questionnaires agree that they perceive most users as peoples with low income. Addressing the expectations of users necessitates an enhancement towards the attractiveness of public transit to potential riders and raise its competitive edge with other transportation modes should be prioritized by AATA. This can be realized by reducing walking distances to access bus stops; improving the waiting and travel time by dedicating facilities and increasing bus frequencies, improving waiting facilities, and facilitating access to real-time transit information by electronic displays.

In spite of the importance of transportation as a key player in the economy of our country lack of readily available continuous stream of GIS data remains a chronic problem. As a result, not all data was in sufficient quality and availability to be used in analysis due to incomplete coverage, confidentiality, inconsistent classifications and resource constraints. In this regard in order to utilize the economic value of geospatial data in the transportation sector which is a great enabler and incentive for researchers doing research state offices should work together.

Furthermore though additional budget requirements are still a critical issue, in order to transfer of the enterprise's towards modern transit agency there are important changes to be made by ACBSE such as to replace conventional diesel vehicles with electric vehicles to reap the benefits of significant energy conservation, environment friendly and emissions reduction, may provide cost advantages compared to conventional diesel buses. Moreover, it is necessary to in-cooperate technological tools like Automatic vehicle location (AVL) and Automatic passenger counts (APC) with operating vehicles which are helpful to conduct cost-benefit analysis along existing and new routes and enhance the environmental and road user effects resulted from the public transit service. The other thing ACBSE should look ahead for in context of customer service is an integrated electronic ticketing system which allows passengers to switch from one mode to another without incurring additional time & cost. It is also important that stakeholders should work with ACBSE in designing new settlement areas, a setoff should be in cooperated for locating bus stops and amenities in design stage of new roads and preferably before the occupation of adjacent premises, to avoid future conflicts and replication of efforts.

In spite of the fact that the government undertook improvement measures in inner-city and outskirts of the city so as to guide, regulate its growth and improve the quality of life of urban residents that have resulted unprecedented development especially with in the past two decades, the result is the confirmation of failure to timely effect the city's master plans have contributed to urban sprawl which is supported in recent report by (UN-Habitat, 2017). Thus, it is possible to hypothesize that the urban sprawl necessitated accessible transportation mode to and from the city centers which may have resulted for inconsistent distribution of bus stops along the routes. To address this and the urban population growth demanding more basic infrastructure expansions the 10^{th} master plan which was prepared by AACPO (AddisBiz, 2017) should be implemented in order to reasonably distribute accessible transit opportunities in the city.

Though the control cost per year accounts for small percent of the annual direct vehicle operating cost which confirms the cost effectiveness of the option. Meanwhile, city transport authorities cannot unilaterally undertake a plantation imitative, the participation of the community and associated government offices is fundamental for its success. With these regard results have shown idling imposes a larger part of the vehicle operating cost and emissions which in turn poses a profound impact in operations and especially environment. Thereupon, idle reduction technologies put forward by experts in the field such as using alternative energy source in lieu of main track engine for the purposes of reducing long duration truck idling and a GPS tracking system should be used pinpoint specific instances of idling and examine the causes that led to each instance. Further specific tax-cut polices related to environmental issues should be implemented to encourage inefficient public transport enterprises to operate more pro-environmental vehicles.

5.3 Future Research Recommendations

Currently Addis Ababa city administration is hard pressed in provision of ever growing of cities public transportation demand. Consequently, the administration is providing public fund to ACBSE; however, there is no record showing the economic value of subsidy in broad details other than the fare reduction showing the economic benefits for every birr of public money spent in terms of reduced congestion, accidents, pollution and improved productivity. Subsequently further researches are needed to estimate the economic value of subsidy and its influences on the efficiencies of other public transit firms.

As it has been witnessed in the literature and questionnaire response presented stop location is subject to so many variables. Moreover, one of the discouraging forces against public bus transportation is prolonged waiting time. An important problem to solve for future researches is to investigate the suitability of existing stations together with in-vehicle time, dwelling time and average travel speed.

Furthermore, during an observation conducted in the case study routes of ACBSE stop's it has been inspected that these locations are shared among the transit firms. Hence an important question to solve for future studies is to estimate the probability of a bus will find an available loading area occupied by other bus stops (failure rate) should also be studied.

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APPENDICES

Appendix A. ACBSE data's

1. ACBSE service routes information

Table 5-1 ACBSE service information

Source: AATA and ACBSE

# route	Origin-Destination
1	MEGENAGNA - KARALO
2	KORE MEKANISSA - ADDIS KETEMA
3	AYER TENA - MENELIK SQUAR
4	KALITI - ADDIS KETEMA
5	KORE MEKANISSA - MENELIK SQUAR
6	KERA - SEMEN GEBEYA SQUAR
7	MEGENAGNA - ALELTU
8	KECHENE - ADDIS KETEMA
9	BOLE BRASS CLINIC - PIASSA
10	KOTEBE COLLEGE - PIASSA
11	KOLFE EFOYETA - MENELIK HOSPITAL
12	GURARA FERENSAY KELA - ADDIS KETEMA
13	ITALY EMBASSY - ADDIS KETEMA
14	SARIS ABO - MENELIK SQUAR
15	MEGENAGNA - ADDIS KETEMA
16	KIDANIMIHRET - ADDIS KETEMA
17	KUSQUM - ADDIS KETEMA
18	KERANIYO - ADDIS KETEMA
19	SANSUSI - PIASSA
20	DIL BER - ADDIS KETEMA
21	FELIDORO - ADDIS KETEMA
22	SUMMIT - LEGEHAR
23	LAMBERET - ADDIS KETEMA
24	DIRE SOLOLIYA -ADDIS KETEMA
25	LEGEHAR - AKAKI
26	ADDIS KETEMA - SEBETA
27	LEGEHAR - KALITI
28	ASKO SANSUZI -ADDIS KETEMA
29	SARIS ADDISU SEFER - ADDIS KETEMA
30	SULULTA -ADDIS KETEMA
31	LEGEHAR -SHIRO MEDA
32	HANA MARIAM -LEGEHAR
33	KOTEBE GEBRIEL - ARAT KILO
34	GERMAN SQUAR - ADDIS KETEMA
35	LEBU MUZIQA SEFER- ADDIS KETEMA
36	KARA KORE - LEGEHAR
37	KERANIYO - MENELIK SQUAR
38	GERMAN SQUAR - SIDIST KILO
39	BOLE SCHOOL - ADDIS KETEMA
40	KARALO - ADDIS KETEMA
41	EYESUS - ADDIS KETEMA
42	MEGENAGNA - LEGEHAR
43	MENAGESHA - ADDIS KETEMA
44	LEGEDADI - ADDIS KETEMA
45	LEGEHAR - DIL BER
46	GERJI - ARAT KILO
47	YENEGEW FIRE SCHOOL - ADDIS KETEMA
48	BOLE MICHAEL - MENELIK SQ;
49	CHEFE AYATE; - MEGENAGNA
50	AYER TENA - MEGENAGNA
51	BETHEL HOSPITAL - ADDIS KETEMA
52	GERJI - ADDIS KETEMA
53	BOLE MICHAEL - SHIRO MEDA
54	LAFTO - LEGEHAR
55	LEGEHAR - GURARA FERENSAY KELLA
56	SARIS ABO - SHIRO MEDA
57	KARA - LEGEHAR
58	LEGEHALR - ALEM BANK
59	BETHEL HOSPITAL - MENELIK SQUAR
60	DEBR ZEIT - LEGEHAR
61	CHEFE AYATE - LEGEHAR
62	SEBETA - LEGEHAR
63	ADDIS KETEMA - MIKILILAND
64	SIDIST KILO - MEGENAGNA GORF ASWEGAJ
65	ADDIS KETEMA - ALEM BANK
66	ADDIS KETEMA - KARA QORRE
67	LEGEHAR - JEMMO MEKANISSA
68	MENELIK HOSPITAL - TORE HAILOCH
69	LOME MEDA - MERKATO
70	AWARE SQUARE - AYER TENA
71	GERJI - BALCHA HOSPITAL
72	HANA MARIAM - SARI ABO
73	LEGEHAR - RING ROAD VIS WINGET
74	CMC SQUARE - ADDIS KETEMA
75	SIDIST KILO - QERA
76	MEGENAGNA - KALITI
77	AYER TENA - KERA
78	MEGENAGNA - GOFA CONDIMINIUM
79	ARAT KILO - SEMIT CONDIMINIUM
80	SEMEN GEBEYA SQUAR - MEGENAGNA
81	SIDIST KILO -SANSUSI
82	GORO ADEBABAY - BALCHA HOSPITAL
83	CHEFE AYATE - SIDIST KILO
84	KOLFE EFOYTA - LEGEHAR
85	ADDIS KETEMA - HOLETA
86	AYER TENA - KORKI
87	WINGET VIS RING ROAD- AYER TENA
88	ADDIS KETEMA -CHANCHO
89	ADDIS KETEMA -SENDAFA
90	BETEL HOSPITAL - LEGEHAR
91	ADDIS KETEMA - TEJI
92	HANA MARIAM RING ROAD- BALCHA
93	BOLE BULBULA - MEGENANGA
94	PIASSA - MIKILILAND
95	ADDIS KETEMA - ADDIS ALEM
96	MEGENAGNA - GORO SEFERA
97	MEGENAGNA - LEGETAFO MISSION
98	DUKEM - SARIS ABO
99	AYER TENA - ALEM GENA MICHAEL
100	ADDIS KETEMA - JEMO
101	MEGENAGNA - ABA KIRROS Sq.
102	KARA - LEGEHAR
103	JEMO - PIASSA
104	WERKU SEFER - KERA
105	ANFO MEDA - LEGEHAR
106	GORO ADEBABAY - SAMMIT MEGENAGNA
107	SARIS ABO - AKAKI QORQORO
108	ASKO ADDISU SEFER - 18 SQ .MENELIK SQ.
109	SARIS ABO - TULU DIMETU SQUARE
110	SIDIST KILO -TULU DIMETU SQUARE
111	DIRE SOLOLIYA - PIASSA
112	CIRCULAR ROUTE WITH IN RING ROAD 4 TU
113	KALITI TOTAL - FECHE KOYE
114	GELAN CONDIMINIUM - SARIS ABO
115	LEBU MUZIQA BET - MEXICO SQUARE
116	MEKANISSA MICHAEL SQ - JEMO NO_ 2
117	KOTARI CoNDIMINNIUM - MEXICO SQUARE
118	MERKATO - TATEQ KELLA
119	MEGENAGNA - SUMMIT CONDIMINNIUM
120	BURAYU KETA - TORE HILOCH
121	JEMO QEDUS GEBREAL - MEXICO SQUARE
122	ARAT KILO -ENTOTO MARIAM
123	MEGENAGNA - YEKA ABADO
124	TULU DIMTU - MEGENAGNA

2. **ACBSE performance for 2008-2009EC**

Though it was the ultimate intention of this research to duly consider absolute and relative performance measures, ACBSE data is crudely aggregated that only leads to evaluate route based on revenue and passengers per trip. Hence mean monthly passengers per route and total distance traveled are examined.

Passenger per trip

As noted in the literature passenger per trip is one of the easiest ways to explain how many passengers were served in a trip (i.e. from origin to destination and back to origin). Hence using ACBSE data's passenger and trip data for route of interest monthly passengers per trip is computed. The results of the analysis for route of interest shows the average passenger per trip ranges from 74 to 107 for the year 2008 and 2009EC respectively. In contrast to earlier year 2008, the average passengers per trip show a reduction which may not be pin pointed due to data limitations. See Table 5-2 for average monthly passenger per trip for 2008-2009EC.

Table 5-2 Average passenger per trip in the year 2008-2009 EC

Source: based on ACBSE monthly reports

Month	Average passenger/trip for route No					
	10		31		101	
	2008EC	2009EC	2008EC	2009EC	2008EC	2009EC
Hamle	62	80	114	93	114	88
Nehase	92	68	108	90	111	80
Meskerem	91	68	103	90	116	80
Tikimt	85	80	109	105	120	91
Hidar	90	75	107	105	103	83
Tahesas	90	74	106	103	96	87
Tir	95	78	115	89	110	68
Yekatit	93	76	109	93	114	80
Megabit	94	78	99	84	99	69
Miyazia	94	77	106	81	101	70
Ginbot	93	76	113	82	110	78
Sene	81	69	104	81	95	70
Average	88.33	74.92	107.75	91.33	107.42	78.67

Moreover, the present results of passenger per trip implicate that ACBSE buses which carry 30 people seated and 70 standing may offer service near and above their capacities. This may be explained by the high demand of public transportation at low fare still remains the last resort of travel mode by the low-income population of the city. As a result according to (AATA, 2016) ACBSE is serving 367,315 passengers per day with 84% market share of bus transit.

While this is the case, further comparison of all routes with in context of yearly passengers served indicate the route level performance relative with other routes in the system based on revenue is tabulated in Table 5-3. From the results in it is shown that Route 10 have served high passengers and generated more revenue in 2009 than the previous year. However, routes percentile rank of route number 101 and route 31 with in overall routes is notably decreased in 2009 than 2008. See Table 5-3 for passenger and revenue per route per year.

Table 5-3 ACBSE passenger and revenue per trip

Source: based on ACBSE monthly reports

Route number		10	31	101
Passenger/year/trip	2008 EC	1,866,568	4,111,960	2,248,572
	2009 EC	2,592,427	2,343,600	1,361,550
Revenue/year/trip	2008 EC	2,760,617.8	5,525,789	3,842,424.2
	2009 EC	4,148,534	3,173,052	2,352,675
Rank in passenger per year/trip	2008 EC	17	2	13
	2009 EC	2	4	17
Rank in Revenue per year/trip	2008 EC	27	4	13
	2009 EC	6	13	26

Vehicle kilometer

In a related analysis consideration of route length versus performance of the routes in 2008 and 2009 in context of passengers have shown routes with length of less than 13 kilometer gave service to more passengers. However, query of well performed routes in context of revenue generated versus route length showed routes which generate good revenue have a route length which stretch up to 48 kilometers.

These results are likely to be related to the changes in the performance of routes described earlier may be attributed to changes in traversed distance to offer Table 5-4 for total distance traversed to offer service in the routes per year reduces in some of the selected route of interest. Further investigation of ACBSE bus performance reports compiled based on ticket sales data appears to support the assumption that there may be situations allocated buses may not provide service or assigned to another route which makes it impossible to pinpoint in which route buses have operated. Despite the known 14 hours of operation hours of ACBSE, query of vehicle hours driven per year is not possible since data record framework of ACBSE exclude the said parameter.

Table 5-4 Total distance traversed in selected routes
Source: own compilation based on ACBSE data

Route number		10	31	101
Total Distance (Km)	2008 EC	261,683.5	282250.8	251,532
	2009 EC	440,613.8	190342.8	206,616
Average distance (Km)		351,148.6	236,296.8	229,074.0

Average trip per route per day

Trip/Month	Route No					
	10		31		101	
	2008EC	2009EC	2008EC	2009EC	2008EC	2009EC
Hamle	1,676	2,702	3,389	2,810	1,780	1,952
Nehase	2,163	3,067	3,832	3,133	1,866	1,954
Meskerem	1,599	3,067	3,728	3,133	1,586	1,954
Tikimt	1,869	2,208	3,503	1,918	1,811	1,313
Hidar	1,668	2,591	3,433	1,836	1,925	1,303
Tahesas	1,505	2,207	3,388	1,589	2,055	1,031
Tir	1,397	2,890	3,271	1,894	1,626	1,394
Yekatit	1,589	2,757	2,973	1,664	1,660	1,248
Megabit	1,771	3,074	3,001	1,966	1,842	1,348
Miyazia	1,493	3,378	2,692	2,013	1,594	1,335
Ginbot	1,326	3,083	2,352	1,961	1,555	1,116
Sene	2,549	3,670	2,580	1,805	1,661	1,270
Total	20,605	34,694	38,142	25,722	20,961	17,218
Average trips per day	72	120	132	89	73	60
	96		111		66	

Notes

1) The average number of operating days per year is taken as 288 days.
2) ACBSE baseline calendar opens in Hamle and closes in Sene.

Monthly Passenger per trip per route for 2008 & 2009

Month	Variable	Route No					
		10		31		101	
	Year	2008EC	2009EC	2008EC	2009EC	2008EC	2009EC
Hamle	Passengers	158,106	217,013	386,820	260,900	203,272	171,807
	trip	1,676	2,702	3,389	2,810	1,780	1,952
	Passenger/trip	62	80	114	93	114	88
Nehase	Passengers	198,604	209,596	414,795	283,361	206,853	157,198
	trip	2,163	3,067	3,832	3,133	1,866	1,954
	Passenger/trip	92	68	108	90	111	80
Meskerem	Passengers	146,294	209,596	383,666	283,361	184,510	157,198
	trip	1,599	3,067	3,728	3,133	1,586	1,954
	Passenger/trip	91	68	103	90	116	80
Tikimt	Passengers	158,425	177,380	382,156	201,489	216,854	119,443
	trip	1,869	2,208	3,503	1,918	1,811	1,313
	Passenger/trip	85	80	109	105	120	91
Hidar	Passengers	150,299	194,202	368,817	192,394	199,143	108,742
	trip	1,668	2,591	3,433	1,836	1,925	1,303
	Passenger/trip	90	75	107	105	103	83
Tahesas	Passengers	135,285	163,101	360,458	164,441	197,240	89,415
	trip	1,505	2,207	3,388	1,589	2,055	1,031
	Passenger/trip	90	74	106	103	96	87
Tir	Passengers	132,917	225,628	377,542	167,674	179,257	94,544
	trip	1,397	2,890	3,271	1,894	1,626	1,394
	Passenger/trip	95	78	115	89	110	68
Yekatit	Passengers	147,309	209,308	322,757	154,045	189,812	100,028
	trip	1,589	2,757	2,973	1,664	1,660	1,248
	Passenger/trip	93	76	109	93	114	80
Megabit	Passengers	167,264	240,508	296,535	165,368	182,025	93,459
	trip	1,771	3,074	3,001	1,966	1,842	1,348
	Passenger/trip	94	78	99	84	99	69
Miyazia	Passengers	140,695	258,532	284,502	163,839	160,675	93,640
	trip	1,493	3,378	2,692	2,013	1,594	1,335
	Passenger/trip	94	77	106	81	101	70
Ginbot	Passengers	123,910	235,614	265,702	161,372	171,715	87,326
	trip	1,326	3,083	2,352	1,961	1,555	1,116
	Passenger/trip	93	76	113	82	110	78
Sene	Passengers	207,460	251,949	268,210	145,356	157,216	88,750
	trip	2,549	3,670	2,580	1,805	1,661	1,270
	Passenger/trip	81	69	104	81	95	70

Appendix B. Public Opinion Survey questioner and response

1. Survey questioner to users

በአዲስ አበባ ዩኒቨርስቲ አዲስ አበባ ቴክኖሎጂ ኢንስቲትዩት (5 ኪሎ) የመንገድ እና ትራንስፖርት ኢንጅነሪንግ ትምህርት ክፍል የምሣር ተማሪ ስሆን በአዲስ አበባ የህዝብ የሕዝብ ባስ ትራንስፖርት ላይ ጥናት እያደረኩ ስሆን ፤ የጥናቱ ዓላማ ኢኮኖሚዳሰሳ በማከናወን የመፍትሔ አቅጣጫዎችን መጠቆም ነው፡ ፡ በዚህም መሰረት የምትሰጡት መልስ ለነገዋ አዲስ አባባ የትራንስፖርት አገልግሎት መሻሻል ከፍተኛ አስተዋፅኦ ያለውእና በሚስጥራዊነት የሚጠበቅ መሆኑን ተገንዝባችሁ ሁሉንም ጥያቄዎች እንድትመልሱ በትህትና እጠይቃለሁ፡ ፡

1. ጾታ _____(ወንድ/ሴት) ፤ እድሜ______ ፤ ስራዎት ምንድን ነው?_____ ___(ሹፌር ፣ነጋዴ፣ ቢሮ ...)?
2. በአብዛኛው ጊዜ የሚጠቀሙት የትራንስፖርት አይነት የቱ ነው?
   በእግር ☐ ሚኒባ☐ አል☐ስ ባስ ☐ ሀይ☐ ባስ ☐ሸገር ባስ አንበሳ ባስ ሌላ _____:
3. የሚጠቀሙትን የትራንስፖርት ዓይነት የመረጡበት ምክንያት ምንድን ነው?
   አነስተኛ ☐ ተመጣጣ☐ዋጋ አማራጭ☐ት ስፍ☐ት
   የጉዞ ምቾ☐ በቅርበ☐መገኘት ሌላ __________
4. በአብዛኛው ጊዜ ለሚጠቀሙት ትራንስፖርት አገልግሎት በቀን ስንት ብር ያወጣሉ?
   < 10 ☐ ከ 10 -15 ☐ ከ 16 - 20 ☐ ሌላ _________
5. የትራንስፖርት አገልግሎት ለማግኘት ምን ያህል በእግር ይጓዛሉ?
   በሠዓት(ደቂቃ) ከ 5-10 ደቂቃ ☐ ከ 11-20ደቂቃ ☐ ከ 21-30 ደቂ☐ ሌላ ___________________ ☐ ☐ ☐

   በርቀት(ሜትር) ከ 300ሜበታች ከ 300-600ሜ ከ 600-900ሜ ሌላ ___
   በአማካይ ምን ያህል ደቂቃ/ርቀት ለመጓዝ ፍቃደኛ ነዎት ___________________ __________
6. ለጥያቄ ቁ.2 መልስዎት አውቶብስ ከሆነ በሳምንት ለምን ያህል ጊዜ ይሳፈራሉ /ይጠቀማሉ?
   ከ 1-6 ☐ ከ 6-12 ☐ ከ 12-20 ☐ ሌላ _________
7. በሕዝብ አውቶብስ ትራንስፖርት ምን ዓይነት ሰዎች ይጠቀማሉ ብለውያስባሉ?
   አነስተኛ ገቢ ያላ☐ት አማራጭ☐ላቸው ተ☐ዎች ሌላ ______________

8. አውቶብስ በሚጠብቁበት ቦታ እና በሚሳፈሩበት ሰዓት በአገልግሎት አሰጣጡን እንዴት ያዩታል?

በጣም ጥሩ ጥሩ ፍትሀዊ ደስተኛ አይደለሁም ሌላ ________

9. የሕዝብ ባስ ትራንስፖርት አገልግሎት የሚጠቀሙ ከሆነ ችግሮቹን በየደረጃው ቢጠቅሱ

ምክንያት	1	2	3	4	5	6
የአውቶብስ መጠበቂያ መጠለያ አለመኖር						
የአውቶብስ መጠበቂያ ቦታ ንፅህና						
ወቅታዊ የአገልግሎት መረጃ አለመኖሩ						
ሌላ፡						

10. በአውቶብስ ትራንስፖርት አሰጣጥ ምክንያት በአማካይ ያጡት ነገር ________

(ሰዓት፣ ገንዘብ፣ ....)

11. የአውቶብስ ትራንስፖርት አገልግሎት አሰጣጥን ለማሻሻል ምን መፍትሔ ይሆናል ብለው ያስባሉ?

ለትብብርዎ እናመሰግናለን መልካም ጊዜ!

2. Public survey response

Table 5-5 Respondents general information

General information		Frequency	Percent	Valid Percent	Cumulative Percent
Sex	Male	117	60.0	60.0	60.0
	Female	78	40.0	40.0	100.0
	Total	195	100.0	100.0	
Age	17-30	128	73.6	73.6	73.6
	30-50	34	19.5	19.5	93.1
	>50	12	6.9	6.9	100
	Total	174	100	100	
Job Type	Other	9	4.6	4.6	4.6
	Driver	2	1.0	1.0	5.6
	Merchant	33	16.9	16.9	22.6
	Office worker	80	41.0	41.0	63.6
	Field employee	5	2.6	2.6	66.2
	Other	59	30.3	30.3	96.4
	Office and Field	7	3.6	3.6	100.0
	Total	195	100.0	100.0	
Transit mode		3	1.5	1.5	1.5
	Walking	7	3.6	3.6	5.1
	Minibus	121	62.1	62.1	67.2
	Alliance Bus	9	4.6	4.6	71.8
	Higer Bus	16	8.2	8.2	80.0
	Sheger Bus	12	6.2	6.2	86.2
	Anbesa Bus	18	9.2	9.2	95.4
	Other	9	4.6	4.6	100.0
	Total	195	100.0	100.0	
Reason for modal choice	Low fare	24	12.3	12.3	14.4
	Fair price	22	11.3	11.3	25.6
	No alternatives	27	13.8	13.8	39.5
	Speed	50	25.6	25.6	65.1
	Travel comfort	19	9.7	9.7	74.9
	Easy to access	44	22.6	22.6	97.4
	Other	5	2.5	2.5	100.0
	Total	195	100.0	100.0	
Transit access distance by walking	>300m	53	72	72	72
	300 – 600m	11	15	15	86
	>600	10	14	14	100
	Total	74	100	100	
Transit access time by walking	5 – 10 minutes	101	59	59	59
	11 – 20 minutes	42	24	24	83
	> 20 minutes	29	17	17	100
	Total	172	100	100	

Table 5-6 Modal choice cross tabulation

Reason for modal choice		Low fare	Fair price	No alternate	Speed	Travel comfort	Easy to access	Other	Total
Age	17-24	5	4	7	13	7	6	0	42
	25-30	8	10	11	25	7	23	1	86
	31-40	3	2	4	3	4	6	1	23
	41-50	3	0	2	1	1	2	2	11
	51-60	2	2	1	1	0	1	0	7
	>60	2	2	0	0	0	1	0	5
	Total	23	20	25	43	19	39	4	174
Sex	Male	13	12	15	30	11	30	1	117
	Female	11	10	12	20	8	14	2	78
	Total	24	22	27	50	19	44	3	195
Daily transit cost (birr)	Below ten	13	5	6	17	7	21	1	70
	10 -15	4	10	8	21	5	15	1	65
	16 -20	6	5	8	9	4	5	1	39
	Other	0	2	5	2	2	3	1	15
	30	1	0	0	0	0	0	0	1
	Total	24	22	27	49	18	44	4	190
Job	Merchant	3	8	4	5	2	11	0	33
	Office	10	6	8	23	11	17	4	80
	Field	0	1	0	0	1	5	0	7
	Office& Field	0	2	1	0	1	2	0	6
	Other	11	5	14	22	4	9	0	67
	Total	24	22	27	50	19	44	4	195

Table 5-7 Daily transportation cost vs. age cross tabulation

Description		Daily transportation cost (Birr)				
		>10	10 -15 Birr	16 -20 Birr	Other	Total
Age	17-24	16	15	7	4	42
	25-30	30	31	18	6	85
	31-40	7	6	7	2	22
	41-50	5	3	2	1	11
	51-60	3	3	1	-	7
	>60	3	2	-	-	5
Sex	Male	34	38	28	13	113
	Female	36	27	11	3	77
	Total	70	65	39	16	190

Table 5-8 Transport access walking distance

Sex	Trans access walking distance (meters)				Total
	>300	300 - 600	600 - 900	Other	
Male	33	10	2	5	50
Female	20	1	2	1	24
Total	53	11	4	6	74

Table 5-9 walking time to access transportation

Sex	Trans access walking (minutes)				Total
	5 - 10	11 - 20	21 - 30	Other	
Male	59	25	12	7	103
Female	42	17	9	1	69
Total	101	42	21	8	172

Table 5-10 Transport Mode Vs. Walking distance

Walking distance(m)	Mostly used Transport mode							Tota l
	Walkin g	Minibu s	Allianc e Bus	Hige r Bus	Shege r Bus	Anbes a Bus	Othe r	
< 300	1	32	3	4	5	7	1	53
300 - 600	0	9	1	0	0	1	0	11
600 - 900	0	2	1	1	0	0	0	4
Other	1	1	0	2	0	1	1	6
Total	2	44	5	7	5	9	2	74

Table 5-11 Frequency of using bus transit

Sex	Frequency of using bus transit per week				Total
	1-6	6-12	12-20	Other	
Male	17	7	3	1	28
Female	18	9	1	3	31
Total	35	16	4	4	59

Table 5-12 Perceived users of public bus transit

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
People with low income	119	61.0	69.2	69.2
People with no alternatives	38	19.5	22.1	91.3
Students	9	4.6	5.2	96.5
Other	6	3.1	3.5	100.0
Total	172	88.2	100.0	

Table 5-13 Preferred walking distance and time to access transit

Description		Frequency	Percent	Valid Percent	Cumulative Percent
Willing walking distance	within 300m	10	5.1	50.0	195.0
	300-600	8	4.1	40.0	380.0
	above 600	2	1	10	195
	Total	20	10.3	100.0	
	Missing	175	89.7		
Willing walking time	Within 5 minutes	10	5	13	16
	5-10 minutes	31	16	39	87
	10-15 minutes	26	13	33	94
	15-20 minutes	18	9	23	116
	20-30 minutes	31	16	39	156
	above 30 minutes	28	14	35	380
	Total	79	40.5	100.0	
	Missing	116	59.5		

Table 5-14 Actual Vs. Preferred walking distance

Willing walking distance	Actual walking distance (meters)			Total
	Less than 300	300 - 600	Other	
within 300m	6	3	0	9
300-600	4	1	0	5
above 600	0	0	2	2
Total	10	4	2	16

Table 5-15 Trasnport acess walking distance Vs Prefernce

Trans access walking	Willing trans walking time (Minutes)				
	5-10m	11-20m	21-30m	other	total
05 - 10 Minutes	14	12	9	1	36
11 - 20 Minutes	11	3	4	3	21
21 - 30 Minutes	7	1	5	1	14
above 30	1	0	2	1	4
Total	33	16	20	6	75

Table 5-16 Frequency of use vs. ratting and problems cross tabulation

Description		Frequency of using bus transit per week				
		1-6 times	6-12 times	12-20 times	Other	Total
Rating for transit waiting environment and riding process	Very Good	5	4	0	0	9
	Good	10	1	0	0	11
	Fair	6	4	1	1	12
	Not satisfied	13	6	3	3	25
	Total	35	16	4	4	59
Primary problems of bus trans first	Shelter unavailable	17	11	1	0	29
	Poor waiting env't: sanitation	7	2	1	1	11
	No service information	5	2	0	0	7
	Loading excess passengers	1	0	0	0	1
	Poor schedule reliability	2	0	0	0	2
	Total	35	16	4	4	59
Secondary problems of bus transit	Shelter unavailable	9	2	0	0	11
	Poor waiting env't: sanitation	3	3	0	0	6
	No service information	4	2	0	0	6
	Total	35	16	4	4	59
Tertiary problems of bus trans	Shelter unavailable	4	1	2	0	7
	Poor waiting env't: sanitation	4	1	0	0	5
	No service information	7	2	0	0	9
	No advance	1	0	0	0	1
	Total	35	16	4	4	59
Perceived users	People with low income	26	8	1	-	35
	who don't have alternatives	6	6	2	2	16
	Students	2	1	1	1	5
	Other	1	1	0	1	3
	Total	35	16	4	4	59
Things lost	Time	21	7	3	1	32
	Money	3	2	0	1	6
	Time and money	3	4	1	0	8
	Other	8	3	0	2	13
	Total	35	16	4	4	59

Table 5-17 Things lost

Things lost	Frequency	Percent	Valid Percent	Cumulative Percent
	94	48.2	48.2	48.2
Time	71	36.4	36.4	84.6
Money	8	4.1	4.1	88.7
Comfort	3	1.5	1.5	90.3
Health	2	1.0	1.0	91.3
Time & Money	13	6.7	6.7	97.9
Time and Robed money	1	.5	.5	98.5
Time, Comfort	1	.5	.5	99.0
Time, Money & assets	1	.5	.5	99.5
Time, Money, Comfort	1	.5	.5	100.0
Total	195	100.0	100.0	

Table 5-18 Transportation access reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.043	0.936	4

Appendix C. Transit expert opinion survey questioner and response

1. Survey Questionnaire to Transport Professionals

I am conducting a research focused on Bus Stop Design in Addis Ababa City for the fulfilment of MSc. degree in Road and Transport Engineering which necessitated an assessment of relative importance of criteria's for locating bus stations should be judged from expert's opinion using preference scales. I appreciate your cooperation for taking the time and effort to respond.

Organization: ________________________ Position:________________

Research title: Evaluating the Economic Impact of Bus Stop design in Addis Ababa City

For this particular research to identify suitable sites for bus stop locations the following criterions are selected for pairwise comparisons using 1 to 9 scales:

- Slope (C1)
- Vicinity to rail station (C2)
- Far from traffic accident black spots (C3)
- Land use (C4)

Circle the values table below in evaluating the relative importance

Factor	Factor weighting score																	Factor
	More importance than								Equal	Less importance than								
C1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
C2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
C3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
C4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1

Further the criterions are classified into sub-criteria's as follows for pairwise comparisons ranging from more suitable (5) to less suitable being (1) as follows:

- Slope: <6%, 6-10%, >10%
- Vicinity to rail station: <100, 100-150, 150-200
- Far from traffic accident black spots: <100, 100-150, 150-200
- Land-use: Residential, Industrial, Commercial, Educational, Public Gatherings

Kindly circle a score to these sub-criteria by comparing pair-wisely according to the 5-point scale given below in Table 5-19:

Table 5-19 Sub criteria score

Factor	Sub criteria	Factor weighting score				
		More suitable	Highly suitable	Moderately suitable	Suitable	Less suitable
Slope	<6%	5	4	3	2	1
	6-10%	5	4	3	2	1
	>10%	5	4	3	2	1
Vicinity to rail stations (m)	<100	5	4	3	2	1
	100-150	5	4	3	2	1
	150-200	5	4	3	2	1
Far from accident black spots	<100	5	4	3	2	1
	100-150	5	4	3	2	1
	150-200	5	4	3	2	1
Land use	Residential	5	4	3	2	1
	Industrial	5	4	3	2	1
	Commercial	5	4	3	2	1
	Educational	5	4	3	2	1
	Public Gatherings	5	4	3	2	1

2. Transport Experts response

Factors	C1	C2	C3	C4	Cumulative normalized score	Priority vector	Consistency measure
C1	0.46	0.46	0.46	0.46	1.84	0.46	4.04
C2	0.08	0.08	0.08	0.08	0.32	0.08	3.86
C3	0.23	0.23	0.23	0.23	0.92	0.23	4.04
C4	0.23	0.23	0.23	0.23	0.92	0.23	4.04
Total	1.00	1.00	1.00	1.00	4.00	1.00	15.98
average eigenvalue of the judgement matrix						λmax	4.00
Degree of consistency						CI	0.00
RI is provided by AHP						RI	0.90
Saaty suggests CR should be less than 0.1 so as this case, the results confirm consistency of respondents.						CR	0.000

Factor	Sub criteria	Mean score
Slope	<6%	5.00
	6-10%	3.00
	>10%	1.00
Vicinity to rail stations (m)	<100	5.00
	100-150	4.00
	150-200	3.00
Far from accident black spots	<100	2.00
	100-150	3.00
	150-200	4.00
Land use	Residential	5.00
	Industrial	1.00
	Commercial	3.00
	Educational	3.00
	Public Gatherings	3.00

Appendix D. HDM 4 Outputs

Route	Quantities in grams per 1000 Vehicle-kilometers					
	Hydrocarbon (HC)	Carbon Monoxide (CO)	Nitrous oxide (NO_x)	Sulphur dioxide (SO_2)	Carbon Dioxide (CO_2)	Particulates (Par)
101	5.97	10.76	20.46	0.76	1517.56	0.3
31	3.06	5.53	10.55	0.39	782.88	0.16
10	7.59	13.7	26.08	0.98	1933.81	0.39

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Annual Emissions Summary

Study Name: **ACBSE - Route101**
Run Date: **10-07-2018**

Section: Ayat-Tafo
Alternative: Work Programming

Sect ID: Route101Ayat-Tafo Road Class: Primary or Trunk
Length: 3.07m Width: 12.00m Rise+Fall: 10.00m/km Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	1.68	3.02	5.72	0.21	423.95	0.08	0.00
2019	1.68	3.03	5.76	0.21	426.87	0.08	0.00

Section: Megnegna-Ayat
Alternative: Work Programming

Sect ID: Route101MA Road Class: Primary or Trunk
Length: 8.20m Width: 12.00m Rise+Fall: 10.00m/km Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	4.29	7.74	14.74	0.55	1,093.61	0.22	0.00
2019	4.29	7.77	14.83	0.55	1,101.27	0.22	0.00

HDM-4 0.0

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Annual Emissions Summary

Study Name: **ACBSE - Route 31**
Run Date: **10-07-2018**

Section: Arat killo - Grand Palace - Hilton Hotel-ECA
Alternative: Work Programming

Sect ID: Route31A-GP-H-ECA Road Class: Primary or Trunk
Length: 2.48m Width: 40.00m Rise+Fall: 10.00m/km Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	1.30	2.35	4.49	0.17	333.05	0.07	0.00
2019	1.30	2.36	4.51	0.17	335.38	0.07	0.00

Section: ECA- Mesquel square-Lagare
Alternative: Work Programming

Sect ID: Route31ECA-M-L Road Class: Primary or Trunk
Length: 1.37m Width: 20.00m Rise+Fall: 10.00m/km Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	0.72	1.30	2.48	0.09	184.09	0.04	0.00
2019	0.72	1.30	2.49	0.09	185.38	0.04	0.00

Section: Shiromeda - Arat killo
Alternative: Work Programming

Sect ID: Route31S-A Road Class: Primary or Trunk
Length: 1.98m Width: 16.00m Rise+Fall: 10.00m/km Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	1.04	1.88	3.58	0.13	265.74	0.05	0.00
2019	1.04	1.88	3.60	0.14	267.60	0.05	0.00

HDM-4 0.0

HDM-4 Annual Emissions Summary

HIGHWAY DEVELOPMENT & MANAGEMENT

Study Name: **ACBSE - Route 10**
Run Date: **10-07-2018**

Section: AratKillo - Piassa
Alternative: Work Programming

Sect ID: Route10 A-P   Road Class: Secondary or Main
Length: 1.72m   Width: 18.00m   Rise+Fall: 10.00m/km   Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	0.90	1.64	3.13	0.12	232.38	0.05	0.00
2019	0.90	1.64	3.15	0.12	234.01	0.05	0.00

Section: Kara-Megenegnga
Alternative: Work Programming

Sect ID: Route10K-M   Road Class: Primary or Trunk
Length: 7.18m   Width: 18.00m   Rise+Fall: 10.00m/km   Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	3.96	7.14	13.59	0.51	1,007.46	0.20	0.00
2019	3.96	7.17	13.66	0.51	1,014.42	0.20	0.00

Section: Megengna-AratKillo
Alternative: Work Programming

Sect ID: Route10MA   Road Class: Primary or Trunk
Length: 5.20m   Width: 30.00m   Rise+Fall: 10.00m/km   Curvature: 15.00 deg/km

Year	Quantities in grammes per 1000 Vehicle-kilometres						
	Hydrocarbon HC	Carbon monoxide CO	Nitrous oxide NO_X	Sulphur dioxide SO_2	Carbon dioxide CO_2	Particulates Par	Lead Pb
2018	2.73	4.92	9.36	0.35	693.97	0.14	0.00
2019	2.72	4.93	9.41	0.35	698.83	0.14	0.00

HDM-4 0.0

The generated reports of road user effects is shown as follows in the form of per-kilometer operating costs of ACBSE bus in Addis Ababa is estimated at $1.09/km.

HDM - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

MT Annual Average Costs per vehicle-km

Study Name: **ACBSE - Route101**
Run Date: **10-07-2018**
Currency: **US Dollar**

Section: Ayat-Tafo
Alternative: Work Programming

Sect ID: Route101Ayat-Tafo   Road Class: Primary or Trunk
Length: 3.07 km   Width: 12.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	41.37	0.599	1.546	2.145	1.840	4.740	6.580
2019	41.37	0.666	1.546	2.212	2.040	4.740	6.780

Section: Megnegna-Ayat
Alternative: Work Programming

Sect ID: Route101MA   Road Class: Primary or Trunk
Length: 8.20 km   Width: 12.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	43.22	0.585	1.479	2.064	4.800	12.120	16.920
2019	43.21	0.652	1.479	2.130	5.340	12.130	17.470

HDM-4 0.0

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

MT Annual Average Costs per vehicle-km

Study Name: **ACBSE - Route 31**
Run Date: **10-07-2018**
Currency: **US Dollar**

Section: Arat killo - Grand Palace - Hilton Hotel-ECA
Alternative: Work Programming

Sect ID: Route31A-GP-H-ECA   Road Class: Primary or Trunk
Length: 2.48 km   Width: 40.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	43.22	0.636	1.479	2.115	1.580	3.670	5.250
2019	43.21	0.696	1.479	2.175	1.730	3.670	5.400

Section: ECA- Mesquel square-Lagare
Alternative: Work Programming

Sect ID: Route31ECA-M-L   Road Class: Primary or Trunk
Length: 1.37 km   Width: 20.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	43.22	0.636	1.479	2.115	0.870	2.030	2.900
2019	43.21	0.696	1.479	2.175	0.960	2.030	2.990

Section: Shiromeda - Arat killo
Alternative: Work Programming

Sect ID: Route31S-A   Road Class: Primary or Trunk
Length: 1.98 km   Width: 16.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	43.22	0.636	1.479	2.115	1.260	2.930	4.190
2019	43.21	0.696	1.479	2.175	1.380	2.930	4.310

HDM-4 0.0

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

MT Annual Average Costs per vehicle-km

Study Name: **ACBSE - Route 10**
Run Date: **10-07-2018**
Currency: **US Dollar**

Section: AratKillo - Piassa
Alternative: Work Programming

Sect ID: Route10 A-P   Road Class: Secondary or Main
Length: 1.72 km   Width: 18.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	43.21	0.682	1.479	2.161	1.180	2.550	3.730
2019	43.20	0.737	1.479	2.216	1.270	2.550	3.820

Section: Kara-Megenegnga
Alternative: Work Programming

Sect ID: Route10K-M   Road Class: Primary or Trunk
Length: 7.18 km   Width: 18.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	40.99	0.700	1.560	2.260	5.020	11.190	16.210
2019	40.98	0.755	1.560	2.315	5.410	11.200	16.610

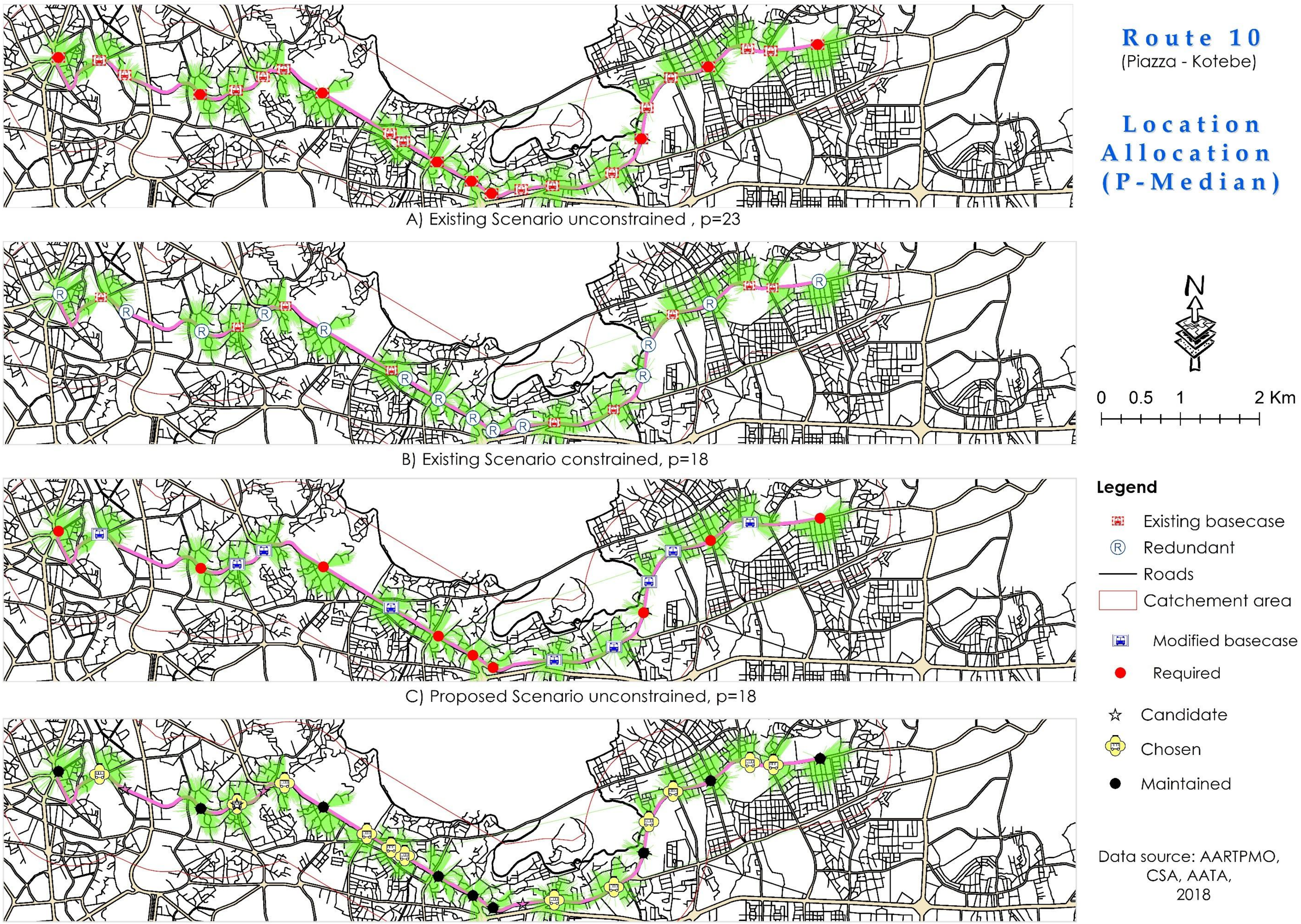
Section: Megengna-AratKillo
Alternative: Work Programming

Sect ID: Route10MA   Road Class: Primary or Trunk
Length: 5.20 km   Width: 30.00 m   Rise+Fall: 10.00 m/km   Curvature: 15.00 deg/km

Year	Average Speed (km/hr)	Annual Average Cost per Vehicle-kilometre			Annual Average Cost per Vehicle-trip		
		VOC	Travel Time	Road User Cost	VOC	Travel Time	Road User Cost
Bus-ACBSE							
2018	43.17	0.585	1.480	2.066	3.050	7.700	10.750
2019	43.17	0.652	1.480	2.132	3.390	7.700	11.090

HDM-4 0.0

Appendix E. Maps



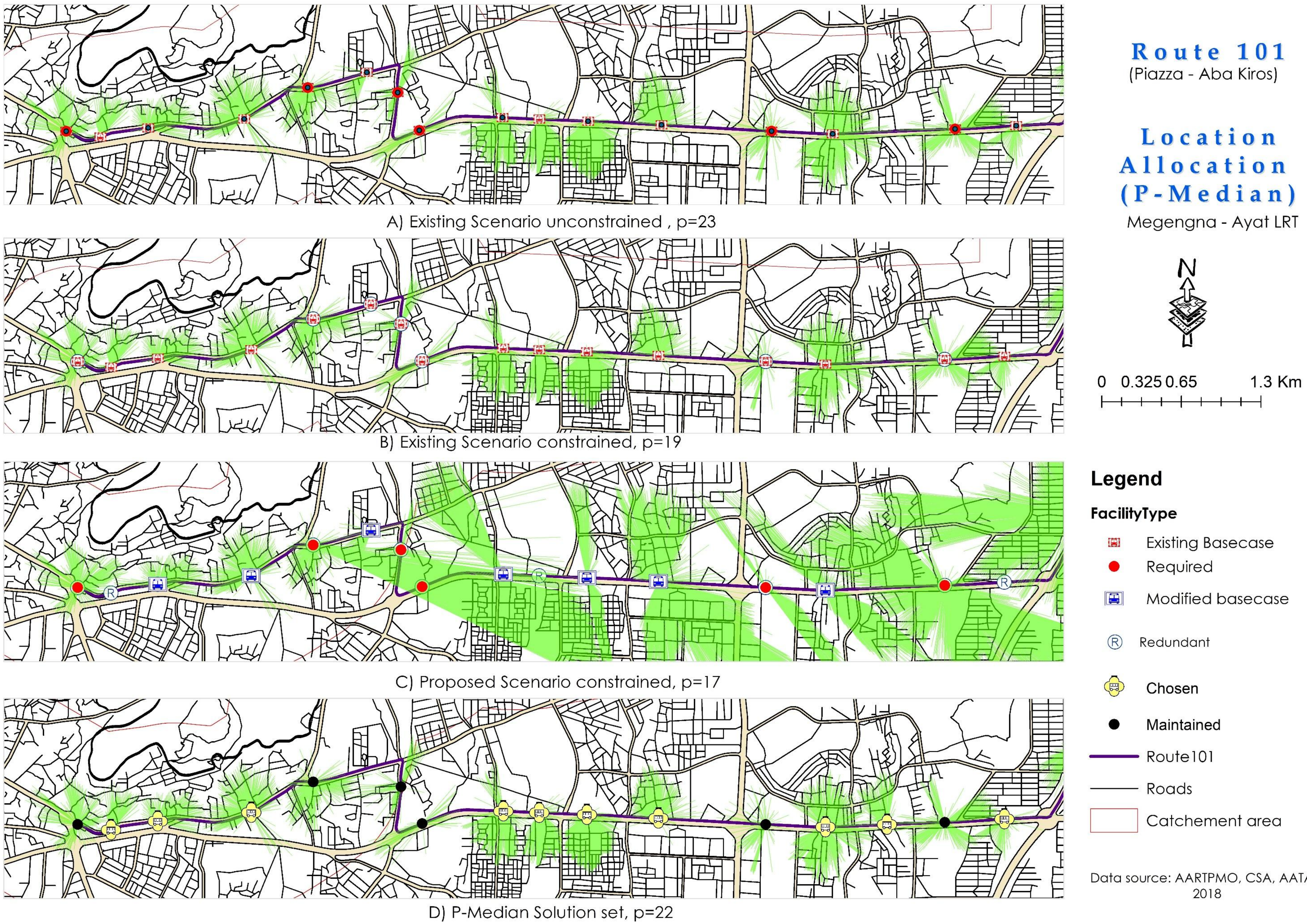
A) Existing Scenario unconstrained , p=23

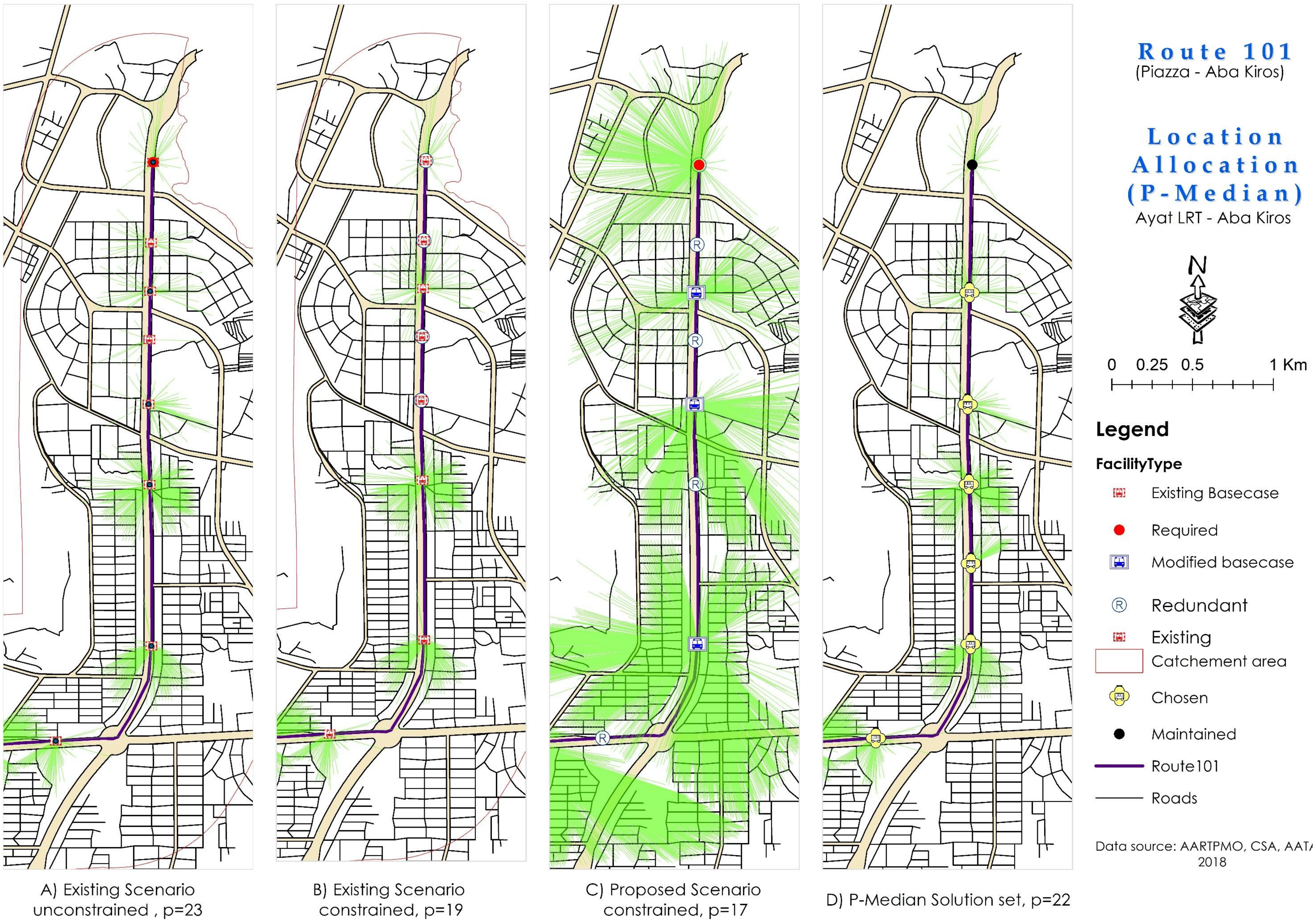
B) Existing Scenario constrained, p=18

C) Proposed Scenario unconstrained, p=18

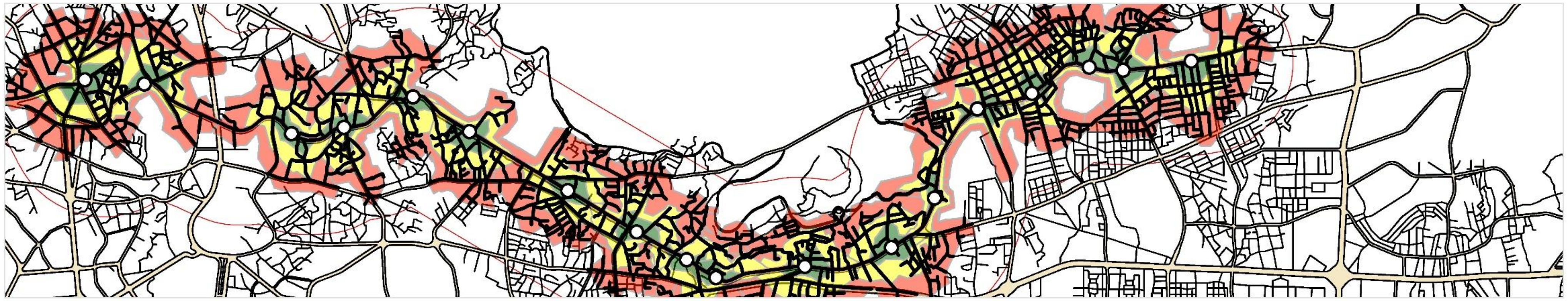
D) P-Median Solution set, p=21


Route 31
(La Gare - Sheromeda)
Location
Allocation
(P-Median)
N
0 0.5 1 2 Km
Legend
Modified basecase
Required
Existing Basecase
Maintained
Chosen
Reachable parcels
Redundant
Route31
Catchement area
Roads
Notes:
A) Existing Scenario unconstrained , p=12
B) Existing Scenario constrained, p=11
C) Proposed Scenario unconstrained, p=11
D) P-Median Solution set, p=14
Data source: AARTPMO, CSA, AATA, 2018


A) Existing Scenario unconstrained , p=23
B) Existing Scenario constrained, p=19
C) Proposed Scenario constrained, p=17
D) P-Median Solution set, p=22
Route 101
(Piazza - Aba Kiros)
Location Allocation (P-Median)
Megengna - Ayat LRT
N
0 0.325 0.65 1.3 Km
Legend
FacilityType
Existing Basecase
Required
Modified basecase
Redundant
Chosen
Maintained
Route101
Roads
Catchement area
Data source: AARTPMO, CSA, AATA, 2018


Route 101
(Piazza - Aba Kiros)
Location Allocation (P-Median)
Ayat LRT - Aba Kiros
N
0 0.25 0.5 1 Km
Legend
FacilityType
Existing Basecase
Required
Modified basecase
Redundant
Existing
Catchement area
Chosen
Maintained
Route101
Roads
Data source: AARTPMO, CSA, AAT/
2018
A) Existing Scenario unconstrained , p=23
B) Existing Scenario constrained, p=19
C) Proposed Scenario constrained, p=17
D) P-Median Solution set, p=22

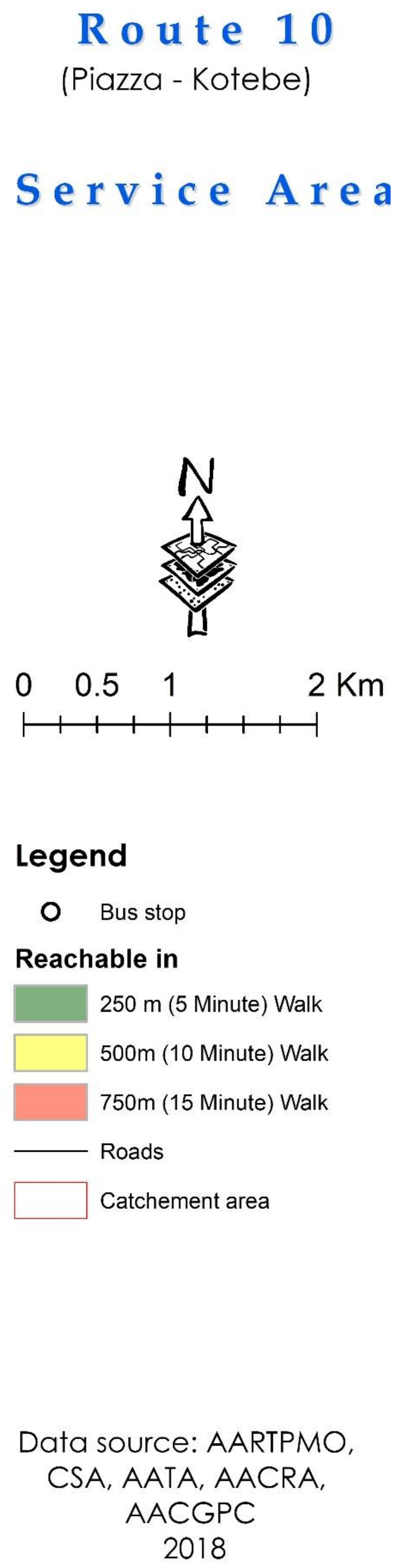
A) Existing Scenario unconstrained , p=23

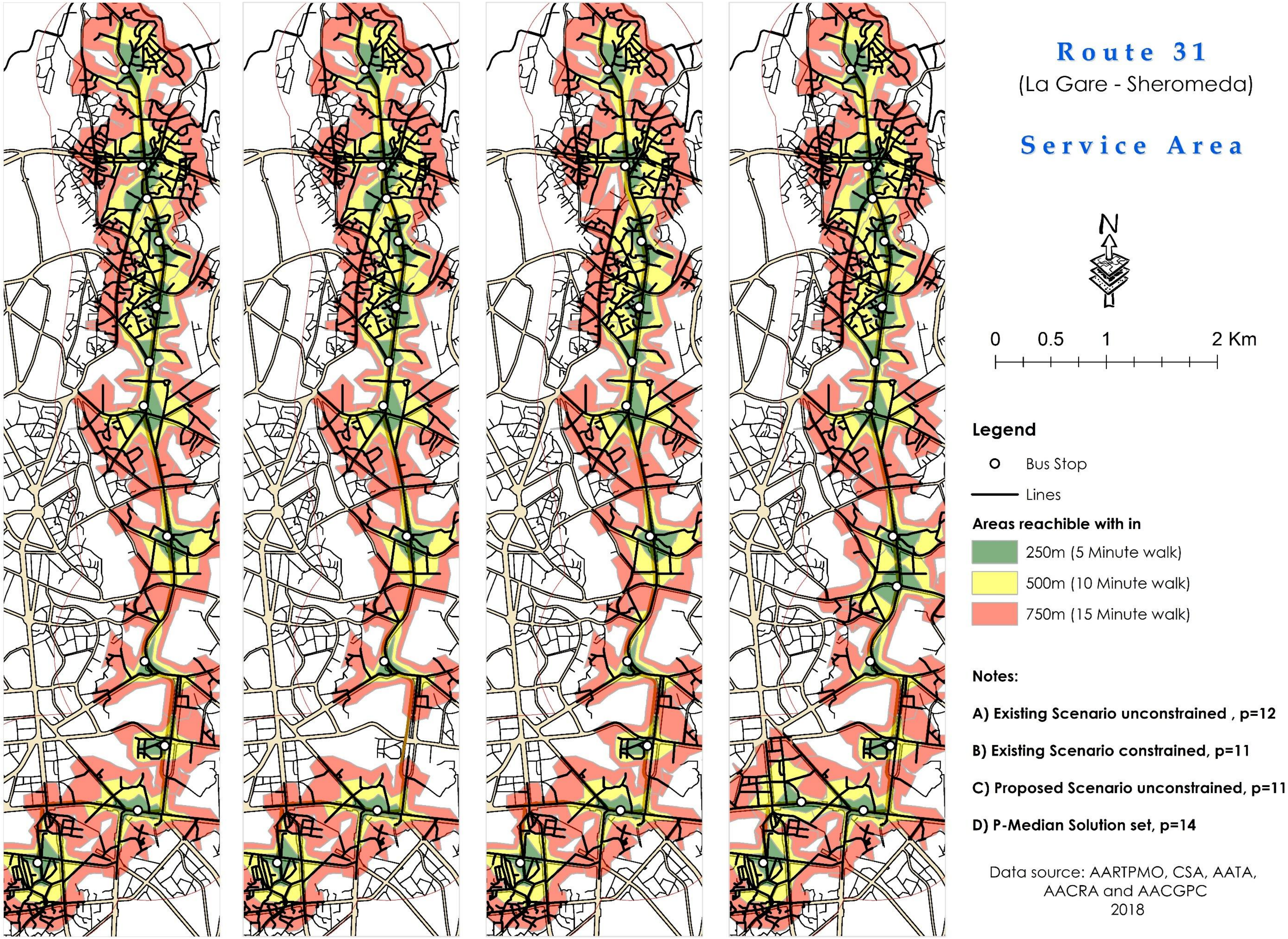


B) Existing Scenario constrained, p=18

C) Proposed Scenario unconstrained, p=18

D) P-Median Solution set, p=21



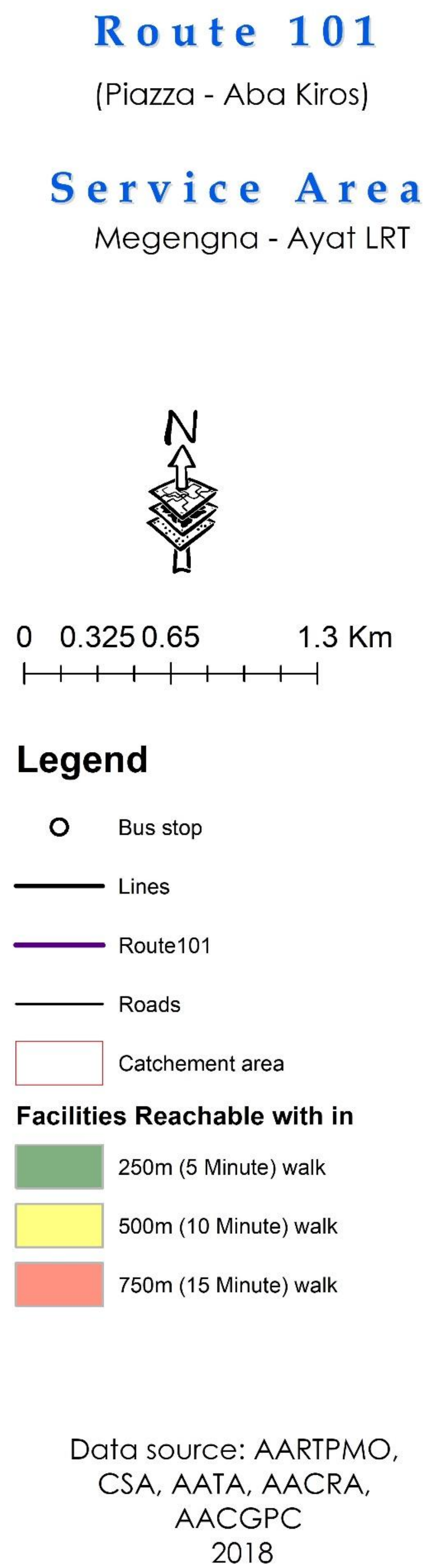

Route 31
(La Gare - Sheromeda)
Service Area
N
0 0.5 1 2 Km
Legend
Bus Stop
Lines
Areas reachible with in
250m (5 Minute walk)
500m (10 Minute walk)
750m (15 Minute walk)
Notes:
A) Existing Scenario unconstrained , p=12
B) Existing Scenario constrained, p=11
C) Proposed Scenario unconstrained, p=11
D) P-Median Solution set, p=14
Data source: AARTPMO, CSA, AATA,
AACRA and AACGPC
2018

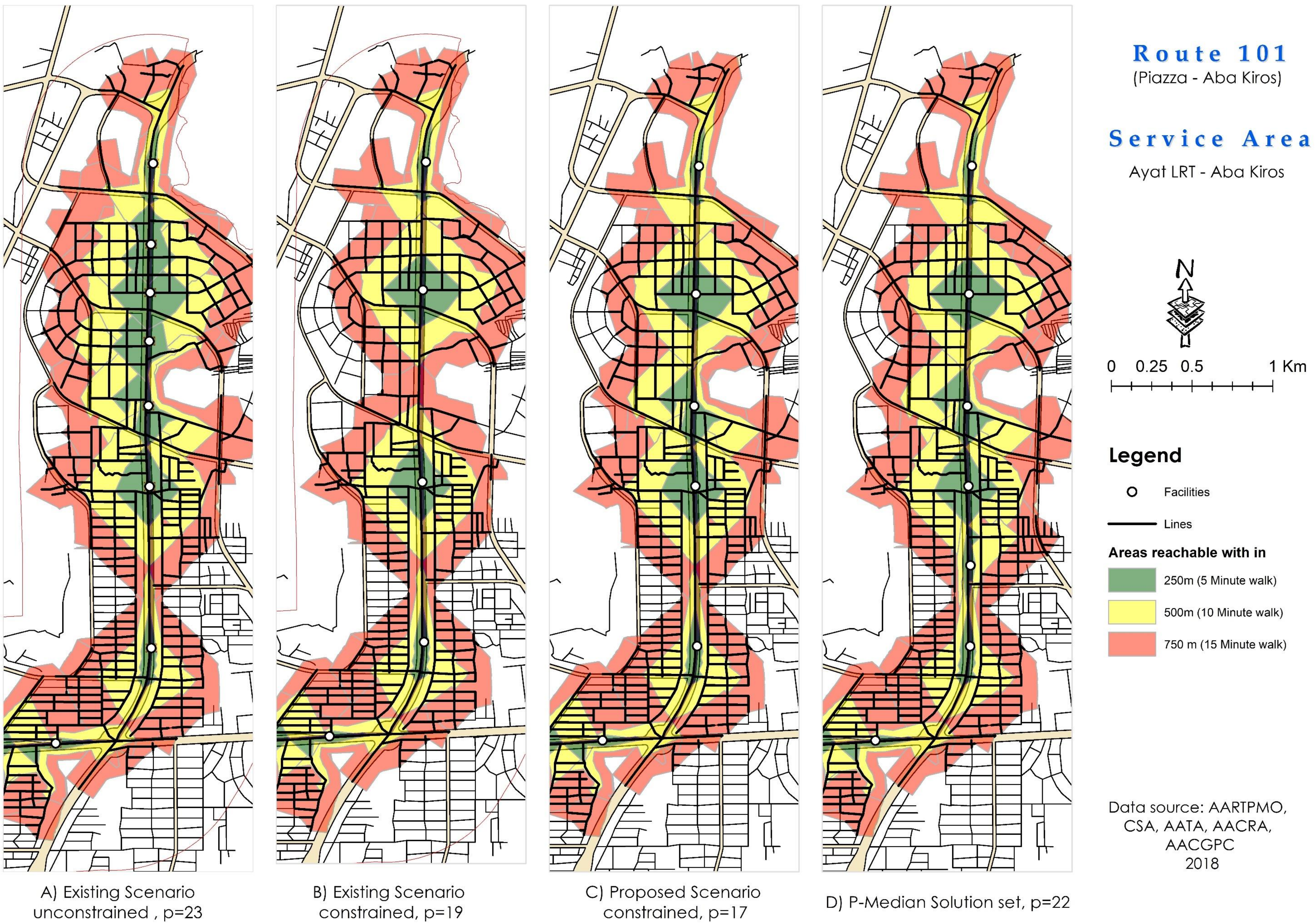
A) Existing Scenario unconstrained , p=23

B) Existing Scenario constrained, p=19

C) Proposed Scenario constrained, p=17

D) P-Median Solution set, p=22




Route 101
(Piazza - Aba Kiros)
Service Area
Ayat LRT - Aba Kiros
N
0 0.25 0.5 1 Km
Legend
Facilities
Lines
Areas reachable with in
250m (5 Minute walk)
500m (10 Minute walk)
750 m (15 Minute walk)
Data source: AARTPMO, CSA, AATA, AACRA, AACGPC 2018
A) Existing Scenario unconstrained , p=23
B) Existing Scenario constrained, p=19
C) Proposed Scenario constrained, p=17
D) P-Median Solution set, p=22

Appendix F. CO_2 sequestration cost

A criterion for selecting the Eucalyptus Saligan was based on its wide adaptability to various geographic locations, soils and climate, seed availability and ease of management as indicated in the literature Tesfaye et al. (2002) cited by (Gebru, 2016), apart from its favorability as compared to other options, afforestation is also efficient in its uptake of CO_2 from the biosphere with in short period of growth time.

Thereby, expense for plantation of Eucalyptus Saligan tress to clear kilogram Carbon Dioxide is estimated as follows as in the literature Andrea Leys, (2011) cited by (Gebru, 2016):

1. Determine the biomass of the tree

It has been recognized that biomass energy used with CO_2 capture and storage (BECS) can yield net removal of CO_2 from the atmosphere because the CO_2 put into storage comes from biomass which has absorbed CO_2 from the atmosphere as it grew (Möllersten et al., 2003; Azar et al., 2003) cited by (IPCC, 2005), referred to as 'negative net emissions', The biomass of the tree is calculated considering the volume of the tree and density of wood assuming eucalyptus will hold cylindrical shape using the equation below:

$$Tree\ biomass\ \ kg\ \ = h * \ d^2 * 0.7854 * \ \varphi \qquad \textbf{Equation 5-1}$$

Where:

h height of the tree assumed as 18meter
d diameter of the tree taken at breast height of the tree (i.e. 0.35m)
φ density of wood taken as 700 kg/m3

Filling those data's in Equation 5-1 result in a tree biomass of 1212.3 Kg

2. Determine the weight of carbon dioxide sequestered by trees per year

To do so two assumptions are made these are:

1. calculating biomass of tress, Andrea Leys, (2011) cited by (Gebru, 2016) used 20% of tree biomass below ground level there by to account for tree bio mass below the ground 120% factor is used
2. Andrea Leys (2011), as cited by cited by (Gebru, 2016), the green Eucalyptus camaldulensis tree after drying (at 70^0C) remain 50% of the dry weight of a tree and is carbon. Thus, percentage of carbon is estimated as half of the bio mass calculated earlier.

Then Equation 5-2 is used to calculate the carbon dioxide sequestered per tree:

$$\boldsymbol{CST\ \ kg} = (\boldsymbol{T} * \boldsymbol{0.5} * \boldsymbol{50\%} * \boldsymbol{3.67} * \boldsymbol{120\%} * \boldsymbol{S})/\boldsymbol{25} \qquad \textbf{Equation 5-2}$$

Where

CST carbon dioxide sequestered per tree per 25 years

T tree bio mass (kg)

S survival percentage (i.e. assumed as 70%)

3.67stands for the weight of carbon dioxide using atomic weight

25 stands for age of the tree in years

6. Expenses for Eucalyptus tree plantation

An average cost of sapling (cultivation, transportation and planting) at 60birr with in Addis Ababa city and surrounding suburbs. However, in order to contribute to carbon sequestration process, they incur a cost of one tree, conservation and management cost estimated at ETB 3.5 per one meter square and with 10 year compensation, ETB 10 per year and 950 ETB per one meter square respectively to twenty five consecutive years, conducted by (Gebru, 2016) is used using these values costs were modified to determine the total cost of plantation considering sapling, land, agency management and conservation work costs.

7. Determine the number of trees and area required for sequestration

The number of trees required for sequestering the annual emission obtained in HDM4 along the specified route of investigation is computed by dividing CO2 released to the environment per year by the uptake of CO_2 per tree per 25 years. Then considering 2x2m (4m^2) Eucalyptus farming the total area required is computed by dividing the number of trees need for sequestering CO_2 emission.

Table 5-20 Conservation work cost for 25 year per tree

Description	Equation	Values	
Tree height (m) in 25 years	A	18	
Tree diameter at breast height of the tree(m)	B	0	
Factor for volume estimation of cylindrical shaped trees	C	1	
Density (Kg/m3)	D	700	
Tree biomass (kg)	$E=A*B^2*C*D$	1,212	
50% of tree weight after drying at 70^{o}c is CO_2	F	0.5	
Factor to account trees biomass below ground	G	1.2	
Equivalent amount of CO_2 (weight of carbon dioxide)	H	3.67	
Tree survival factor	I	0.7	
Dry weight which is 50% of the tree bio mass	J	0.5	
CO_2 sequestered per tree per 25 years (Kg)	K=E*F*G*H*I*J	37.4	
Average cost of sapling (ETB)	L	60	
Land cover per one tree(m2)	M	4	
Land cost for single tress & 10-year land acquisition (ETB)	N=M*3.5*10	140	
Agency management cost per tree for 25 years (ETB)	O=M*950	3,800	
Conservation work cost for 25 year per tree (ETB)	P=10*25	250	
Route wise CO_2 Sequestration cost per year	Route		
	10	31	101
CO2 released to the environment per year	679	185	348
No of trees need for sequestering CO_2 emission	18	5	9
Total land required for plantation (meter square)	73	20	37
Total sapling, land, agency management and conservation work cost for 25 years (ETB)	305,654	83,273	156,506
CO_2 emission cost allocated for Buses per years (ETB)	12,226	3,330.9	6,260

Table 5-21 CO_2 sequestration cost per route per year

Route wise CO_2 Sequestration cost per year			Route		
			10	31	101
CO2 released to the environment	Base case	Operating	679.1	185.0	347.7
		idle	67.6	58.6	43.6
	Alt case	idle	65.4	61.2	45.9
No of trees need for sequestering CO2 emission	Base case	Operating	18.2	5.0	9.3
		idle	1.8	1.6	1.2
	Alt case	idle	1.7	1.6	1.2
Total land required for plantation (meter square)	Base case	Operating	72.7	19.8	37.2
		idle	7.2	6.3	4.7
	Alt case	idle	7.0	6.5	4.9
Total sapling, land, agency management and conservation work cost for 25 years (ETB)	Base case	Operating	305,654.4	83,272.7	156,505.9
		idle	30,431.3	26,358.5	19,609.4
	Alt case	idle	29,417.0	27,530.0	20,659.9
CO2 emission cost allocated for Buses per years (ETB)	Base case	Operating	12,226.2	3,330.9	6,260.2
		idle	1,217.3	1,054.3	784.4
	Alt case	idle	1,176.7	1,101.2	826.4

Appendix G. Station classification

Id	Route 101		Route 31		Route 10	
	Station Name	Stop type	Station Name	Type	Station Name	Type
1	Megenagna	Key	Shiromeda	Key	Piassa	Key
2	Israel Embassy	Ordinary	Sebseba Maekel	Ordinary	Ras Mekonen Bridge	Ordinary
3	Elfora	Ordinary	Teferi Mekonen	Ordinary	2nd police office	Ordinary
4	Lamberet	Ordinary	Sidest killo university	Key	Holy trinity college	Key
5	Lamberet Menhearya	Connection	Anbesa Gebi	Ordinary	Ginfele	Ordinary
6	Meberathayel Garage	Ordinary	Amest Killo	Ordinary	Beler	Ordinary
7	St Sealitemeherte Church	Key	Arat Killo	Key	Mismar factory	Ordinary
8	Civil Service	Key	Fitber	Ordinary	Kokebe Tsibahe School	Key
9	CMC St. Michael Church	Ordinary	Betemengist	Ordinary	British Embassy	Ordinary
10	Tekureabaye	Ordinary	Hilton	Ordinary	Yeka Michael Tsebel	Ordinary
11	CMC Homes entrance	Ordinary	St. Estifanos	Connection	Yeka First instant court	Connection
12	Yetebaberut Petroleum	Ordinary	Lagare	Key	Webit Building	Connection
13	Meri	Key			Diasspora Megenagna	Connection
14	Meri market (Deldeye)	Ordinary			Israel Embassy	Ordinary
15	AALRT last station	Connection			Elfora	Ordinary
16	Ayat Zone 2 entrance	Ordinary			Lamberet	Ordinary
17	Kibure Demnea	Ordinary			Menaharia	Connection
18	Oliyad Clinic	Ordinary			Civil Service	Ordinary
19	Yeka Wereda 03 HO	Ordinary			Bereta Beret	Ordinary
20	Meberathayel DC	Ordinary			02 Kebele	Connection
21	Safari Academy	Ordinary			Hana Mariam	Ordinary
22	Condominm chaf	Ordinary			Wendyrad School	Ordinary
23	Abakiros roundabout	Key			Kotebe College	Key

Appendix H. Annual idle CO2 emission

<table>
<tr><th rowspan="2">Route</th><th rowspan="2">Station type</th><th colspan="2">Quantity</th><th rowspan="2">Expected Idle (min)</th><th rowspan="2">No of trips per day</th><th colspan="2">Total idle time (min)</th></tr>
<tr><th>Alt case</th><th>Base case</th><th>Alt case</th><th>Base case</th></tr>
<tr><td rowspan="5">10</td><td>Ordinary</td><td>10</td><td>14</td><td>1</td><td rowspan="4">76</td><td>379</td><td>530</td></tr>
<tr><td>Key</td><td>4</td><td>4</td><td>3</td><td>909</td><td>909</td></tr>
<tr><td>Connection</td><td>4</td><td>5</td><td>4</td><td>1,212</td><td>1,515</td></tr>
<tr><td colspan="3">Miscellaneous cases</td><td>5</td><td>379</td><td>379</td></tr>
<tr><td colspan="5">Hours of idling per day</td><td>48</td><td>56</td></tr>
<tr><td rowspan="5">31</td><td>Ordinary</td><td>6</td><td>7</td><td>1</td><td rowspan="4">87</td><td>262</td><td>306</td></tr>
<tr><td>Key</td><td>4</td><td>4</td><td>3</td><td>1,050</td><td>1,050</td></tr>
<tr><td>Connection</td><td>1</td><td>1</td><td>4</td><td>350</td><td>350</td></tr>
<tr><td colspan="3">Miscellaneous cases</td><td>5</td><td>437</td><td>437</td></tr>
<tr><td colspan="5">Hours of idling per day</td><td>35</td><td>36</td></tr>
<tr><td rowspan="5">101</td><td>Ordinary</td><td>12</td><td>16</td><td>1</td><td rowspan="4">52</td><td>314</td><td>418</td></tr>
<tr><td>Key</td><td>4</td><td>4</td><td>3</td><td>628</td><td>628</td></tr>
<tr><td>Connection</td><td>2</td><td>2</td><td>4</td><td>418</td><td>418</td></tr>
<tr><td colspan="3">Miscellaneous cases</td><td>5</td><td>262</td><td>262</td></tr>
<tr><td colspan="5">Hours of idling per day</td><td>27</td><td>29</td></tr>
<tr><td colspan="8">Note:
1) Total idle time (minute) = No of trip X Expected idle X No of stations
2) Expected idle time for different station types are assumed as follows:
Ordinary 30 seconds
Key 180 seconds
Connection 240 seconds
3) Miscellaneous cases in the traffic stream that will make the bus idle are taken as 5 minutes</td></tr>
</table>

<table>
<tr><th colspan="2">Route</th><th>Route 10</th><th>Route 31</th><th>Route 101</th></tr>
<tr><td rowspan="2">Hours of idling per day</td><td>Base case</td><td>56</td><td>36</td><td>29</td></tr>
<tr><td>Alte. Case</td><td>48</td><td>35</td><td>27</td></tr>
<tr><td colspan="2">Number of operating days per year</td><td colspan="3">365</td></tr>
<tr><td colspan="2">CO2 emissions from a gallon of diesel (gram)</td><td colspan="3">2,778.00</td></tr>
<tr><td colspan="2">Idle engine fuel consumption (gallon/hour)</td><td colspan="3">0.97</td></tr>
<tr><td colspan="2">Ratio of molecular weight of CO2 to carbon</td><td colspan="3">3.67</td></tr>
<tr><td colspan="2">Oxidation factor</td><td colspan="3">0.99</td></tr>
<tr><td rowspan="2">Yearly Idle emission rate (Kilogram)</td><td>Base case</td><td>198,335.0</td><td>127,541.5</td><td>102,699.4</td></tr>
<tr><td>Alte. Case</td><td>171,289.3</td><td>124,938.6</td><td>96,475.2</td></tr>
<tr><td colspan="5">Notes
1) Average trip per day from 2008 and 2009 ACBSE performance is consumed
2) Hours of idling is a function of buses assigned and trips made in a day</td></tr>
</table>

Appendix I. Annual direct operating costs in idling

Route	Station type	Quantity		Expected Idle (min)	No of trips per day	Total idle time (min)	
		Alt case	Base case			Alt case	Base case
Route 10	Ordinary	12	14	0.3	76	227	265
	Key	4	4	1.0		303	303
	Connection	5	5	0.5		189	189
	Miscellaneous cases			5.0		379	379
					Hours of idling per day	18	19
Route 31	Ordinary	9	7	0.3	87	197	153
	Key	4	4	1.0		350	350
	Connection	1	1	0.5		44	44
	Miscellaneous cases			5.0		437	437
					Hours of idling per day	17	16
Route 101	Ordinary	15	16	0.3	52	196	209
	Key	5	4	1.0		262	209
	Connection	2	2	0.5		52	52
	Miscellaneous cases			5.0		262	262
					Hours of idling per day	13	12

Note:
1) Total idle time (minute) = No of trip X Expected idle X No of stations
2) Expected idle time for different station types are assumed as follows:

Ordinary	15	seconds
Key	60	seconds
Connection	30	seconds

3) Miscellaneous cases in the traffic stream that will make the bus idle are taken as 5 minutes

Vehicle type			IVECO 150E 18			
Engine Size:			6 cylinders			
Idle RPM			1,200			
Route			Route 10	Route 31	Route 101	Remark
Duration of idling per day (Hours)		Base case	19	16	12	
		Alt case	18	17	13	
R is the burn rate of fuel at idle for transit bus (R) from the U.S. department of Energy (www.energy.gov)			0.97			
Number of operating days per year			365			
Fuel cost per gallon (USD)			2.89			
Annual idling cost per year	Base case	USD	19,377.5	16,784.1	12,486.5	
		Birr	528,811	458,037	340,757	
	Alt case	USD	18,731.55	17,530.02	13,155.43	
		Birr	511,184	478,394	359,012	

Remark
1) IVECO 150E 18 is assumed since it simulates the engine types of ACBSE buses
2) The annual idling cost per year includes $350/year in service and maintenance expense.
3) Exchange rate of 27.29 as of 09 July 2018 is used to convert USD to equivalent birr
4) Alternative case the final location-allocation p-median results.

Appendix J. Route level direct operating cost recovery ratio

Route number			10	31	101
Total Distance (Km)	2008 EC		261,683.50	282,250.80	251,532.00
	2009 EC		440,613.80	190,342.80	206,616.00
VOC ($/veh-km)	route wise		0.66	0.64	0.59
	Average		0.63		
VOC	2008 EC		171,664.38	179,511.51	148,906.94
	2009 EC		289,042.65	121,058.02	122,316.67
Average VOC			230,353.51	150,284.76	135,611.81
Annual idling cost (birr)	Base case		528,811	458,037	340,757
	Alt. Scenario		511,184	478,394	359,012
Total operating cost (birr)	Base case		759,164.4	608,321.7	476,368.5
	Alt. Scenario		741,537.4	628,678.9	494,623.4
	Change over base	Birr	17627.03	-20357.20	-18254.83
		Percent	2.32%	-3.35%	-3.83%
Ratio of idling cost to Total VOC	Base case		70%	75%	72%
	Alt. Scenario		69%	76%	73%
	Change over base		1%	-1%	-1%
Annual Revenue		2008 Ec	2,760,617.8	5,525,789.0	3,842,424.2
		2009 Ec	4,148,534.0	3,173,052.0	2,352,675.0
Average Annual Revenue			3,454,575.9	4,349,420.5	3,097,549.6
Fare recovery ratio	Base case		455%	715%	650%
	Alt. Scenario		466%	692%	626%
	Change over base		11%	-23%	-24%

Appendix K. Value of travel time

To calibrate local value of working and non-working time analysis is made based on the World Bank Group (WBG, 2018) data GDP of Ethiopia which is 80 billion for the year 2017 together with (UN-Habitat, 2017) that report shows Addis Ababa hosts an estimated 3.238 million people, which is about 17% share of Ethiopia's total urban population. In addition, the State of Ethiopian Cities 2015 report cited by (UN-Habitat, 2017) shows Addis Ababa's share in GDP accounts for 29% of the total urban centers which is about 8% of the national GDP in the year 2015. Using these economic values, the GDP per-capita of Addis Ababa is calculated by dividing the GDP contribution of Addis Ababa by the number of people in the city (i.e. 3.238 million), resulted 1976.53$ (i.e. 53,939.47 birr considering an exchange rate of 27.29 as of 09 July 2018) of GDP per capita.

$$GDP\ of\ A/A = \frac{\text{Addis Ababa GDP contribution} * \text{GDP of Ethiopia}}{Addis\ Ababa\ Population} \quad \text{Equation 5-3}$$

Then GDP per-capita per year is converted to the average amount each person makes in an hour taking into account the productive working days as 288 day's hours in the week days as 8hours. Consequently, 0.86$/hr (23.41birr/hr) is the average value of time per hour for an individual living in the city. Thereafter, to capture the value of non-working time it is assumed that value of non-working time to be 30% of the value of working time, will be 0.26$/hr (7.02birr/hr).

This result showed a significant enhancement as compared to city's Bureau of Finance and Economic Development (2016) cited by (UN-Habitat, 2017), that state Addis Ababa's per capita income is USD 1,359 in 2015 which turns out to be 0.59$/hr (16.09birr/hr) considering 288 day's hours in the week days as 8hours at the said year which may be attributed to the high rate of economic growth the city is achieving in the last decade, thereby the value of time is in cooperated in HDM software.

Appendix L. Challenges and lessons learned

Issue	Why is it a problem?
Availability	Continuous streams of data are not readily available in many bureaus; the snapshot nature of data available makes it difficult to analyze specific conditions during unique events or over time in particular: • Data sets often contain enormous data or have gaps of missing data (i.e. crudely aggregated) which need significant cleaning before they can be used and accuracy is compromised. • In spite of ACBSE provides fixed-stop services since 1942, there were no historic archived on-and-off passengers surveys, at each station, bus running speed, and dwell time data's that are crucial in determining the relationship between stop spacing and demand. • Besides Geocoded walk trip records collected using interviews along with trip and demographic characteristics were not available to determine walking distances to stop stations.
Coverage	Since ACBSE data is only available for a daily passenger served in the transportation network it is difficult to accurately assess the entire interrelationships among stop spacing, service use, and operating performance. Besides due to the limitations in data though limited bus stops have travel time savings the data's acquired during the research the study had not developed optimal limited bus stop routes in the case studies.
Quality	Data sets often contain enormous data or have gaps of missing data (i.e. crudely aggregated) which need significant cleaning before they can be used and accuracy is compromised.
Standards	Bus stop design guidelines is not established for Addis Ababa city public transport which makes it difficult establishes economic evaluation methodologies since data banking standards are not designed to meet certain analysis methods.