



**ADDIS ABABA INSTITUTE OF TECHNOLOGY  
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING  
POST GRADUATE STUDIES**

## **Determinants of Bus Dwell Time for Addis Ababa City Bus Transport**

By

Belete Tsegaye

B.Sc (Civil Engineering, Addis Ababa University, 2014)

A Thesis Submitted to School of Civil and Environmental Engineering in  
Partial Fulfillment of the Requirements for Degree of Master of Science in  
Civil Engineering (Road and Transport Engineering)

Advisor: - Dr. Alemayehu Ambo

June, 2018

Addis Ababa

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## **Declaration**

I, Belete Tsegaye, declare that this thesis titled “**Determinants of Bus Dwell Time for Addis Ababa City Bus Transport**” is my own work under the supervision of my advisor Dr. Alemayehu Ambo and I confirm that it has not been presented to any other institution for assessment or award of any certificate, diploma or degree except at Addis Ababa Institute of Technology and all information and materials used are acknowledged properly.

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**Date** \_\_\_\_\_

## **ABSTRACT**

Bus dwell time, which is the time needed for buses to board and alight passengers at bus stops or stations and door opening and closing time, is one of the components bus travel time. Longer dwell times and variability of dwell times leads to an increase in total travel time thus passenger delay and passengers' discomfort is eminent. The variability of dwell time makes the schedule of Addis Ababa city bus enterprise agencies unpredictable. The emphasis of this research is so to identify and quantify the determinant factors which play a role to the variability and increase of dwell time of Addis Ababa City buses and to develop multiple linear regression models to predict dwell time based on manually collected data of nine routes in Addis Ababa.

Passengers boarding and alighting, number of standing passengers, fare collection media, time periods of the day, floor levels of buses, number of lanes of the roads the bus travelling on, and bus types are the factors considered in the research. 868 dwell time data are collected manually for the research and terminus stops are not considered as they lead to wrong bus dwell time estimation.

Three types of analysis are involved: statistical and regression analysis along with model development. The results of the analysis are presented and interpreted in tabular, chart and in calculation forms. Dwell time takes up to 14% on average of the total travel time of the studied routes and the minimum recorded dwell time is 5 seconds and the largest dwell time is 175 seconds. The average dwell time is 25.64 second and the overall dwell time model has a significant value of F less than 0.05. Finally the 12 closed type questions were presented to 60 bus users and the response of the questionnaire are included in the research. In addition to this the capacity of bus stops and performance of two bus stops are done.

**Key Words:** Dwell Time, Passengers boarding, Passengers alighting, Number of standees.

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**Abbreviations**

- DT= Dwell Time
- TCRP= Transit Cooperative Research Program
- CV= Coefficient of variation
- ACBSE= Anbassa City Buses Service Enterprise
- HCM= Highway Capacity Manual
- SPSS= Statistical Package for Social Sciences(latter Scientific Product and Service Solution)
- TCQSM= Transit Capacity and Quality of Service Manual
- VIF=Variance of Inflation Factor
- RMSE= Root Mean Square Error
- AU= African Union
- UNECA =United Nations Economic Commission for Africa
- SMTSE = Sheger Mass Transportation Service Enterprise
- RMSE= Root Mean Square Error
- PAS= Principal Arterial Street
- SAS= Sub Arterial Street
- NI= Near Intersection
- MB= Mid-Block
- E= Error term
- $\sigma$ = Standard deviation
- Z= statistical value from table
- $\alpha$ = significance level
- ANOVA= Analysis Of VAriance
- GPS= Global Positioning System
- APC= Automatic Passenger Counting
- AVL= Automatic Vehicle Location
- AFC= Automatic Fare Collection
- RFID= Radio Frequency IDentification
- SSE= Sum of Square of Error
- SST= Sum of Square of Total

## CHAPTER 1 INTRODUCTION

### 1.1 Background

In developing countries, buses generally spend a lot of time serving passengers boarding and alighting since there are a lot of loading and unloading passengers. As a result, more time is wasted and queues are common for many vehicles. This creates congestion and delay for the whole route and when it is repetitive customers complain and dissatisfaction results. In developed world however, travel time prediction is common to make the transportation system as customers demand and make transportation as it is scheduled. To do that, dwell time determination models are developed by different researchers in order to make the total time prediction so that the transportation system flows smoothly.

Ethiopia is a developing country which has been growing fast in the last twenty years and Addis Ababa, the capital city, is even growing faster with significant population concentration. Addis Ababa is located within the center of the country at 9<sup>0</sup>1'48"N latitude and 38<sup>0</sup>44'24" longitude. Currently, the population of Addis Ababa is 2.738 million with growing rate of 2.1% (Central Statistical Agency, 2007). The people in Addis Ababa use different transport activities during their daily lives such as: commuting to/from offices, students going to/from schools, shopping, visiting families and friends, etc. In order to perform their mobility, the population use different modes of transportation mainly: walking, private cars, buses, taxis and other public transportation. As stated by 2014 year, taxis, city buses and private cars cover 30% of the urban mobility of which 26% is covered by buses and 72% is covered by taxis and 4% is covered by private cars (AATB 2014). 43.76% of the transport is covered by walking and other mode of transport accounts 8.65 % (Eshetie .B 2013).

Bus transportation is one of the oldest means of public transportation in Addis Ababa with Anbassa bus as the oldest providing both urban and inter-urban public transportation services. Recently, privately owned buses such as Sheger, Alliance etc. are providing transportation services in the City. Despite the availability of public and private bus services in the city, residents however are not satisfied with bus availabilities and operations and they spend so much of their travel times waiting for their services.

Therefore, this research is focused on study of bus dwell times at bus stops considering the four types of buses in Addis Ababa such as single Sheger bus, Articulated bus, Double Decker bus and the single Anbassa bus as a case study.

Most of the time buses spend a lot of time serving passengers boarding and alighting. For example, Levinson (1983) found, for US operations observed from 1957–1980 in many US cities, that dwell time made up about 20% of total travel time within urban areas (Lijun Sun et.al 2014). For developing countries where there is a lot of loading and unloading passengers, more time is wasted by these huge buses and make queue of vehicles behind them. This creates congestion and delay for the whole route and when it is repetitive customers complain and dissatisfaction results.

In developed world, travel time prediction is common to make the transportation system as customers demand and make transportation as it is scheduled. To do that, dwell time determination models are developed by different researchers in order to make the total time prediction so that the transportation system flows smoothly.

## **1.2 Statement of the Problem**

Dwell time is defined as the time spent during passenger boarding and alighting together with the time for door opening and closing (Transit Capacity and Quality of Service Manual—2<sup>nd</sup> Edition part 4). The Highway Capacity Manual (HCM) defines dwell time as a time a transit unit (vehicle or train) spends at a station or a stop, measured from stopping to starting. In general it is the time spent by buses for giving services at the bus stop or station. However, if buses took so long during passenger alighting and boarding it could cause traffic congestion and delay to passengers and to the whole systems. So, attention should be given to the estimation of this time (dwell time) and in reducing it.

It is usually on the side of the road that the Addis Ababa buses will stop to alight and board passengers. We call this curbside bus stop. It is here the interaction of the buses, the passengers alighting and boarding and the side vehicles is happening. When a bus is maneuvered for a complete stop, the driver should get an acceptable gap and stops there and starts alighting and boarding passengers. After loading and unloading have been done, the driver closes the door and tries to get an acceptable gap to leave the station. In the meantime, if there is a passenger who is running to catch the bus, it would be the driver's decision to let him/her get in; although those kinds of activities are random in

nature and incidental in developed countries, it is however common in the Addis Ababa bus transportation services .

The other thing that should be considered during the estimation of the dwell time in Addis Ababa city bus services is the fare collection system. On some buses fares are collected while the passengers are outside and this increases the dwell time in general. On some other buses, fares are collected after the passengers are fully entered and take their places. On some other occasions the backdoors are opened for alighting passengers and boarding passengers will get in through the front door and pay their fare there.

In Addis Ababa, there is high demand for public transportation and buses are the main mode of transport since 1945 ([www.addisallaround.com/classfields/anbessa-city-bus-enterpris](http://www.addisallaround.com/classfields/anbessa-city-bus-enterpris)). If used properly, they can solve the shortage of transportation which is commonly observed in Addis Ababa nowadays. The estimation of dwell time in solving shortage of transportation has a paramount importance. Not only it solves transportation problems, dwell time calculation is useful in estimating bus capacity, major component in bus travel time. Accordingly, the bus dwell time estimation is essential for bus operators and public transport planners (Meng et al 2013).

A regression technique has been employed to estimate the dwell time incorporating different factors. Some of the factors as indicated in HCM are passenger demand and loading, stop/station spacing, fare payment procedures, vehicle types, on-board circulation, wheelchair and bicycle boarding. A good estimation dwell time helps bus operators and public transportation planners in a number of ways. First thing, it helps in design of bus loading areas and where to locate these loading areas. By doing so, it reduces congestion and delays on most bus operation routes.

Mass transportation using buses is becoming a trend in Addis Ababa streets. Several of the Addis Ababa buses run through different routes of the city carrying thousands of passengers daily. Although these buses transport multitude of passengers, delays and congestion are most common in the streets of the city on daily basis. The unavailability of convenient vehicle parking places, erratic driver behaviors and poor traffic rules enforcement are among others that exacerbate the situation. In this regard, a thorough study is required in respect of passengers boarding and alighting times in comparison with international standards and this is the motivation of this research. The outcome of this study is envisaged to come up with possible solutions for the current problems of

inefficient and ineffective public transportations in general and the four types of buses operation in particular.

In addition to the above, prediction of dwell time is useful to encourage private vehicle owners to use public transport. Since congestion is a problem both to private and public vehicle users, it would be preferable to use public transportation modes if the overall time spent is reduced. One such measure is to provide accurate bus arrival information to users pre-trip and in bus stops to minimize waiting time. Therefore, a growing interest has been developing in bus arrival time/travel time prediction (Cen Z. et al 2013)

### 1.2.1 Why Dwell Time Study

- ❖ To design and evaluate performance of bus stops and bus terminals.(TCQSM)
- ❖ Vehicle dwell time affects both system performance and service quality of transit agencies/service enterprises.
- ❖ Dwell time study ensures the effectiveness of real time control which aims to avoid bus/BRT vehicles congestion (Fazhi. L et al 2012).
- ❖ Dwell time at a bus stop which needs to be modeled in terms of ridership allows bus travel time to be accurately estimated. (Fang Zhao and Ming-Tang Li 2005)
- ❖ It plays a vital role in developing Transit Travel Time Model and transit travel time affects the overall effectiveness and attractiveness of the system. (Amita J. et al 2016). The purpose of a mass transit system is to move as many people as possible in a fast, safe, and inexpensive manner. Achieving this efficiency is difficult since there are several conflicting requirements, including dwell time. Extended or inconsistent dwell times lead to longer trips, delays, and irregular headways. (Wright, 2015 as in Jake K. et. al 2016)
- ❖ Accurate estimation of bus dwell times at bus stops and stations is important to provide real time information for passengers and increase the attractiveness of the bus service. This increases the reliability of travel times (Sumeet K.J. 2010). Travel time reliability depends on the accurate estimation of dwell time and other factors like the provision of real time information and bus priority signal design.

## **1.3 Research Hypothesis and Questions**

### **1.3.1 Hypothesis**

By developing a multiple linear regression models for different scenarios of collected dwell time data, factors that determine the estimation of bus dwell time for Addis Ababa city bus services would be identified. It is hypothesized that boarding, alighting and standing passengers affect bus dwell time for different scenarios (determinant factors).

### **1.3.2 Questions**

The following are pertinent questions that are envisaged to be answered by the outputs of this research,

- What are the factors that influence the estimation of dwell time and which factors affect the determination of dwell time mostly?
- What kind of model is more effective for the estimation of the dwell time and why?
- What are the passengers' opinions regarding the services of the buses and the waiting time of the bus stops?
- What are the effects of fare collection methods on dwell time determination and for the overall system of the bus service (when passengers are inside or outside bill collection methods)?
- What are the effects of the bus floor level on the estimation of dwell time?
- How would in-vehicle crowdedness influence the total dwell time estimation?

## **1.4 Objectives**

### **1.4.1 General Objective**

The General objective of this study is to identify the most significant factors which affect the estimation of dwell times for Addis Ababa City Buses Specific Objectives and investigating bus passenger's questionnaire response.

### **1.4.2 Specific Objectives**

The following are specific objectives of the study:

- Develop a regression model to estimate dwell time using the SPSS/Excel software;

- Field measurement of dwell time and comparison with TCQSM formula and then estimate dwell time variability.
- To investigate the response of bus passengers regarding the service and dwell time of buses.
- To investigate the performance and level of service of selected bus stops.
- To compare the average total bus dwell time with the total bus travels time.
- To estimate the bus stop vehicle capacity of selected bus stops.

### **1.5 Scope and Limitations**

During the research period especially during data collection period the following challenges are encountered.

- Collecting dwell time data needs patience and a tremendous amount of time to collect all the necessary data especially when it is done manually.
- Getting the three or the two data collectors for three or two door buses respectively at the same time for several days is the main challenge.
- Data collection during evening times especially after 7PM is challenging to count the boarding and alighting passengers due to poor lighting conditions.
- Questionnaire collection from a number of respondents is a bit hard.
- The study is limited to the nine selected routes of Addis Ababa.

## CHAPTER 2 LITERATURE REVIEW

### 2.1 Introduction

This chapter discusses different literatures reviewed for the purpose of finding the determinant factors of dwell time. It begins by reviewing the history of the Anbessa City Bus Service Enterprise.

### 2.2 The History of the Anbessa City Bus Service Enterprise (ACBSE)

The Anbessa city bus started giving transportation services in 1943 G.C. after collecting and modifying used trucks by of Fascist Italians. It was then in 1959 that Anbessa was re-established as a share company. Figure 2.1 below shows one of the Anbessa buses during old times.



Figure 2.1 Anbessa City Bus during old times

In the 1974 Ethiopian Revolution, the company was nationalized and continued providing transportation service under the name "Public Transport Corporation-PTC". In 1994, the Company was again re-established by the Council of Ministers Regulation No.187/97 under the name "Anbessa City Bus Service Enterprise" and continued operation as an autonomous business enterprise. In 2011, the Enterprise was transferred to the Addis Ababa City Administration. The Administration revised the city travel demand and recognized that additional buses were required and so purchased 500 new

buses through a grant from the City Administration. An agreement was made between the Enterprise and the Metals & Engineering Corporation with regards to the supply of the new buses. In this regard, a technical specification was prepared by the enterprise and some modern features like air conditioning, Euro three emission standards, and electronic equipment and route indicators were included. Out of the total 500 buses, 100 were articulated (18m.) and 400 were standard rigid buses. ACBSE provides three types public transportation services to the residents of the city of Addis Ababa and these are presented below.

## **2.2.1 Types of Transportation services provided by ACBSE**

### **2.2.1.1 Regular scheduled service**

This is a scheduled service provided by the Enterprise to the commuters on 119 fixed routes. According to ACBSE, the city bus is working fulltime from Monday to Sunday between 6:30 AM to 20:30 PM. The services are operated from:

- Three depots (Yeka, Shegole and Mekanisa);
- Four Bus Terminals at: Legehar, Merkato, Menillik Square and Megenagna;
- Twenty-eight check points (destination); and
- One thousand four hundred fourteen (1,414) bus stops.

### **2.2.1.2 Premium Service**

This is a service provided by the enterprise to government and nongovernment organizations, schools and other institutions based on distances covered and agreed with the user ahead of time.

### **2.2.1.3 Special service**

This is a service provided by the Enterprise when special occasions occur like: mourning, meeting and festivity; charges are based on distance coverage and duration of service.

### **2.2.1.4 AACBSE Depot Locations**

The AACBSE had three depots and one of the depots (Shegole Depot) is not currently functioning and has been transferred to the main head office located at Yeka due to a huge project undertaking in that area. The three depots are described below:

- The AACBSE head office is located at Yeka on 70,000 square meters area with workshop facilities equipped with machines, garage equipment and special tools. The Yeka Depot has an operating fleet strength of about 434 buses at the end of Tikimt, 2005 E.C. (October, 2013).
- The AACBSE also owns the Shegole Depot lay on a land covering an area of 53,996 square meters. This facility has a satellite spare parts store, satellite fuel station, greasing and washing bay, in addition to light machines garage equipment and special tools. This Depot has an operating fleet of 349 buses at the end of Tikimt 2005 E.C. (October, 2013).
- The third depot is located at Mekanisa which covers an area of 72,861 square meters and there are about 193 buses that run their operations from this depot.

Table 2.1 below shows the fleet strength of AACBSE

Table 2.1 : AACBSE Depot Fleet Strength

Depot bus Serving Capacity				
Bus Type	Yeka	Shegole	Mekanisa	Total
DAF	114	Na	86	200
Bishoftu Single	198	Na	105	303
Bishoftu Articulated	67	Na	48	115
Double Decker	25	Na	25	50
Total	404	NA	264	668

Source: AACBSE Head Office at Yeka

### 2.2.1.5 Terminals

There are four (4) major bus terminals in Addis Ababa City. It's here where operations like minor maintenances and mechanical checks are done. These major terminals are located at Addis Ketema (Merkato), Legehar, Megenagna and Menillik II Square. The Enterprise has also other minor terminals for its operations specifically located at: Ledeta, Sidist kilo, Arat kilo, Ayer Tena, Mesalemiya and Shromeda. The dwell time data collection exercise considered these locations taking most of the terminals into account.

### **2.2.1.6 Routes**

The bus routes of ACBSE are both radial and tangential, where most of them are radial starting from the center and extending outwards. Due to the increasing demand of the customers, the number of routes and route lengths increase from time to time. Currently, there are more than 124 routes with a total route length of more than 1,550 km. The shortest route is the Hanamariam-Saris Abo-58 Kebele which is 3.8 km in length. Conversely, the longest route is from Merkato to Teji through Torhailoch with a total length of 52 km. The average waiting time for the services of the AACBSE buses is 30 - 90 minutes. Averages of 61.5 trips daily are performed on a route with a maximum of 188 trips and minimum of 12 trips. The travel time ranges from 20 minutes to 110 minutes for a single trips based on the route length and topography (AACBSE).

### **2.2.2 Sheger Bus**

The Sheger Mass Transportation Service Enterprise (SMTSE) started its service in May 2016 at with a capital of two billion Birr in Addis Ababa city (Ethiopian Herald 28 May 2016). The SMTSE is well known for its modern services and it was included in this research of dwell time factor determination aiming to study the effect of the latest technological advancements in the determination of dwell time. Some of the latest technologies included in the SMTSE operations are: Low floor of the bus, availability of ramp and seats for disabled passengers, LED television installed inside the bus, electronic displays showing the bus routes and destinations, as well as the use of Geographical Positioning Systems (GPS) to be tracked and identified, etc. The availability of a ramp for passengers with wheelchairs in the Sheger bus is the first in the Ethiopians Bus Service history. The SMTSE started its operations using 200 buses aiming to reduce the longest queues of the Addis Ababa passengers, especially during peak periods. Figures 3.8 and 3.9 shows the Sheger Double Decker Bus at Menillik II Square and the Availability of a Ramp in Sheger Express Buses (Photo courtesy City of Addis Ababa) respectively.

## **2.3 Components of delay**

### **2.3.1 General**

Since dwell time takes up a significant fraction of the trip time along a serviced bus line, variation of dwell time may largely affect the accuracy of travel time prediction. Most of

the studies in the area of bus travel time prediction include bus dwell time implicitly in the link travel time. Indeed, running time in links and dwell time at stops are affected by different issues. Recently, the new approach is to divide the bus travel time into two components: running times and dwell time at bus stops and analysis of each separately. (Cen Zhang, Jing Teng 2013)

Delay components arise from different service times such as from dwell time (the time spent serving passengers), delay associated with deceleration and acceleration of vehicles, delay due to door opening and closing, delay due to bus clearance time, and delay due to passenger boarding and alighting. Generally, this kind of delay is called stop delay (S.K. Jaiswal, 2010)

Delay due to vehicles deceleration from cruise speed to stop the bus and acceleration from stop back to cruise speed is given by the formula below (Changshan and Murray, 2005 as in S.K. Jaiswal, 2010).

$$\delta_i = 0.5v_i \left( \frac{1}{\alpha_i} + \frac{1}{\beta_i} \right) \dots \dots \dots \text{Equation 2.1}$$

Where

**V<sub>i</sub>**: bus cruise speed;

**α<sub>i</sub>**: acceleration to get to back to cruise speed;

**β<sub>i</sub>**: deceleration from cruise speed to stop the bus;

**δ<sub>i</sub>**: delay time due to bus acceleration and deceleration.

The second type of delay is delay due to door opening and closing of the bus. This delay type can be taken from onsite observations and different literatures suggest nearly equal values for door closing and opening of buses. A value of 2 to 5 seconds for door opening and closing is reasonable for normal operations (Bus Transit Capacity Manual p 4-6).

The third type of delay which is observed in most congested roads is the time spent to clear the loading/alighting area so that the next bus is ready to serve the passengers accordingly. This time is called clearance time and based on the way of the bus stop in the traffic lane. Clearance time has different components. When buses stop in the traffic lane (on-line), this is the only component of clearance time (the time for a bus to start up and travel its own length, clearing the stop). However when bus stops out of traffic it is

called off-line; there is an additional time spent for the bus searching for suitable gap to re-enter into main traffic flow. So this time clearance time needs additional re-entry delay time (Jaiswal p17, 2010)

The fourth component of stop delay is delay due to passengers boarding the bus and passengers leaving the bus. Together with the door opening and closing delay, this type of delay comprises the bus dwell time. Dwell time is the time spent during passenger alighting and boarding plus the door opening and closing times.

### 2.3.2 Bus dwell time

According to the Bus Transit Capacity Manual (BTCM), dwell time is the average amount of time a bus is stopped at the curb to serve passenger movements, including the time required to open and close the doors. It is an important parameter in calculation of bus loading area capacity and it has a potential to determine the level of service of the whole route in which the bus is travelling (Bus Transit Capacity Manual, p 4-4, 2<sup>nd</sup> edition)

There are six main factors that influence dwell time according to the BTCM and three of these relate to passenger demand, while the other three relate to passenger service times. These are described below:

- i. **Passenger Demand and Loading:** The number of people passing through the highest-volume door is a key factor in how long it will take for all passengers to be served. The proportion of alighting to boarding passengers through the busiest door also affects how long it takes all passenger movements to occur.
- ii. **Bus Stop Spacing and Type:** The smaller the number of stops, the greater the number of passengers boarding at a given stop. A balance is required between providing too few stops, each with relatively high dwell times and relatively long passenger walk times, and providing too many stops (which reduce overall travel speeds due to the time lost in accelerating, decelerating, and possibly waiting for a traffic signal every time a stop is made).
- iii. **Fare Payment Procedures:** The average time to pay a fare is a major influence on the time required to serve each boarding passenger. Some types of fare payment procedures allow passengers to board through more than one door at busy stops, thus allowing all passengers to be served more quickly.

- iv. **Vehicle Types:** Having to ascend or descend steps while getting on and off the bus increases the amount of time required to serve each passenger.
- v. **In-Vehicle Circulation:** When standees are present on a bus, it takes more time for boarding passengers to clear the fare box area, as other passengers must move to the back of the bus.
- vi. **Floor Height:** floor height has an effect for determination of dwell time like the other factors. The effect is exacerbated by the presence of older people and passengers with luggage.

In addition to that, other factors also contribute to the total travel time of the route such as: floor level, bunching of passengers outside the bus who tries to board, age of passengers, presence of luggage, etc.

### 2.3.2.1 Passenger boarding and alighting

Many studies on bus dwell time considered different factors affecting bus dwell time; but, it was Lavinson (1983) who put a landmark for the first time. He used a simple regression approach to analyze and predict bus dwell time for bus stops across the United States (US) cities. Equation 2.2 was developed by, Levinson, H S (1983).

$$Dwell\ Time = 5.0 + 2.75N \dots\dots\dots Equation\ 2.2$$

Where:  $N$  is the sum of boarding and alighting passengers at the stop.

This model includes a constant, which is presumed here to reflect lost time that could be attributed to door opening and closing amongst other activities. It also includes another constant presumably for the time spends in processing each passenger (Jaiswal, Bunker and Ferreira, 2008)

The proportion of alighting to boarding passengers through the busiest door affects how long it takes all passenger movements to occur. Guenthner and Sinha, 1983 as in S.K. Jaiswal (2010) developed the following:

$$DT/passenger = 5.0 - 1.2 * \ln(BA) \dots\dots\dots Equation\ 2.3$$

Where

DT: Dwell Time

BA: Number of boarding and alighting passengers at a bus stop.

A logarithmic model was developed to estimate the dwell time per passenger (J.D. Fricker, 2010). As can be seen from the above model, passenger service time decreases when the number of passengers alighting and boarding increases. The models developed by Lavinson, Guentner and Sinha, 1983 as in S.K. Jaiswal (2010) are single variable models. Other researchers studied dwell time by adding other parameters to get a better understanding of dwell time. These variables include the nature of crowding in the bus (the number of standees), the nature of fare payment methods, the nature of the bus floor height, etc. These are called multi-variable dwell time studies.

J.D. Fricker, (2010) studied dwell time for a shuttle route in Purdue University's Campus where bus services are provided. Video cameras were installed inside the Campus. One of the elements of shuttle loop operation was determination of dwell time for passengers boarding and alighting in the school environment. So, a good estimate of dwell time was required for the bus to determine the time required to complete the loop. The experiment revealed several lessons such as: adequate range of values present in the dataset is more important than the number of bus stops (data points) in the dataset and the data should include other day's data to settle down the model. Several dwell time models were developed from the worksheet and the video record. In this regard, Equation 2.4 was developed as follows:

$$DT = 6.237 + 0.484*A + 2.542*B \quad \text{Equation 2.4}$$

Where

DT:

A: Number of Alighting passengers

B: Number of Boarding passengers

This was the mode with fewer variables and the loop can be traversed in ten minutes and 5-minute headway can be maintained, if the dwell time estimates from this model are reliable. This is a simpler equation, which includes only number of passengers alighting and boarding.

Cen Z. et al (2013) developed three models for estimation of dwell time in Shanghai China. The first two models consider only passengers boarding and alighting while the third one involves crowdedness of the bus during service times. Model A considers only passengers boarding and Model B considers only passengers boarding and alighting.

Christoforou et.al (2013) investigated the determinants of railway vehicle dwell time at public transport facilities in Nantes France. Nantes is the sixth largest city in France with a lot of passengers boarding and alighting activities daily. Automatic Passenger Counting (APC) system was employed to archive data and it was attached on the tramway's door. The APC detects the entrance and exit of passengers. The variables they considered were: volumes of passengers boarding and alighting, on board passengers, floor levels of the tramway, time of the day (peak, off-peak, inter-peak) and location of the stop (city center, proximity to points of interest).

Two types of analyses were employed for Nantes Tramway; one is investigation of dwell time using graphical method and the other is the use of inferential statistics to identify further relationship between dwell time and the determinants. The graphical method lays a ground to the dwell time models developed using multiple regression methods. Six graphical interpretations of dwell times demonstrating the spatial and temporal variation with respect to time of the day and the route line were reported. Three multiple linear regression models were used to model dwell time from field observations. Descriptive statistics of dwell time with its determinant parameters were also given. The statistical analysis and the model developed showed different directions of the same line having different dwell time characteristics.

#### **2.3.2.2 Fare collection method**

The other determinant factor of dwell time is the fare collection procedure that the bus fare collector follows. The time spent during fare paying is a major component of dwell time. In the case of ACBSE, for example, some buses collect fares after the passengers are fully inside the bus while some others buses collect fares while the passengers are outside lined up for their order. This imposes additional time on the dwell time as well as the total delay on the whole route.

Some types of fare payment procedures allow passengers to board through more than one door at busy stops; thus, allowing all to be served more quickly. Having to ascend or descend steps while getting on and off the bus increases the amount of time required to serve each passenger. In addition, when standees are present on a bus, it takes more time for boarding passengers to clear the fare box area, as other passengers must move to the back of the bus Wang et al (2016).

On their study Grant et al (2013) focusing on fare collection and inside crowding, they analyzed the effects of fare collection policy and crowding on dwell time. Certain fare collection policies have a significant impact on the service time. They indicated that passengers boarding with prepaid fare are the fastest to board (of paying passengers) as they have no interaction with the fare box and only need to show their pass to the driver (2.2 s per passenger). Each passenger using a magnetic swipe ticket adds 3.0 s to dwell time, while those using cash add 4.2 s while keeping all other variables constant at their mean value. Finally, each passenger who boards through the front door and does not pay the fare, even though the passenger does not interact with the fare box or show a pass to the driver, adds 1.6 s.

Alejandro T. (2013) studied the effect of fare collection method, floor level and age of the passengers on the determination/estimation of dwell time. He used multiple regression models to estimate the influence of different payment methods, the existence of steps at doors, the age of passengers and the possible friction between users boarding, alighting and standing on explaining observed variation in dwell times. As other researchers indicated, most of the total travel time is spent on stops and stations. Dwell time surveys were conducted in two areas of Sydney, Australia (the city center and the Black town area in the western suburbs). Two types of buses were used for study (low floor buses and buses with two steps at front doors). He also classified passengers by their age groups into three distinguish classes such as [School students (6-18 years old), Adults (18-65 years old), seniors (65+)]. Eight scenarios for fare collection system were considered in the study. It was concluded that important time savings are achievable when upgrading the payment method from slow to quick technologies, which has benefits for both users and operators.

The boarding times for adults and seniors have differences of 1.83 s/pax (6.26-4.43) and 2.17 s/pax (7.49-5.32) respectively when paying with a card at the right device and a left device. In terms of alighting, the differences are 0.82 s/pax (3.09-2.27) and 1.13 s/pax (2.38-1.25). On the other hand, the extra boarding time due to the existence of two steps at the front door is estimated to be 0.57 s/pax for adult and senior passengers, which measures the extra effort for users to walk up two steps (Alejandro, 2013).

### 2.3.2.3 *In-Vehicle Circulation*

The numbers of standees, boarding and alighting the bus affect the determination of dwell time. A passenger who is in the middle of the bus takes a lot of time to leave the bus as he/she faces a lot of oppositions from the crowd inside the bus. Researchers in this regard examined the effect of in-vehicle circulation or crowding on the determination of dwell time. A dwell time study was done by Lin and Wilson (1992) dealing with the effect of the number of standees departing the light rail transit found that number of standees could affect dwell time by up to half a minute. Equation 2.5 below was developed in this regard.

$$DT = 9.24 + 0.71*B + 0.52*A + 0.16*LS \dots \dots \dots \text{Equation 2.5}$$

Where DT: dwell time

B: number of passengers boarding the train;

A: number of passengers alighting from the train; and

LS: number of departing standees

In addition to crowding inside the bus of the light railway transit, there is what is called bus-way platform crowding outside the bus which affects the determination of dwell time. Platform crowding is usually observed at transit stations where a lot of passenger's activity is expected (Jaiswal, 2008). In the study relating bus dwell time and platform crowding at a bus way station, Jaiswal et al (2008) indicated how important crowd management at station platform is in efficiently improving dwell time. A proper understanding of crowd phenomena at the bus way station is therefore very crucial. It is possible to reduce dwell time as well as delays at stations by properly managing crowd at stations, by creating favorable and organized environment at the bus way station platform. A passenger-bus interface variable could be incorporated with the traditional dwell time models to account for the platform crowding effect.

Grant et al (2013) studied the effects of crowding and fare collection methods on dwell time and they used manual data collection method to capture the important information. They conducted their study along three heavily used bus routes in the TransLink system in Vancouver, British Columbia, Canada and these routes were chosen as they experienced crowding on regular basis. They collected data predominantly during the morning (7 a.m. to 10 a.m.) and afternoon (3 p.m. to 6 p.m.) peak hour periods to capture

best data that shows the impact of crowding and fare collection method. Weather condition, time of day, driver's age and driving experience were also included in the study. They used two types of models: the first one the traditional model and the second one the extended model. The traditional model only counted passengers boarding and alighting and the number of standees while the extended one recorded the effects of crowding and different fare collection policies, in addition to passengers count, both boarding and alighting. The analysis indicated that the dwell time has a distinct difference for crowded and non-crowded conditions. Crowded conditions which were defined as loads with greater than 70% of bus capacity, showed an increase in service time per passenger of from 3.69 to 5.35 s on Route No. 5 (a 1.66 s increase) and from 3.58 to 4.06 s on Route No. 9 (a 0.48 s increase).

The above showed that during crowded condition increase in dwell time existed. But some routes showed a decrease in dwell time by 0.41 s and this was because all doors were open during passenger boarding which reduced the total time, especially in crowded conditions. Using the longest dwell time, two regression analyses (traditional and extended model) were conducted. The traditional model uses the non-detailed variables, while the expanded model uses all the collected variables. The expanded model explained 86% of the variation by using a sample size of 1,764 dwells, compared with the traditional model, which explained only 58% of the variation.

Nowadays the application of Automatic Vehicle Location (AVL) and Automatic Passengers Counters (APC) systems are increasingly implemented for transit operation. Cen et al (2013) applied AVL and APC to capture many real time data to estimate dwell times by including various factors like crowding and fare type. They also divided the total travel time into running time and dwell time.

The study conducted by them was initiated because of traffic congestion in Shanghai, China. The problem is exacerbated by a great number of people in need of public transport during peak hours. During peak hours, the phenomenon that vehicles are so crowd that people can't get on and off easily even sometimes passengers have to wait for the next bus since there is no room for one more. So under such kind of conditions, the estimation of dwell time is so essential as it is the largest portion of the total travel time.

AVL and APC systems made it possible in capturing the real time data of passengers boarding and alighting in addition to other data. They developed three models: Model A

only takes boarding passengers into account; Model B considers the effect of both boarding and alighting passengers and Model C considers the effect of crowdedness in vehicles and the capacity limits for Jiading 3 in Shanghai, China. Three days of real time data were collected and two of them were used for model development and the third was used for model validation. For non-crowded condition, the three models didn't show significant differences while in crowded condition Model C was the one with minimum error terms. So, Model C which has low error terms was used to predict dwell time and total travel time in transit operations.

Alejandro (2013) observed the effect of inside crowdedness in Sydney, Australia and described that passengers standing inside the vehicle made it hard for passengers boarding and alighting, especially when the level of crowding is noticeable. It was found that when passengers board forming two queues at the same time, there is a friction effect between the two lines, which is translated into extra time for the passengers at the left line of 1.25 s/pax. This is interpreted as the right queue making it more difficult for access of passengers to the left device or to the driver to pay in cash.

#### **2.3.2.4 Floor height**

Floor height has an effect for determination of dwell time, like the other factors. The effect is exacerbated by the presence of older people and passengers with luggage. In Addis Ababa city buses, there are two types of buses with different floor height; one is the bus with raised floor or a number of steps and the other is the bus with low floor level. The effect of floor height on dwell time determination is studied by different researchers and a summary of their work is presented here under.

On their research, Catherine et al (2016) experimented dwell time with three different gap heights and the effects of age and luggage type on the time to board and alight on the train transport in the United Kingdom (UK). The results indicated that when there are more steps, longer time is required to board and to alight the train. But, younger people are less affected by the presence of more steps and the presence of luggage on the train while older people take more time to get into the train and so more dwell time is recorded. The dwell time even increased when there was luggage carried by the passengers. The quantification of these effects has implications for accessibility of train services and for train dwell times and can be used by others in the design and planning stages of rail projects.

Alejandro (2013) explained how the presence of steps on buses is statistically significant during boarding of passengers and not on alighting passengers. He found that average boarding times were larger in raised steps and the average alighting times were almost similar to the one with low floor level. The extra boarding time due to the existence of extra raised steps is 2.2 s/pas for adult and senior passengers.

In general, there are other factors which influence the duration of the dwell time such as location of the bus stop, involvement of road side parking specially near to the bus stop or station, drivers' age and state during driving, etc... For example, if the bus stop is located near an intersection with light, drivers may keep the door open to other late passengers to get in until the light is green. Passengers may also oblige the drivers to open the door once it was closed and such kind of irregularities wouldn't be recorded during the dwell time survey. Extra delays which resulted from reopening of doors or other unexpected events wouldn't be counted as a data point.

### **2.3.3 Bus stop location**

Depending on the situations or the factors considered, there are three typical location options for bus stops. These stop locations are near side, far side and midblock locations and are shown in the figure below (Transit Capacity Manual, 2<sup>nd</sup> edition). For the purpose of this study, near side and far side locations of bus stops are taken as near intersection bus stop locations. Before locating any new bus stop locations, the following factors such as: site constraint, safety considerations, traffic patterns, intersection geometry, passenger origins and destinations, pedestrian accessibility, route design and available space and population density need to be considered as it is reported in Transport bus stop design standards and guidelines (Emma et.al, 2015).

Stops should be placed based on population density and/or major passenger generators (i.e. major employment centers, regional shopping centers, hospitals, etc.) as stated by Kimley (2004).

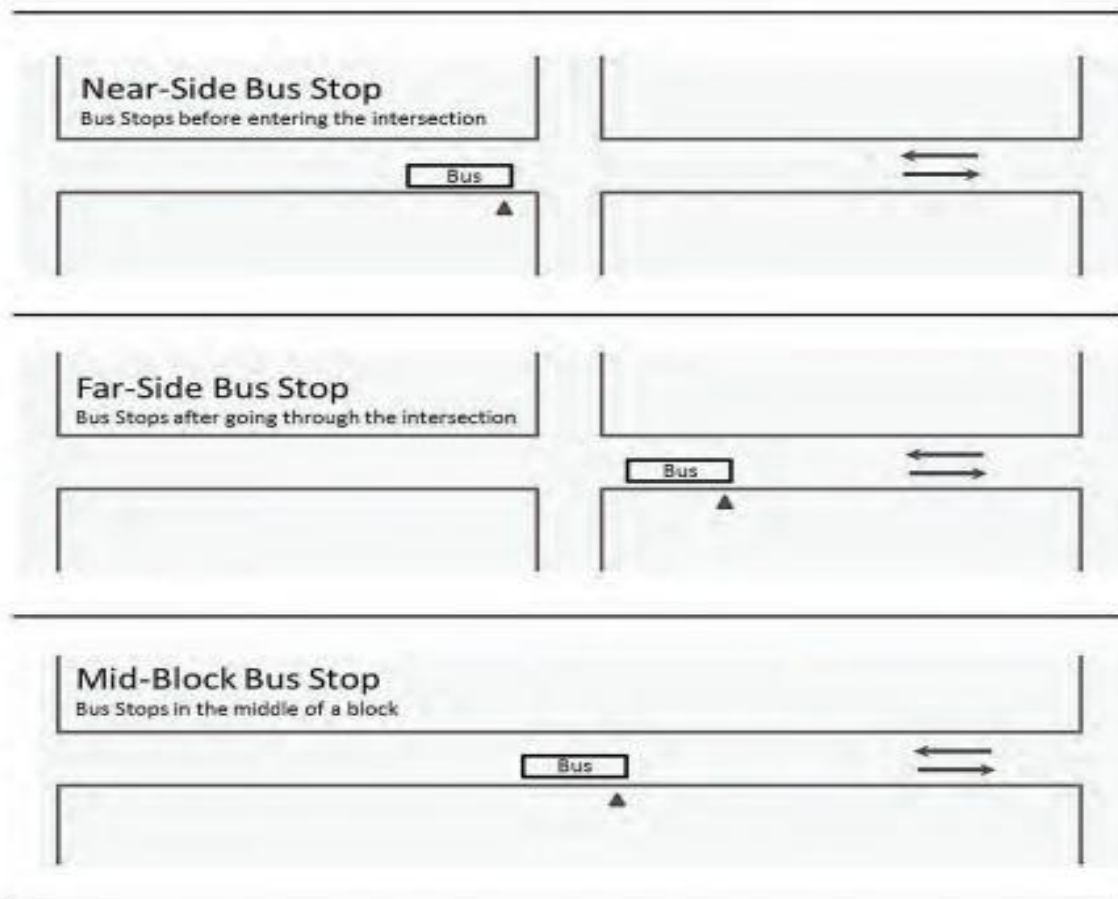


Figure 2.4: Types of Bus Stop Locations

### 2.3.4 Advantages and disadvantages of bus stop location types

Each type bus stop location has its own merits and demerits. In Table 2.2 below, the advantages and disadvantages of each type of stop locations are summarized under what circumstances we should use them.

Table 2.2 Bus Stop Location, advantage and disadvantages

Stop Location	Advantages	Disadvantages
<p><b>NEAR-SIDE STOP</b> Use if:</p> <ul style="list-style-type: none"> <li>• Destinations are focused at the near-side corner</li> <li>• Route pattern calls for near-side location</li> <li>• Available space is limited on far-side</li> </ul>	<ul style="list-style-type: none"> <li>• Allows passengers to access buses close to the crosswalk.</li> <li>• Eliminates the potential for double stopping — passenger loading can occur when bus is stopped at the signal.</li> </ul>	<ul style="list-style-type: none"> <li>• Increases conflict with right-turning vehicles.</li> <li>• May result in stopping buses obscuring curbside traffic control devices and crossing pedestrians.</li> <li>• May block the through traffic lanes during peak hours.</li> <li>• May cause sight distance</li> </ul>

		<p>problems for pedestrians and motorists.</p> <ul style="list-style-type: none"> <li>• May increase rear-end accidents if drivers aren't anticipating the bus stopping before the intersection</li> <li>• Vehicles may attempt to turn in front of a stopped bus that is beginning to pull away</li> </ul>
<p><b>FAR-SIDE STOP</b> Use if:</p> <ul style="list-style-type: none"> <li>• Destinations are on both sides of street or on the far side of the intersection</li> </ul>	<ul style="list-style-type: none"> <li>• Minimizes conflicts between right turning vehicles and buses.</li> <li>• Allows for additional right-turn capacity (because bus is not stopping in the right turn lane).</li> <li>• Minimizes sight distance difficulties on approach to intersections.</li> <li>• Encourages pedestrians to cross behind the bus.</li> <li>• Bus can merge into traffic more easily, taking advantage of gaps.</li> </ul>	<ul style="list-style-type: none"> <li>• Stopped buses may block intersections during congested periods.</li> <li>• May cause a bus to stop twice in short order: once at a red light and once at the bus stop.</li> <li>• May increase rear-end accidents if drivers do not anticipate the bus stopping after the intersection.</li> </ul>
<p><b>MID-BLOCK STOP</b> Use if:</p> <ul style="list-style-type: none"> <li>• Block size is large and/or destinations are focused mid-block.</li> <li>• Route pattern calls for mid-block stop.</li> </ul>	<ul style="list-style-type: none"> <li>• Minimizes sight distance difficulties at intersections</li> <li>• Removes the influence of traffic congestion occurring at intersections</li> </ul>	<ul style="list-style-type: none"> <li>• Encourages passengers to cross mid-block (jaywalk).</li> <li>• Increases walking distance for patrons to cross at intersections.</li> </ul>

Source: Transport bus stop design standards and guidelines, Emma et.al (2015)

## 2.4 Clearance time

The time required for buses on the bus stop to start up and go with the existing moving traffic is called clearance time. Based on the number of lanes the bus stops, there are two components of clearance time. The first one is when the bus stops in the traffic lane (on-line) and the component of clearance time is the time for a bus to start up and go. The

second one is when the bus stops out of traffic (off-line) and this adds another component of time which is the time the bus waits for getting a suitable gap in the traffic to reenter. Transit Capacity and Quality of Service (TCQSM) Manual, 2nd Edition reports clearance time between 9 to 20 seconds as it is obtained from various studies. Table 2.4 below presents the average bus reentry delay into adjacent traffic stream.

Table 2.4 Average Bus Reentry Delay into Adjacent Traffic stream

Average Bus Reentry Delay into Adjacent Traffic Stream	
Adjacent Lane Mixed Traffic Volume (Veh/h)	Average Reentry Delay (s)
100	0
200	1
300	2
400	3
500	4
600	5
700	7
800	9
900	11
1000	14

Source: HCM, Random vehicle arrival volume and delay time

## 2.5 Dwell time variability

The variation of dwell time on stops is expressed in terms of coefficient of variation of dwell times ( $C_v$ ). For the United States cities,  $C_v$  ranges from 0.4 to 0.8 from various field measurements. It is one of the variables considered to estimate the bus loading area capacity. Bus capacity analysis incorporates the concept of a failure rate that sets how often a bus should arrive at a stop only to find all loading areas occupied (Transit Capacity and Quality of Service Manual (TCQSM) and HCM 2000).

## 2.6 Bus loading area capacity

Bus loading areas are spaces on the road side which are used to stop buses and give services for passengers. They can either be on line to traffic or off line to traffic. The most common form of loading area is a linear bus stop along the bus stop. The capacity of each loading area is fundamental to determine the capacity of bus stops. The capacity

of each loading area in turn depends of dwell time, clearance time, dwell time variability and failure rate. The formula for bus loading area calculation is given below as provided by Transit Capacity and Quality of Service Manual (TCQSM) 2<sup>nd</sup> edition.

$$B_l = \frac{3600\left(\frac{g}{C}\right)}{t_c + t_d\left(\frac{g}{C}\right) + t_{om}} = \frac{3600\left(\frac{g}{C}\right)}{t_c + t_d\left(\frac{g}{C}\right) + zc_v t_d} \dots\dots\dots \text{Equation 2.6}$$

where:

$B_l$ : loading area bus capacity (bus/h);

3,600: number of seconds in 1 hour;

$g/C$ : green time ratio (the ratio of effective green time to total traffic signal cycle length, equals 1.0 for unsignalized streets and bus facilities);

$t_c$ : clearance time (s);

$t_d$ : average (mean) dwell time (s);

$t_{om}$ : operating margin (s);

$Z$ : standard normal variable corresponding to a desired failure rate; and

$c_v$ : coefficient of variation of dwell times.

## 2.7 Review on data collection Scheme

### 2.7.1 Bus stop selection scheme

Many researchers used different data collection schemes for dwell time study; like some of them used as multiple selected stops for dwell time survey while others follow the routes of the bus to determine many features of the dwell time. For example, Alejandro (2013) surveyed three routes' bus stations of Sydney, Australia and different components of dwell time were considered. These routes are Commercial services in the Blacktown area; Commercial services in the inner Sydney area; and Free CBD shuttle. The Blacktown route is characterized by collection fares in cash while the commercial service in the inner Sydney area is characterized by both cash and card fare collection methods and the CBD shuttle is known by its free service for passengers. Amita et al (2016) collected data for two urban bus routes in Delhi, India to develop regression model to analyze Parameters of Trip Time Model.

The other type of data collection scheme is using selected bus stops for multiple times. The selected bus stops are chosen based on previously known information in which the bus stop consumes a lot of time at that selected bus stop and many other characteristics like location of the stop is favorable for the kind of study the researcher was dealing with to come up with the expected findings. Stephen et al (2015) used 60 selected bus stops on heavily travelled bus routes within the District of Columbia for their study. They selected these sixty bus stops based on the number of passengers boarding and alighting at each stop. Two types of bus stops were selected based on the location of the stop such as those located in the mid-block of the road and those located near intersection of the road.

Table 2.5 List of some of the researchers reviewed

Paper Title	Researcher/s	Place/ Location	Number of Stops	Mean Dwell Time(seconds)	Feature of the Study
The Effects of Articulated Buses on Dwell and Running Time	Ahmed M. et al 2011	Montreal, Canada	from 15 stops to 72	24.44	compares articulated and regular buses in terms of standard deviation, effect of extra one door in articulated bus
Bus Dwell Time: The effect of different fare collection system, bus floor levels, and age of passengers	Tirachini A. 2013	Sydney, Australia			applies multiple regression model to analyze the effect of different fare collection system, bus floor level and age of passengers on dwell time.
Dwell time estimation models for bus rapid transit stations	Fazhi LI*, Zhengyu Duan, Dongyuan Yang 2016	Changzhou, China		16.8BRT stations 12.66 Non BRT stations	To ensure the effectiveness of real-time control which aims to avoid bus/BRT vehicles congestion,

					accurate dwell time models are needed, Comparing BRT stations with Non BRT stations
Predicting Dwell Time by Bus Stop Type and Time of the Day	Stephen A et al 2015	Columbia	60 Stops	22.06 Mid-Block 32.4 Near Intersection	DT models for bus stops located in dense urban areas taking in consideration the bus stop type(located near intersections and at mid-blocks ), and by time of day(morning, mid-day and evening)

## CHAPTER 3 RESEARCH METHOD

### 3.1 Introduction

Chapter three discusses data collection methods, dwell time factors determination, models development, and the analysis methods. The chapter incorporates the following sub topics: Study route description; types of buses used in the research; variables selection; research data; company profiles of the Anbassa City Bus Services Enterprise (ACBSE) and the Sheger Bus Service Enterprise; materials used in the research; analysis methods and validation techniques.

### 3.2 Study route description

Addis Ababa, with an area of 540 km<sup>2</sup> is divided into 10 sub-cities and 116 woredas. The city is the country's political and economic center, the seat of the Head Offices of African Union (AU) and United Nations Economic Commission for Africa (UNECA). It also accommodates many international Aid and Development organizations and more than 100 embassies. More than 70% of registered vehicles in the country are found in Addis Ababa (Addis Ababa Transport Policy, 2011). Road side loading and unloading is expected which will lead to re-entry delays and congestion of road traffic especially during peak hours. All of the routes considered for the purpose of dwell time study are situated in Addis Ababa. Following are: description, origin-destination, classification, number of lanes, and length of the subject routes.

Dwell time in a bus stop is highly correlated with the number of passengers boarding and alighting because a higher demand at a bus stop means a higher dwell time for passengers to get on or off the bus (Zhao and Li, 2005). In selecting process of the study routes, the six factors which were stated in literature review together with the route directions were incorporated into dwell time study. Then, the following roads were considered for the study of dwell time determination. The routes were selected based on different factors and the factors are: (BTCM)

- Variety of number of lanes along the routes;
- Number of passengers alighting and boarding;
- Number of standees that vary along the origin and destination;

- The location of stops which are either near intersection (NI) or Mid-Block (MB) and its composition along the routes;
- Route directions on the road network centering mostly at Menillik II Square and Megenagna Terminals;
- Based on distances and to catch more stop dwell time data, the following routes were considered in the study:
  - Piassa - Saris Abo Road,
  - Piassa - Mebrat Condominium Road,
  - Jemmo - Piassa Road,
  - Piassa - Megenagna Road,
  - Piassa - Ayer Tena Road,
  - Ayer Tena - Winget Road,
  - Megenagna - Ferensay Legasion,
  - Burayou - Merkato Road, and
  - Sidist Killo - Hayat Condominium Road.

Figures 3.1 and 3.2 below illustrate the study routes of Addis Ababa and the Menillik II - Jemmo Condominium route respectively.

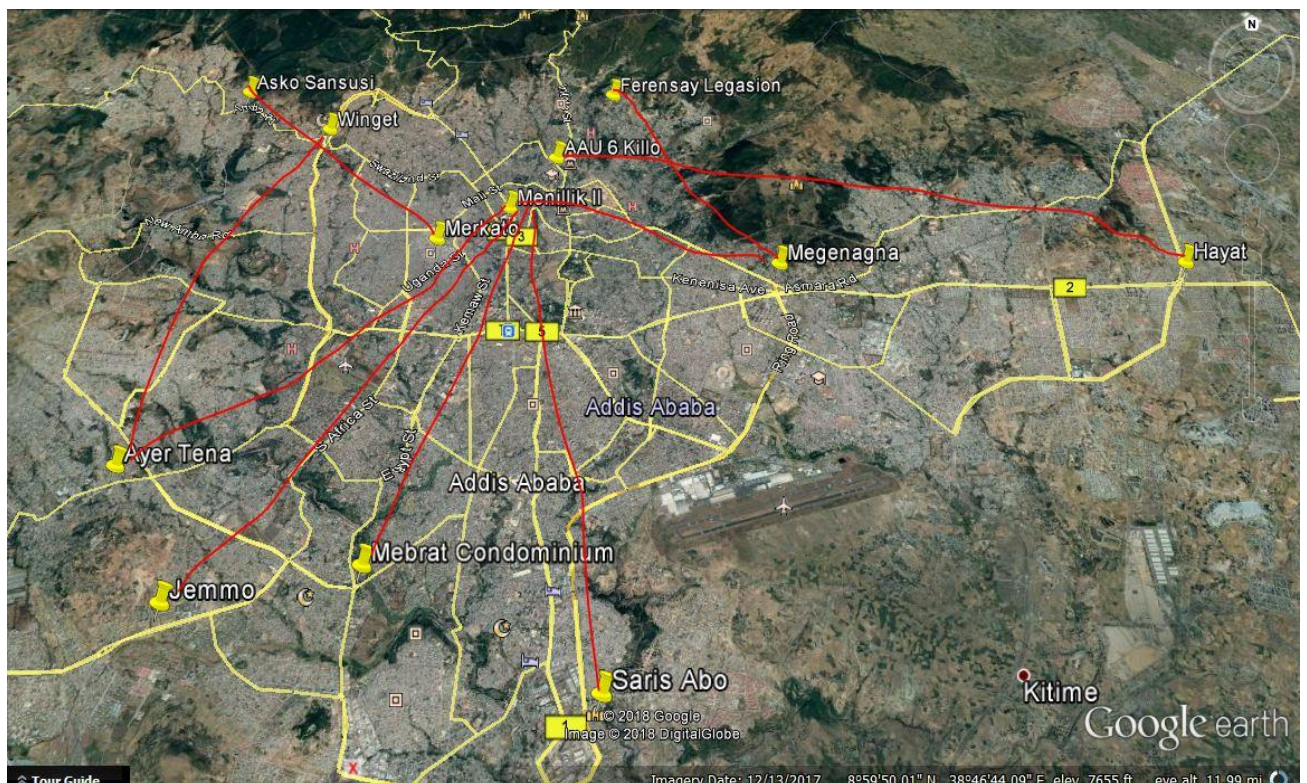


Fig 3.1 Study Routes of Addis Ababa



Figure 3.2: Menillik II to Jemmo Condominium route

### 3.3 Road Classification, Number of lanes and Length of Road

The Bus Transit Capacity Manual classifies bus lanes into two types: Type 1 and Type 2. Type 1 bus lanes are mixed traffic lanes which have one traffic lane in the direction of the bus movement shared by buses and other vehicles; whereas, Type 2 bus lanes are mixed traffic lanes with two or more traffic lanes in the direction of the bus movement. In Type 2 case, buses usually use curb side lane. In the case of Addis Ababa city buses, the lane composition ranges from one (1) lane two-way roads to four (4) lanes two-way roads along the studied routes. For the purpose of this study, lanes are classified into two: road segments with one and two lanes are classified in one group and road segments with three or more lanes are classified in another group to show the dwell time variability due to an increase lane numbers. Table 3.1 below shows road names, lane composition, road classification and length of roads in kilometers. Subsequently, Figures 3.3 and 3.4 illustrate a four lane road from Megenagna to Gurd Shola and a two lane two way road around Arat Killo respectively.

Table 3.1 Road name lane composition road class and length of the road of the studied routes.

Road Name	Lane Composition	Road Classification	Length of Road (km)
Piassa - Saris Abo Road	2, 3 two way	PAS-1, PAS-3, PAS-4, SAS-2	12.3
Piassa - Mebrat Condominium Road	1, 2, 3 two way	PAS-1, PAS-4, SAS-2	10.0
Jemmo - Piassa Road	2, 3 two way	PAS-1, PAS-4	12.2
Piassa - Megenagna Road	2, 3 two way	PAS-3, PAS-4	7.5
Menillik - Ayer Tena Road	2, 3 two way	PAS-1, PAS-3, SAS-1	10.8
Ayer Tena - Winget Road	2, 3 two way rapid road	RR	10.5
Megenagna - Ferensay Legasion	1, 2, 3, 4 two way	PAS-3, PAS-4, SAS-2	8.6
Sidist (6) Killo - Hayat Condominium	2, 3, 4 two way	PAS-3, PAS-4, PAS-2	18.0
Sansusi - Menillik II Road	2, 3 and three and two way	PAS-4	10.2

NB: the percentage composition of the number of the lanes of the studied routes is 3.7%, 37.2%, 52.4%, and 5.9% for one (1) lane, two (2) lanes, three (3) lanes and four (4) lanes two way roads respectively.



Figure 3.3: A four lane road from Megenagna to Gurd Shola



Figure 3.4: A two lane two way road from around Arat Killo

### 3.4 Bus Stop Type

TCRP Report 19 (1996) discussed that there are two types of bus stops: Curb side Stops and Bus bays. In the routes surveyed in Addis Ababa, three bus bays are found which are located around British Embassy and Churchill road and the rest are curbside stops and so it was found that comparison of dwell time determinant factors was difficult to make a few number of loading and unloading of passengers is happening there. 96 % of the bus stops on the surveyed routes are curbside stops.

### 3.5 Types of Buses Serving the Study Route

#### 3.5.1 Articulated Anbassa Buses

The use of articulated buses has many advantages over the other types of buses. They reduce the number of buses required on the particular routes if they are available on that route. They decrease passengers boarding and alighting times as they have more space for passengers who stand there and give more room for standees movement. Levinson et al. 2002, (as referred in Ahmed M. et al 2011) recommended the use of articulated buses as a part of bus rapid transit (BRT) system. The Addis Ababa articulated bus has a length of 18 m with three separated doors. Each can carry up to 150 passengers (50 seating and 100 standing) at once. Figure 3.5 below shows the Bishoftu Anbassa Articulated Bus at Megenagna Terminal.



Figure 3.5: Bishoftu Anbassa Articulated Bus inside Megenagna Terminal

### 3.5.2 Single Anbassa bus

They can carry more than 100 passengers per trip and have 12m length. These buses are nowadays few in number and they are being replaced by the new single Bishoftu buses. Figure 3.6 below illustrates the Old Anbassa Bus operating on the Arat Killo - Piassa road.



Figure 3.6: Single Anbassa Bus Arat Killo - Piassa road

### 3.5.3 Sheger Buses

Sheger buses are well known for their modern technological application to the mass transport in Addis Ababa. Low floor of the bus, availability of ramp and seats for disabled passengers, LED television installed inside the bus, electronic displays showing the bus routes and destinations, as well as the use of Geographical Positioning Systems (GPS) to be tracked and identified, etc. are some to mention. Two types of buses, which are the Sheger Double decker bus and the single Sheger bus, are investigated in this research. The Double decker bus can carry up to 140 passengers and the single Sheger bus can carry up to 100 passengers seating and standing.



Figure 3.7: Sheger Double Decker Bus Menillik II Square

Table 3.2 below show the characteristics of Common Bus Transit Vehicles in the United States and Canada presented for comparison purposes (Bus Transit Capacity Manual, as in Highway Capacity Manual).

Bus Type	Physical Characteristics		Typical Passenger Capacity		
	Length(ft/m)	Width(ft/m)	Seated	Standing	Total
Small Bus/Minibus	18-30/5.5-9.1	6.5-8.5/2-2.6	8-30	0-10	8-40
Transit Bus (High Floor)	35/10.7	8.0-8.5/2.4-2.6	35-40	20-30	50-60
	40/12	8.5/2.6	40-45	20-35	65-75
Transit Bus (Low Floor)	35/10.7	8.0-8.5/2.4 2.6	35-40	20-35	55-70
	40/12	8.5/2.6	35-40	25-40	55-70
Articulated (High Floor)	60/18	8.5/2.6	65	35-55	100-120

Table 3.3 presents bus types and bus capacities of the AACBSE. Next, Table 3.4 shows the actual operating bus types and capacities.

Table 3.3 presents bus types and bus capacities of the AACBSE

Bus Type	Bus Capacity		
	Seating	Standing	Total
Single Anbassa	30	70	100
Articulated	50	100	150
Double Decker	80	60	140

Table 3.4: Bus Capacity based on Field Count

Bus Type	Bus Capacity		
	Seating	Standing	Total
Single Anbassa	29	83	112
Articulated	48	130	178
Double Decker	72	60	132

### 3.6 Variable Selection

The types of variables involved in dwell time study which were acquired from Literature reviews and field pilot study before the commencement of the research are:

- Passengers boarding and alighting the bus;
- In vehicle circulation which is expressed in terms of crowdedness of the bus and the number of passengers without a seat or standees;
- Number of lanes in the bus moving direction (number of approach lanes);
- Floor level raised/steps and low floor level;
- Bunching effect which is expressed as presence of bunching in the bus and no bunching;
- Bus stop/station type Curbside, Road Side, Bus Bay;
- Bus Stop/station location based the nearness to the intersection Near Intersection or Mid-Block;
- Number of Doors: Two or Three;
- Type of Buses; and
- Time of the day.

Table 3.5 Bus and Number of Doors its Use as entrance and Exit

Type of Bus	Number of Doors	Door Use	Note
Single Anbessa Bus	3	Only the middle and the back doors were effective	The doors open and close slowly as the buses are old.(took 10.3 seconds on average)
Single Sheger Bus	2	Front door is for entrance and Back door is for exit	The doors easily open and close.
Double Decker Bus	2	Front door is for entrance and Back door is for exit	The doors easily open and close.
Articulated Bus	3	All the three doors are effective for both entrance and exit	The doors easily open and close.

Table 3.6 below presents the study variables and their corresponding descriptions.

Table 3.6 : Research Variables with their description

Variables	Description
Passengers boarding and alighting the bus	The main determinant factor of dwell time (BTCM and pilot study)
In-vehicle circulation which is expressed in terms of crowdedness of the bus and the number of standing passengers.	The number of standees in Addis Ababa city buses is also the second most determinant factor in dwell time study. BTCM and literature reviewed
Number of lanes in the bus moving direction (number of approach lanes)	For the purpose of this study, number of lanes is classified into two: 2 or less and 3 or more lanes.
Floor level raised/steps and low floor level	The effect of floor level significantly affects dwell time especially if there are a lot of old passengers on the bus.(BTCM and Literature reviewed)
Bunching effect which is expressed as presence of bunching in the bus and no bunching	
Bus stop/station type Curbside, Road Side, Bus Bay	In Addis Ababa, almost all (96% of the studied routes) buses stop alongside of curb sides.(Pilot Study)
Bus Stop/station location based on the	The installment of bus stops: near side and far side

nearness to the intersection Intersection or Mid-Block	Near	intersection stop (NI) or Mid-Block (MB) intersection stops
Number of Doors: Two or Three		The effect of number of doors is seen in Articulated buses which have three doors which gives more room for movements of standees.
Type of Buses		Four types of buses considered here are: single Anbessa, single Sheger Bus, The Long Articulated Bus, and Double Decker Sheger and Anbessa.
Time of the Day		Time of the day is classified into three categories: morning time, mid-day and evening time.(Literature review )

### 3.7 Bus dwell time estimation methods

Bus dwell time can be estimated using three methods (TCQSM 2<sup>nd</sup> edition)

- Field measurements
- Default values and
- Calculation

#### 3.7.1 Field measurements

This is the most accurate and reliable bus dwell time measurement and the average bus dwell time is obtained through a series of observations.

#### 3.7.2 Default values

Sometimes when direct field measurements are not possible representative values can be obtained from manuals. For example TCQSM 2<sup>nd</sup> edition suggests: 60 seconds at a downtown stop, transit center, major on-line transfer point, or major park-and-ride stop; 30 seconds at a major outlying stop; and 15 seconds at a typical outlying stop.

#### 3.7.3 Calculation

The third method requires passenger counts or estimates of passengers boarding and alighting. The calculation method also takes into account the door opening and closing times. Below is the formula which is used to calculate or estimate dwell time as it is suggested by the TCQSM manual.

$$t_d = P_a * t_a + P_b * t_b + t_{oc} \dots \dots \dots \text{Equation 3.1}$$

Where

- t<sub>d</sub> is dwell time;
- P<sub>a</sub> is number of passenger alighting;
- t<sub>a</sub> is time taken by an alighting passenger;
- P<sub>b</sub> is number of passenger boarding;
- t<sub>b</sub> is time taken by one boarding passengers; and
- t<sub>oc</sub> is door opening and closing time.

TCQSM 2<sup>nd</sup> edition suggests a 2-5 seconds for door opening and closing time.

### 3.8 Research Data

#### 3.8.1 Sample size determination

The determination of sample size is essential for any research. Different methods of data size calculations and assumptions are employed by different researchers and some of the techniques employed are presented here.

- Stephen et al (2015) collected 1,783 bus stop events at 60 bus stops from field using field data collection sheet.
- Douglas et al (2014) estimated sample sizes based on the error E and the deviance σ of the mean from the true mean μ and the formula is given by

$$n = \left( \frac{Z_{\alpha/2}}{E} * \sigma \right)^2 \dots \dots \dots \text{Equation 3.2}$$

Where σ is standard deviation from of dwell time data and ε is the error term, α is the significance level of the model and Z the standard value for the given confidence interval.

Given μ=22.7s, σ=9.9 t<sub>d</sub>=20sec, ε= [20-22.7] = 2.7, Z<sub>α/2</sub>=1.96 for 95% confidence interval

$$: n = \{1.96 * 9.9 / 2.7\}^2 = 52 \text{ sample size}$$

$$n \geq 50 + 8m \dots \dots \dots \text{Equation 3.3}$$

Where

n: the sample size

m: the number of independent variables (Green, 1991)

The above is a simple rule of thumb for the estimation of the sample size n on multiple regressions with m independent variables (Green, 1991).

When the regression model uses three (3) variables to develop the model, at least 74 data points are required based on the rule of thumb method. Comparing the formula and the rule of thumb method, 74 data points are required for multiple linear regression model development. A total of 868 data were collected for dwell time analysis, excluding the terminus stops. Out of this; 234 were collected during morning period, 297 were collected during midday period and 259 were collected during the evening period. Table 3.6 and 3.7 below shows Summary of Number of Data by Time of Day and Bus and Number of Doors its Use as entrance and Exit.

Table 3.7: Summary of Number of Data by Time of the Day

Bus Type	Bus Size	Morning (12:00AM- 9:00AM)	Mid-day (10:00AM - 4:00 PM)	Evening Peak (5:00PM-8:00 PM)	Total
Old Anbessa Bus	12m length	78	90	60	228
Sheger Bus	12m	77	51	57	185
Double Decker Bus	12m	74	56	60	190
Articulated Bus	18m length	83	100	82	265
Total		234	297	259	<b>868</b>

### 3.8.2 Primary Data Collection Procedure

#### 3.8.2.1 General

Prior to field data collection, information related to other data collection schemes was studied. Most of the researchers followed manual data collection schemes as it results better. Daniel B.S. et.al (2015) employed the Automatic Passenger Counting (APC) and Automatic Fare Payment (AFC) to develop regression model of dwell time. Stephen A. et al (2015) tried to employ Automatic Passenger Counting (APC) and Automatic Vehicle Location (AVL) system for the purpose of dwell time and total travel time data collection. Comparison of data using the APC/AVL and field data for the trial sample of

study-related locations revealed major differences that could not be reconciled such as missing records in the APC and AVL data base when compared to the records obtained in the field data collection. So they concluded that it is better to collect dwell time data manually. So recording data manually, which uses stop watch and data collectors at each door, is a proven method in capturing quality assured data for dwell time study.

The primary data of this study includes the following field data collected for the study. The field data included principally the counting of passengers boarding and alighting the bus while the bus stops and the number of standees inside the bus. The data were collected for three periods of the day: Morning time (12:30AM - 9:00AM), Midday time (10:00AM - 4:00PM) and Evening time (5:00PM - 7:30PM) to capture the differences which could be obtained from day time and peak hour activities. The times were selected based on the passengers' activities of boarding and alighting. During morning peak and evening peak periods, a lot of passengers boarding and alighting were expected and conflicts with the onboard passengers were high so did dwell time. For the purpose of this study, Morning times represents 12:30AM up to 9:00AM and Mid-Day represents from 10:00AM to 4:00M and Evening time represents from 5:00PM to 7:30PM.

### **3.8.2.2 Procedure**

The following procedure is used to collect the important dwell time data for this study.

- Four types of buses were initially selected for this study. The types of buses selected were supposed to include the effects different types of buses on dwell time determination of the factors. The types of buses included in the study were the following: Old Anbessa Buses, Anbessa Articulated Buses; from Modern Buses, Sheger Bus was selected, and Double Decker Buses were selected because of the difference in its structure.
- Preparing essential equipment for data collection like: pencil, sheets, stop watch video recording cameras and also a supervisor, and others. Data collectors were assigned at each door to count the boarding and alighting passengers;
- The supervisor takes note of the road geometry like number of lane, fare collection system, stop location, stop types, and initially records the bus type, number of doors, and the bus capacity by counting the number of seats, route origin and destination, starting and end time of the bus, floor level of the bus to distinguish between low floor from raised floors.

- The supervisor uses stop watches to record the elapsed time between door opening and door closing. When the bus comes to a complete halt and door starts opening, stop watch starts counting and when doors are completely closed the stop watch stops counting and the time is recorded.
- The other data collectors that were assigned at each door (two data collectors in case of two door buses and three data collectors in case of three door buses) counts the number of passengers alighting and boarding.
- The initial and the final stops were not considered as they were terminal stations and recording begins between initial and final passengers loading and unloading as the terminal stations don't tell the real dwell time of the routes selected.
- Finally, the recorded data were summarized in a sheet of paper and is attached in Appendix B.
- The final data collecting sheet included the following information
  - Name of the Bus,
  - Bus Floor Type,
  - Number of Doors,
  - Starting Time, End Time,
  - Time of day (Morning ,Mid-day, Evening),
  - Route Origin, Through and Destination,
  - Bus Stop Number,
  - Elapsed time,
  - Number of Boarding Passengers  $P_b$ , Alighting Passengers  $P_a$ , Number of Standees  $N_s$ ,
  - Location of Stop [Mid-Block(MB) or Near Intersection(NI)],
  - Stop Type [Curbside Stop(CS) or Bus Bay(BB)], and
  - Number of lanes along bus travelling directions.
  - Fare collection scheme (inside the bus or outside the bus)

The following assumptions were made during bus dwell time data collection:

- Terminus (start and end) stops are not taken for dwell time analysis as they lead wrong impression of dwell time due to too much extended time in there;
- The number of standees (passengers on a standing position while travelling) is calculated from initial volumes, cumulative passengers alighting and cumulative boarding passengers at each station/stop as shown in the formula below and takes

some control volumes of standing passengers to check it's true that the formula is working right.

$$NS_i = \sum_{i=1}^n CB_i - CA_i - SC \dots \dots \dots \text{Equation 3.4}$$

Where:

- $NS_i$  is Number of Standees at station  $i$ ;
- $CB_i$  is cumulative of passengers boarding at station  $i$ ;
- $CA_i$  is cumulative of passengers alighting at station  $i$ ; and
- $SC$  is the Seating capacity of each type of buses.

The four types of buses are assumed to represent the dwell time determinant factors for Addis Ababa city. The four types of buses (single Anbessa City Buses, the Articulated Anbessa City buses, the single Sheger Buses and the New to the country Double Decker Anbessa and Sheger buses) could represent the whole buses' dwell time activities in the city.

Most of the terminals are incorporated (Megenagna and Menillik II square and Merkato from Major terminals and Ayer Tena, 6 Killo and 4 Killo from minor terminals) in the dwell time data collection to consider the variability.

### 3.9 Research Materials

#### 3.9.1 General

The materials used for this research are grouped under three categories these are: data types, software used for data recording and analysis, and equipment for data recording and writing.

#### 3.9.2 Data types

##### 3.9.2.1 Primary data types

- Counts of the number of passengers boarding, alighting and standing;
- Number of lanes along specified routes;
- Total travel time of the bus on the specified routes;
- Dwell time data on that route;
- Types of buses;

- Number of bus doors (two or three);
- Time of day (Morning ,Mid-day, Evening),
- Fare collection method;
- Origin, through and destination names of each route;

### **3.9.2.2 Secondary data types**

- Passenger seating capacity of buses;
- Notes and remarks during data collection; and
- Office interviews.
- Length of the routes;
- Passenger seating capacity of buses;
- Origin, through and destination names of each route;

### **3.9.3 Software**

- Microsoft Excel 2010 was utilized for minor data analysis, recording and arranging.
- Analysis ToolPAK in Excel was utilized as the Main Analysis tool.
- SPSS Software was used as the analysis tool to check results.
- Google Earth was utilized to get the aerial map of different routes and Addis Ababa.

## **3.10 Analysis Methods**

### **3.10.1 General**

The methods of analysis and the validation techniques of the analysis are discussed below. Two types of analysis such as descriptive statistical analysis and model development using multiple regression techniques are used along with the validation methods of the developed models. In addition to analyzing the collected dwell time data, a questionnaire is used to grab bus users' response towards bus dwell time and the overall bus usage.

### **3.10.2 Statistical Analyses**

Descriptive statistics was used to determine the mean, median, and standard deviation, among others. This was done for: four bus types, two bus stop locations, three times of

the day (periods), two types of fare collection methods and for two categorized lane group types.

### 3.10.3 Model Development

Based on statistical analysis results and data characteristics, of dwell time, a generalized regression model was developed for dwell time (DT). The generalized regression model for DT is a function of: passengers boarding, passengers alighting, and number of standees for different types of buses, time of the day, different fare collection methods, different number of lane groups and different types of bus floor levels. The DT function model is depicted in Equation 3.1 below,

$$DT=f(Pa,Pb,Ns).....Equation\ 3.5$$

where

- DT: Dwell Time in seconds;
- Pb: Number of passengers boarding;
- Pa: Number of passengers alighting; and
- Ns: Number of passengers who stand on the bus

### 3.10.4 Regression Analysis

Standard multivariate regression analysis was employed to develop the DT models for the bus stops during morning, midday, and, evening peak hours. The statistical analyses were conducted using Excel and validated using the SPSS software. The statistical significance of the regression coefficients of the resulting model(s) were tested at 5% level of significance. In addition, the overall statistical significance of each regression model for each bus stop type was tested using the *F*-test (ANOVA) at 5% significance level.

#### 3.10.4.1 Regression Model Validation Methods

The following methods were employed to validate the developed models: R<sup>2</sup> and adjusted R<sup>2</sup>, *F*-Test, residual plots, normal probability plots,. The first two are based on two sums of squares: sum of squares total (SST) and sum of squares error (SSE). SST measures how far the data were from the mean and SSE measures how far the data are from the model's predicted values. Different combinations of these two values provide different information about the validity of the regression model compared to the mean model.

#### 3.10.4.1.1 $R^2$ and Adjusted $R^2$

As explicitly stated in "blog.minitab.com/blog/adventures-in-statistics-2/regression-analysis", these parameters were used to determine the goodness of fit of the model.  $R^2$  scale is intuitive: it ranges from zero to one, where zero indicates no improved prediction over the mean model and one indicates perfect prediction. Improvement in the regression model results in proportional increases in  $R^2$ . One drawback of  $R^2$  is that it can only increase as predictors are added to the regression model. This increase is artificial when predictors are not actually improving the model's fitness. To remedy this, a related statistic, adjusted  $R^2$ , incorporates the model's degrees of freedom. Adjusted  $R^2$  decreases as predictors are added if the increase in model fit does not offset the loss of degrees of freedom. Likewise, it will increase as predictors are added if the increase in model fit is worthwhile. Adjusted  $R^2$  should always be used with models having more than one predictor variable. It is defined as the proportion of total variance that is explained by the model.  $R^2$  cannot determine whether the coefficient estimates and predictions are biased, which is why it is necessary to assess the residual plots.  $R^2$  doesn't indicate whether a regression model is adequate. You can have a low  $R^2$  value for a good model, or a high  $R^2$  value for a model that doesn't fit the data.

#### 3.10.4.1.2 F-test

As further stated in "blog.minitab.com/blog/adventures-in-statistics-2/regression-analysis", the F-test evaluates the null hypothesis that all regression coefficients are equal to zero, versus the alternative that at least one does not. An equivalent null hypothesis is that  $R^2$  (or adjusted  $R^2$ ) equals zero. A significant F-test indicates the observed  $R^2$  (or Adjusted  $R^2$ ) is reliable and not a fake result of oddities in the data set. Thus, the F-test determines whether the proposed relationship between the response variable predictors is statistically reliable. This is useful particularly when the research objective is to develop a predictive model. If the value of this test statistic is large, then the regression "works well" and at least one predictor in the model are relevant for the response. The F-test statistic and p-value are reported in the regression ANOVA table (columns F value and Pr (>F). M. Bremer (2012).

#### 3.10.4.1.3 Residual plots

Regression models were checked for homoscedasticity (constant variance). The residuals from a fitted model are the differences between the observed variables and the

corresponding predicted values using the regression function developed. Mathematically, the definition of the residual for the  $i$ th observation in the data set is defined as: (Stephen A. & Errol N. 2015).

$$e_i = y_i - f(x_i; \beta) \dots \dots \dots \text{Equation 3.4}$$

With  $y_i$  denoting the  $i$ th response in the data set and  $x_i$  the vector of explanatory variables, each set at the corresponding values found in the  $i$ th observation in the data set. If the model of the data were correct, the residuals would approximate the random errors that make the relationship between the explanatory variables and the response variable in a statistical relationship. Therefore, if the residuals appear to behave randomly, that would indicate the model fits the data well. On the other hand, if a non-random structure were evident in the residual plots, this would be a sign that the model fits the data poorly. (D.C. Montgomery et al 2014)

#### **3.10.4.1.4 Normal probability plots:**

Normal probability plots a graphical technique that indicates whether a data set is approximately normally distributed – were used to validate the model. In a normal probability plot, if all the data points fall near the line, an assumption of normality is reasonable. Otherwise, the points will curve away from the line, and an assumption of normality is not justified (Stephen A. & Errol N. 2015).

#### **3.10.4.1.5 Collinearity Statistics**

Collinearity Statistics is used to check the presence of multicollinearity in the independent variables. The presence of multicollinearity affects the models coefficients severely and leads to poor fit of the model. Two methods of checking for the presence of multicollinearity have been discussed in the report. The Variance of Inflation Factor (VIF) and the significance of the coefficients of the developed models are the two methods of checking the presence of multicollinearity in the developed models. (D.C. Montgomery et al 2014)

### **3.11 Bus Users Questionnaire**

Bus Users Questionnaire is included in the research to strengthen and compare the findings of the research with people's attitude towards the dwell time of the buses and

the overall performance of bus loading areas. 12 closed type questions are prepared for bus users and non-bus users to answer and 60 numbers of respondents are involved in the questionnaire. The questionnaire includes the following type of questions such as: whether they use buses for transport and how often they use it, the comfortable bus type, on the waiting time for buses, bus stop locations, difficulty on loading and unloading of passengers, how to encourage mass transportation usage, regarding dwell time duration. The questionnaires are filled by bus users and responses are obtained through interviewing the questionnaire, via social networks and directly filled by respondents. The sample questionnaire is attached on the appendix part E at the end of the page.

## **CHAPTER 4 RESULTS AND DISCUSSION**

### **4.1 Introduction**

Chapter four presents the results and discussion of the analysis of dwell time. three types of analysis results are discussed below such as descriptive analysis results, multiple linear regression analysis results and model results. The results of the analysis were discussed using graphs, tables, and statistical parameters. Aside from those results of the questionnaire analysis and case study on the performance of the bus stops would also be discussed.

### **4.2 Dwell Time Descriptive Statistics**

Organizing and summarizing the data in ways that facilitate its interpretation and subsequent analysis is called descriptive statistics (Douglas C. and George C. 2014). Descriptive statistics includes the mean, mode and median, the standard deviation and etc. Both numerical and graphical methods were employed in analyzing the dwell time data to capture important features of the data which helps the decision making process. The dwell time data are collected, organized, sorted and grouped so that it would be comfortable for the subsequent analysis.

The overall mean dwell time was found to be 25.41 seconds without considering any determinant factors and the overall mean values of boarding and alighting passengers and numbers of standees were calculated to be 3.24, 4.01, and 27.80 passengers respectively. Due to the stochastic nature of public transport operations, statistical measures such as standard deviation or percentiles are logical indicators. Standard deviation of travel times is the most commonly used measure of travel time variability. The coefficient of variation (CV) which is standard deviation divided by the mean dwell time indicates journeys reliability and as it tends towards zero the reliability increases (Parsons B. 2013)

#### **4.2.1 By Type of Bus**

Analysis of bus dwell time uses four types of Addis Ababa city buses along different routes of the City and during different times of the day (includes the three periods of

time such as Peak Morning, Mid-day and Peak Evening time). From descriptive analysis of dwell time, the mean dwell time was found to be higher for Sheger buses which seemed contrary to the expectation as Sheger bus is new and modern to the Addis Ababa City and next was single Anbassa buses with higher mean dwell time value as expected due to the oldness of the buses that would logically take more time serving passengers during boarding and alighting. The congested passengers are the reasons for the increase in dwell time for single Anbassa bus and the presence of only two doors in single Sheger bus contributes for an increase in dwell time.

The other important determinant factor was the mean number of standees inside the buses. The mean number of standees was higher for Articulated buses and Old Anbassa buses. The Sheger and Double Decker buses do not allow too many passengers to be congested inside the vehicle. The mean passenger boarding and alighting are more or less the same. Sheger and Double decker buses use one door for entrance and the other for exit while the other buses' doors are not restricted either for entrance or exit.

**The mean dwell time of Single Anbassa bus is less than Single Sheger bus as the single Anbassa bus has three doors for loading and unloading passengers. This is shown on the average boarding passengers of the two bus types. The number of boarding passengers of single Sheger bus is more than the number of boarding passengers in single Anbassa bus.**

The coefficient of variation (CV) is another important parameter indicating the dwell time variability and depends on the factors that dwell time is affected by. It is calculated by dividing standard deviation of dwell time by the mean dwell time. It can be as large as 0.8 for US cities and for Addis Ababa the CV value is as large as 1.0 which shows that some values of dwell time are two time greater or lesser than the mean dwell time which indicates the less reliability of the bus transport.

$$Cv = \frac{SD}{\mu} \dots \dots \dots \text{Equation 4.1}$$

Where

: SD represents the standard deviation of the dwell time; and

:  $\mu$  represents the mean dwell time.

The detailed results of the descriptive statistics analysis by bus types are attached in Part C of the Appendix and the relevant values are presented in Table4.1 below.

Table 4.1: Descriptive Statistics of dwell time variables for four types of buses

Variable	Type of Bus			
	Single Anbassa	Single Sheger	Double Decker	Articulated
Mean Dwell Time	26.37	27.86	23.05	24.38
Mode of Dwell Time	15.00	13.00	12	12
Mean Passenger boarding	3.00	3.39	3.33	3.25
Mean Passenger alighting	4.32	4.68	3.45	3.57
Mean Number of Standees	38.00	20.00	13.00	39.00
S.D for Dwell Time	24.92	29.36	21.03	20.86
Cv for Dwell Time	94%	105%	91%	85%

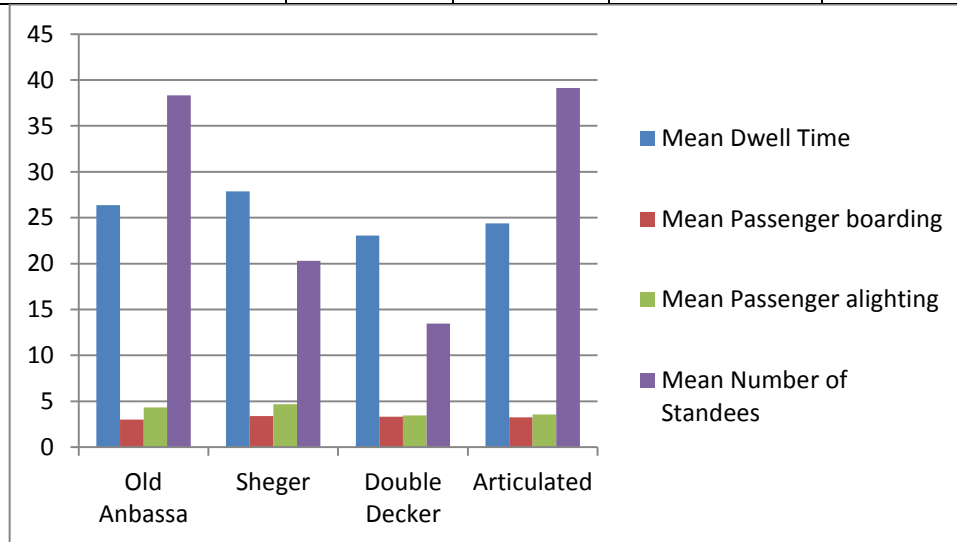


Fig 4.1 graphical comparison of mean of dwell time, passenger boarding and alighting and number of standees

**4.2.2 Time of the Day**

One of the determinant factors of dwell time is considered to be the time of the day in which dwell time data are collected. Three different times of the day were considered here. The Morning peak which ranges from 12:00AM to 9:00 AM, the mid-day period which ranges from 10:00AM to 4:00PM and the evening peak period which ranges from 5:00PM to 8:00PM were the times the data were collected and the results of the analysis are presented in Table 4.2 below. Subsequently, Figure 4.2 illustrates the graphical description of mean of dwell time and number of standees

The mean dwell time for evening peak periods was found to be higher than the morning period and the morning dwell time was higher than the mid-day period. The mean number of standees during mid-day was 18.00 indicating that the Addis Ababa city buses are almost always giving services beyond their seating capacity and the dwell time increases as the number of the standing passengers inside the bus increases.

During peak periods of morning and evening time, the buses are full and seating chairs are not available and standing positions are also not available that much. So during loading and unloading of passengers crowding effect is inevitable. Passengers took too much time to aboard to the bus and alight from the bus. In addition to the crowding effect, the poor fare collection mechanism also contributes to the increase of dwell time in an extreme way. The increase of dwell time due to poor fare collection mechanism is exacerbated when a couple of passengers needs a change to their fare.

Table 4.2: Descriptive Statistics of dwell time variables for the three periods d=of the day

Statistics Values	Time Period		
	Morning AM	Mid-Day MD	Evening PM
Mean Dwell Time	25.36	18.79	32.79
Mean Passenger Boarding	3.05	2.49	4.29
Mean Passenger Alighting	4.44	2.97	4.60
Mean Number of Standees	32.62	18.06	38.04
S.D. for Mean D.T.	24.19	17.25	28.06
Confidence Level for Mean (95.0%)	2.72	1.97	3.42

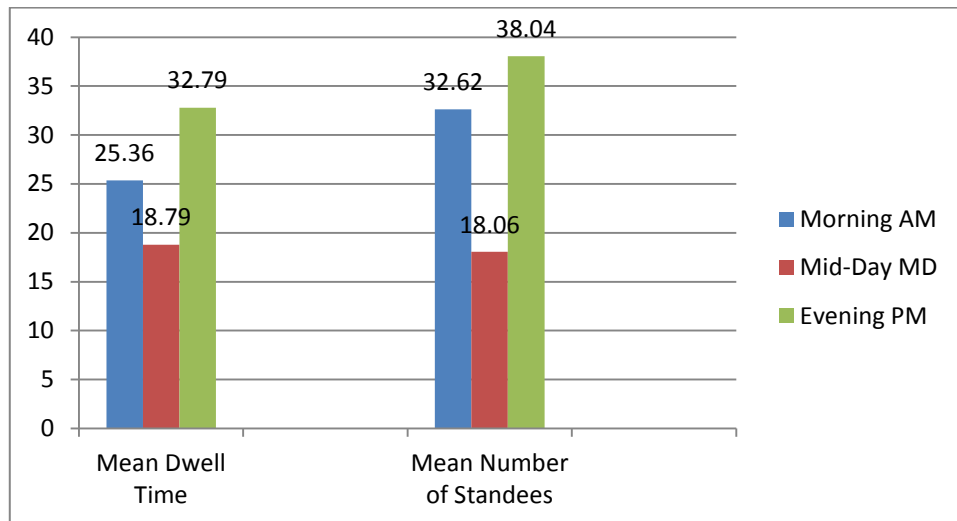


Fig 4.2: Graphical description of mean of dwell time and number of standees for three time periods

### 4.2.3 Bus stop location

The bus stop location is divided into three categories as follows: mid-block, near side and far side bus stop locations. For the purpose of this paper, the near side and the far side bus stop locations are categorized under the same group and called near intersection bus stop location. The mean dwell time of the near intersection bus stop location is greater than the mean dwell time of the mid-block bus stop location by 2.33 seconds. The other descriptive statistical values were found to be more or less the same. So, stop location is one of the determining factors of the Addis Ababa City bus transportation. Table 4.3 below presents descriptive statistics of dwell time variables by bus types.

Table 4.3: Descriptive Statistics of dwell time variables for two types of bus stop locations

Statistics Values	Location of Stop	
	Mid-Block (MB)	Near Intersection (NI)
Mean Dwell Time(sec)	24.28	26.61
Mean Passenger Boarding (#)	3.15	3.36
Mean Passenger Alighting (#)	3.49	4.57
Mean Number of Standees (#)	29.00	29.00

S.D. for Mean	25.40	22.22
Confidence Level for Mean (95.0%)	2.28	2.23

#### 4.2.4 Fare Collection System

The fare collection systems of Addis Ababa city buses are not modern. They don't use modern technologies like Electronic smart media cards, Magnetic Swipe, prepay etc. During the pilot survey of this research, it was observed that the fare collection system was manual. Although the fare collection media is manual, it was observed that the technique was also two types: the first one is after the passengers are fully inside the bus and the second one type is while the passengers are outside of the bus and they pay their respective bills and go to one of the two/three doors to get in.

It can be seen in Table 4.4 below that the mean dwell time for the outside fare collection system is much higher than the inside and the outside fare collection is employed when the numbers of standees in the buses were high and in this case the mean number of persons was calculated at 58.00. Figure 4.3 below illustrates one of the outside fare collection Schemes. This is not a scheme, the ticket buyers are not in a proper queue.



Figure 4.3: Outside fare collection Scheme

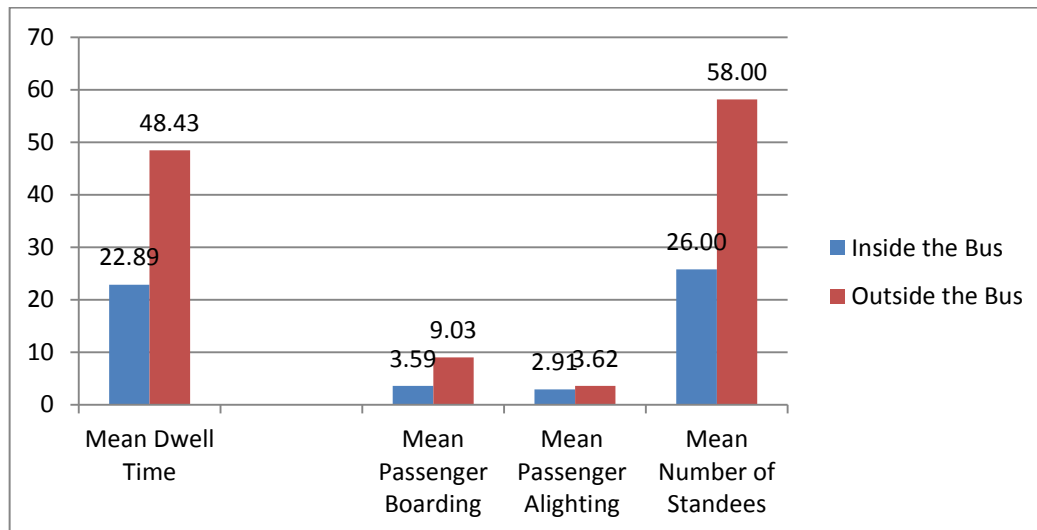


Fig 4.4: Descriptive statistics of fare collection systems

#### 4.2.5 Number of Lane groups

The number of lanes along the study routes range from one lane to four lanes. In this study, the numbers of lanes were categorized into two groups. Most of the studied routes comprise of either two or three number of lane roads. So the routes were categorized into two groups: in first group; routes with two or less lanes and in the second group routes with three or more lanes. The mean dwell time for three or more lane groups is a bit higher than that of two or less lane group routes as the average number of boarding and standing passengers is a bit higher. Other descriptive statistics parameters are more or less the same.

Table 4.5: Descriptive Statistics of dwell time variables for two types of lane groups

Statistics Values	Number of Lane in the direction of bus movement	
	Two or Less	Three or More
Mean Dwell Time(sec)	24.75	25.77
Mean Passenger Boarding (#)	3.08	3.32
Mean Passenger Alighting(#)	3.99	3.99
Mean Number of Standees(#)	27.19	30.76
S.D. for Mean	25.85	22.79
Confidence Level for Mean (95.0%)	2.71	1.99

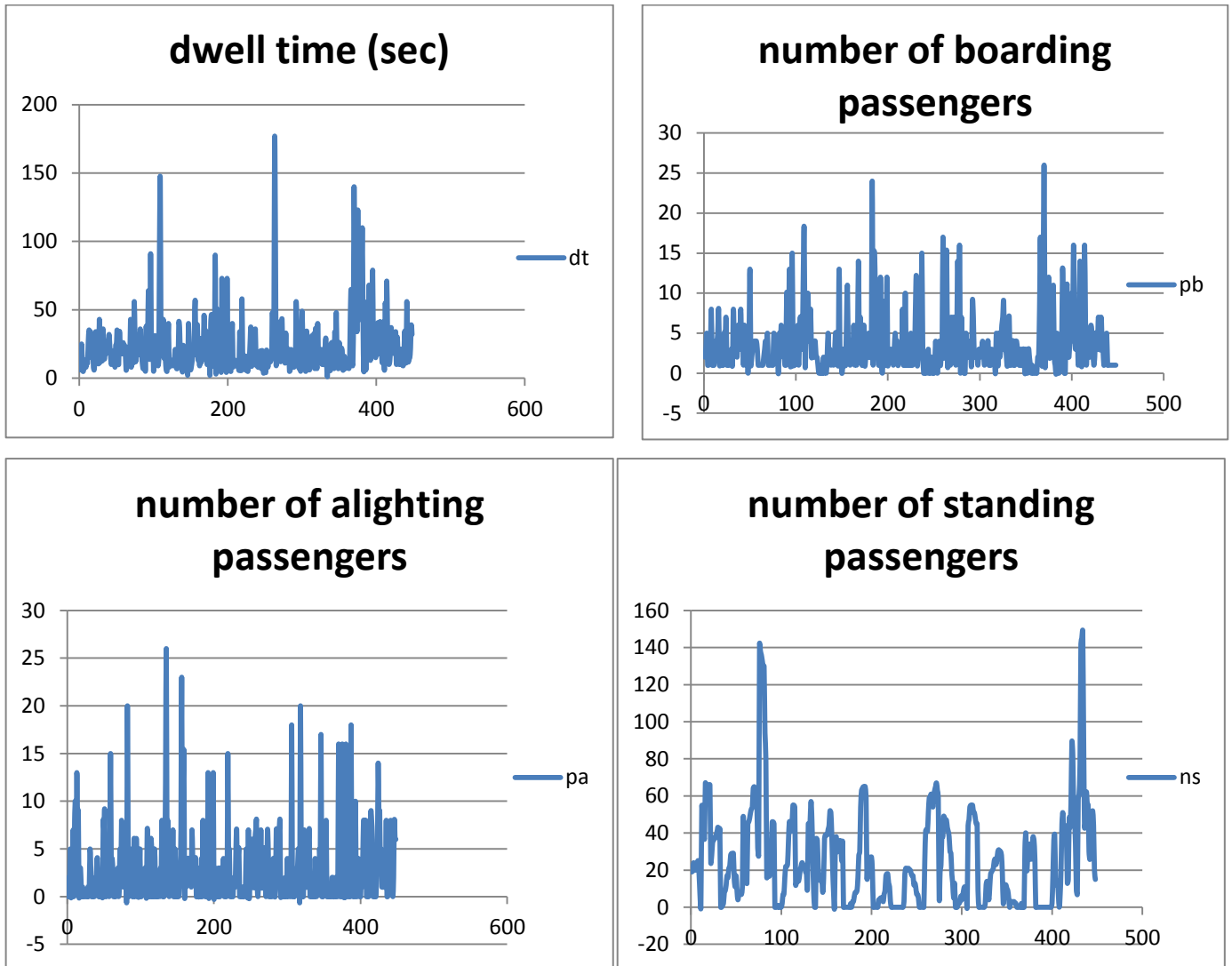
#### 4.2.6 Bus floor level

The floor levels of the Addis Ababa City buses were divided into two categories. Low floor buses are buses with no stairs to climb up the bus whereas raised floor buses have one or two steps to climb up the bus. Sheger and Double Decker buses have low floor level floors while the old Anbassa buses and the Articulated buses have raised floor levels. In this regard, the results of the descriptive statistical analysis of this research indicated that the floor levels of buses do not affect the mean dwell time. The number of standees in high raised floor buses is greater than in low floor buses. The mean dwell time during passengers alighting and boarding for the two types of floor levels are more or less similar. Table 4.6 below presents the descriptive statistics in both cases of floor levels.

Table 4.6: Descriptive Statistics of dwell time variables for two types of bus floor levels

Statistics Values	Floor Level of Bus	
	Low Floor	Raised Floor
Mean Dwell Time (sec)	25.43	25.29
Mean Passenger Boarding(#)	3.36	3.13
Mean Passenger Alighting (#)	4.07	3.92
Mean Number of Standees (#)	17.00	39.00
S.D. for Mean	25.58	22.82
Confidence Level for Mean (95.0%)	2.60	2.03

In general from the dwell time descriptive analysis, it can be said that the dwell time duration shows a similar pattern with the number of passengers boarding and alighting but not with the number of standees in the bus. This can be demonstrated in Figure 4.5 below. The pattern of the scatter chart shows similarity between dwell time, passengers alighting and passengers boarding but not with number of standees inside the bus.



Note: Ns: Number of standings; Pa: Passengers Alighting; Pb: Passengers Boarding; DT: Dwell time

Figure 4.5: Scatter diagram of dwell time, number of standees, passenger alighting and passenger boarding

The detailed descriptive analysis of dwell time which includes: mean, standard error, median, mode, standard deviation, sample variance, Kurtosis and skewness of data, range, minimum and maximum of the data, sum of the data and counted data under each categories, and the 95% confidence interval are attached in the Appendix part C.

### 4.3 Model Development

#### 4.3.1 General

It is hypothesized that the number of passengers boarding the bus and alighting the bus affects the dwell time. The number of passengers standing inside the bus also affects the dwell time estimation when they are beyond the capacity of the buses.

Regression models were developed for all cases; four bus types, three periods of the day, two fare collection types, two lane groups, two floor level types and for location of the stops. The regression model was developed using the Analysis ToolPak software in Excel and checked by SPSS software. It was found that the Analysis ToolPak software in Excel is handy for this analysis. Analysis ToolPak is a tool for financial and scientific data analysis.

#### 4.3.2 Multiple Linear Regression Analysis to develop Regression Models

A number of ways is possible to the regression analysis for dwell time determination like simple ordinary least square (OLS) regression that is multiple linear regression and logarithmic regression technique as developed by Levinson (1983). Lijun et al (2014) used multiple linear regression models involving passengers boarding, alighting and standing on the floor.

For all types of developed models, the regression model relates the dependent variable which is the dwell time and the three independent variables which are the number of passengers boarding, the number of passengers alighting and the number of standees inside the bus.

$$DT = f(Pb, Pa, Ns) \dots \dots \dots \text{Equation 4.2}$$

Where

Pb = number of passenger boarding;

Pa= number of passengers alighting; and

Ns= number of passengers standing.

The adequacy and significance of the regression models were tested at a significance level of 5% or 95% confidence interval. For all dwell time models, the number of passengers and the number of passengers alighting contributed to the model significantly

and the coefficients of the developed models indicates that too. The RMSE of the developed models differ one from the other which indicated that the developed models are significantly different from each other and dwell time model developed for Evening period should not be used for dwell time model for mid-day period. Summaries of the regression analyses are presented in Table 4.7 below and the detailed results of the regression analysis are presented in Appendix D.

Table 4.7: Summary of Model results

ANOVA					
Model Equations		R2	Adjusted R2	F-value	Significance F
<b>Bus Type</b>					
Old Anbassa Bus	$DT=0.92+3.32Pb+1.40Pa+0.25Ns$	0.60	0.57	101.97	0.000
Articulated Bus	$DT=9.91+2.40Pb+1.94Pa-0.01Ns$	0.51	0.50	89.90	0.000
Sheger Bus	$DT=5.21+4.13Pb+1.46Pa+0.09Ns$	0.70	0.67	126.69	0.000
Double Decker Bus	$DT=4.68+3.82Pb+1.79Pa-0.02Ns$	0.60	0.59	91.40	0.000
<b>Time of the Day</b>					
Morning	$DT=8.88+3.40Pb+1.25Pa+0.02Ns$	0.60	0.56	130.74	0.000
Mid-day	$DT=4.62+2.99Pb+1.54Pa+0.12Ns$	0.60	0.58	135.17	0.000
Evening	$DT=9.77+3.34Pb+1.84Pa+0.11Ns$	0.52	0.51	90.44	0.000
<b>Bus Stop Location</b>					
Mid-Block	$DT=5.44+3.38Pb+1.66Pa+0.08Ns$	0.60	0.59	226.31	0.000
Near Intersection	$DT=8.81+3.22Pb+1.44Pa+0.02Ns$	0.52	0.51	134.75	0.000
<b>Fare Collection Scheme</b>					
ANOVA(Continued)					
Model Equations		R2	Adjusted R2	F-value	Significance F
Inside	$DT=5.32+3.42Pb+1.44Pa+0.05Ns$	0.54	0.53	171.77	0.000
Outside	$DT=21.68+3.28Pb+0.94Pa-0.11Ns$	0.50	0.50	19.18	0.000

<b>Floor Level</b>					
Low Floor	$DT=4.68+3.99Pb+1.59Pa+0.06Ns$	0.65	0.64	226.71	0.000
Raised Floor	$DT=8.22+2.82Pb+1.52Pa+0.06Ns$	0.50	0.50	161.2	0.000
<b>Number of Lanes</b>					
Two or Less	$DT=4.82+3.62Pb+1.60Pa+0.09Ns$	0.62	0.62	190.98	0.000
Three or More	$DT=8.92+3.09Pb+1.51Pa+0.02Ns$	0.52	0.51	178.37	0.000

### 4.3.3 Model Validation

#### 4.3.3.1 R-Squared, Adjusted R-Squared Values and F-Statistics

The R-Squared and Adjusted R-Squared values of each model are well above the marginal value which is 0.5 and the F-statistic for the developed models and for each variable are significant. The R-Squared, Adjusted R-Squared Values and F-Statistics with its significance level are shown on the above tables in respect of each determining factor and along with the developed models.

#### 4.3.3.2 Residual Plots and Probability Plots

In addition to the F-statistic and adjusted R-Squared values, residual and probability plots of the developed models are used to check whether the data fits the developed models well. So the developed models show randomness of residuals about zero line indicating that the fitted models are viable enough. Probability plots of the developed models shows the points are near the straight line for most of the time indicating the appropriateness of the fitted data points.

The randomness of the distributed residuals which are the error terms of the developed models indicates also the predicted values are not taken from only one side values. If the graph were fallen in one side of the zero line, the developed model is not fair enough to be trusted.

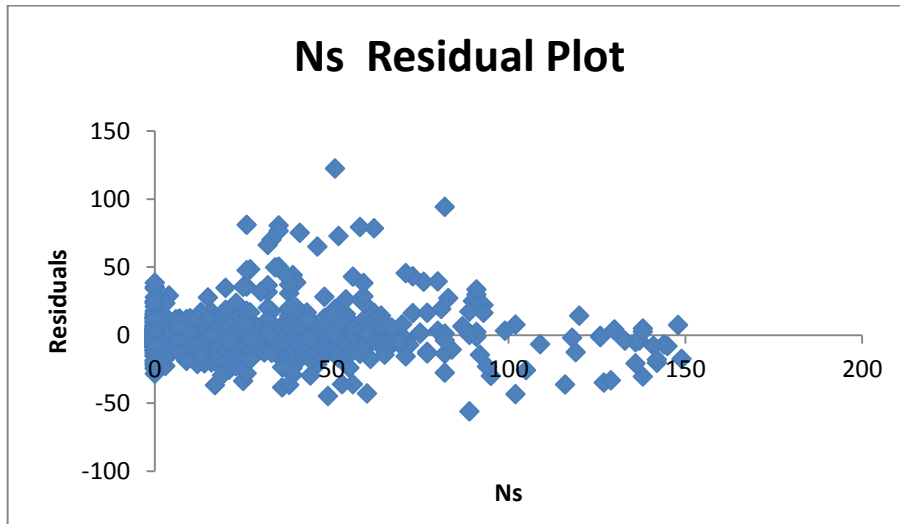


Fig 4.6: Residual plot of number of standees for the overall developed model

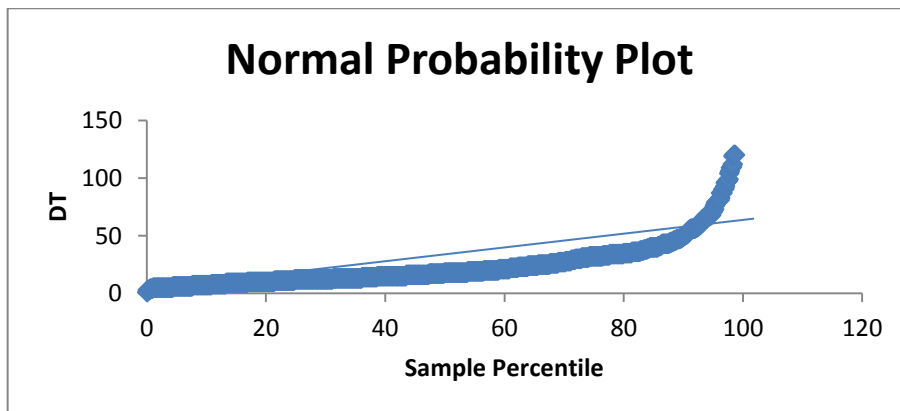


Fig 4.6: Probability plot of Dwell time showing similarity with the regression line

#### 4.3.3.3 Collinearity Statistics

The presence of multicollinearity in the developed models has serious effects on estimation of the regression coefficients and on the general applicability of the estimated models. The estimate the regression coefficients are imprecise when multicollinearity is present. Two of the several methods of checking the presence of multicollinearity are presented here as it is discussed in Douglas C. Montgomery, George C. Runger.

- a) The variance inflation factors are very useful measures of multicollinearity. The larger the variance inflation factor, the more severe the multicollinearity. Some authors have suggested that if any variance inflation factor exceeds 10, there is a problem of multicollinearity.
- b) If the  $F$ -test for significance of regression is significant but tests on the individual regression coefficients are not significant, multicollinearity may be present.

Using the above two techniques, the presence of multicollinearity was checked for all developed models using: the SPSS Software, the Variance of Inflation factor (VIF) and the F-test statistic method in Analysis ToolPak in Excel Software. The VIF values are close to unity for all developed models which indicate multicollinearity is not a problem for the developed models. Table 4.13 below presents the Variance of Inflation Factor of the SPSS output for the Old Anbassa bus

Table 4.13: The Variance of Inflation Factor of the SPSS output for the single Anbassa bus

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1 (Constant)	0.916	2.290		0.400	0.690	-3.597	5.428		
passenger boarding	3.324	0.238	0.628	13.967	0.000	2.855	3.793	0.937	1.067
passenger alighting	1.402	0.193	0.321	7.264	0.000	1.021	1.782	0.968	1.033
standees	0.246	0.045	0.250	5.493	0.000	0.158	0.335	0.913	1.095

## 4.4 Bus Travel Times

### 4.4.1 General

Bus Travel Times are used to check for preparing schedules and monitoring on-time performances by transit agencies. Speed and delay measurements of bus operations on arterial streets are sometimes part of transit and traffic studies. However, there have been relatively few systematic analyses of bus travel times (TCRP Report 26).

Maloney and Boyle (in Fang Zhao and Ming-Tang Li, 2005) stated that actual travel time along the route takes 59% of the total travel time and dwell time accounts for 7% of the total travel time. Total travel time is time from the beginning of the initial bus stop to the final destination stop. Total travel time is measured by recording the buses initial and destination times. In this study, the dwell time was found to be 14.0% of the total travel time which was twice of the Maloney and Boyle findings. Tables 4.14, 4.15, 4.16 and 4.17 below presents total travel time, total dwell time and the percentage of dwell time

out of the total travel time for Old Anbassa Bus, Sheger Bus, Articulated Bus and Double Decker Bus respectively.

The percentages were calculated using the following formula:

$$X = \frac{TDT}{TTT} * 100\% \dots \dots \dots \text{Equation 4.4}$$

Where

X: percentage of dwell time out of the total travel time;

TDT: total dwell time

TTT: total travel time from beginning of the journey to end of the journey.

Table 4.14: Total Travel Time, Dwell Time and Dwell time as a percentage of total travel time for the single Anbassa Bus

Single Anbassa Bus						
Route	Time Period	Data Count	Total Travel Time (min)	Total Dwell Time(min)	Length(Km)	TDT/TTT(%)
Burayou to Merkato	AM	23	77.00	5.00	12	6.49
Sansusi to Piassa	AM	21	84.00	14.13	9.7	16.83
Addisu Gebeya to	AM	18	65	7.05	13	10.85
Megenagna to Addisu	AM	18	48.00	6.48	13	13.50
6 Killo to Hayat	MD	29	67.00	6.28	18	9.37
Burayou to Merkato	MD	26	74.00	13.20	12	17.84
6 Killo to Hayat	MD	29	70.00	6.45	18	9.21
Piassa to Megenagna	MD	10	28.00	2.63	7.5	9.39
Hayat condominium to Megenagna	PM	14	74.00	4.63	13	6.26
Piassa to Ayer Tena	PM	13	59.00	11.77	11	19.95
Piassa to Ayer Tena	PM	16	68.00	11.42	8.6	16.79
Piassa to Sansusi	PM	21	88.00	10.27	9.7	11.67
Average						12.35

Table 4.15: Total Travel Time, Dwell Time and Dwell time as a percentage of total travel time for the single Sheger Bus

<b>Sheger Bus</b>						
Route	Time Period	Data Count	Total Travel Time (min)	Total Dwell Time (min)	Length (km)	TDT/TTT (%)
Piassa to Saris Abo	AM	20	36.00	5.23	12	14.53
Saris Abo to Piassa	AM	19	74.00	7.65	12	10.34
Piassa to Saris Abo	AM	21	49	8.40	12	17.14
Saris Abo to Piassa	AM	20	81.00	9.62	12	11.88
Piassa to Mebrat Condominium	MD	19	75.00	3.47	10	4.63
Mebrat to Piassa	MD	22	64.00	8.22	10	12.84
Piassa to Megenagna	MD	13	26.00	3.98	7.5	15.31
Mebrat to Piassa	PM	16	42.00	4.78	10	11.38
Piassa to Mebrat Condominium	PM	15	46.00	10.55	10	22.93
Piassa to Mebrat Condominium	PM	15	48.00	11.65	10	24.27
Piassa to Mebrat Condominium	PM	16	69.00	12.37	10	17.93
Average						14.83

Table 4.16: Total Travel Time, Dwell Time and Dwell time as a percentage of total travel time for the Articulated Bus

<b>Articulated bus</b>						
Route	Time Perio	Data Coun	Total Travel	Total Dwell Time (min)	Length (km)	TDT/TTT (%)
Piassa to Ayer Tena	AM	22	52.00	7.75	8.6	14.90
Piassa to Ayer Tena	AM	20	51.00	7.90	8.6	15.49
Ayer Tena to Piassa	AM	23	69.00	10.12	8.6	14.67
Megenagna to	AM	21	63.00	10.38	8.8	16.48
Ayer Tena to Winget	MD	23	46.00	6.42	7.0	13.96
Megenagna to	MD	21	33.00	9.35	8.8	28.33
Ferensay legasion to	MD	20	47.00	6.82	8.8	14.51
Ayer Tena to Winget	MD	23	43.00	6.83	7.0	15.88
Addisu Gebeya to	MD	17	33.00	3.62	13.0	10.97
Ferensay legasion to	PM	20	78.00	8.95	8.8	11.47
Ferensay legasion to	PM	20	82.00	8.70	8.8	10.61
Megenagna to	PM	23	77.00	9.65	8.8	12.53
Megenagna to	PM	24	74.00	10.77	8.8	14.55
Average						14.95

Table 4.17: Total Travel Time, Dwell Time and Dwell time as a percentage of total travel time for the Double Decker Bus

<b>Double Decker bus</b>						
Route	Time Perio	Data Coun	Total Travel	Total Dwell Time(min)	Length (km)	TDT/TTT (%)
Sansusi to Piassa	AM	18	66.00	8.33	9.7	12.62
Piassa to Megenagna	AM	15	33.00	6.32	7.5	19.15
Piassa to Megenagna	AM	11	26.00	2.82	7.5	10.85
Sansusi to Piassa	AM	19	87.00	9.40	9.7	10.80
Piassa to Megenagna	AM	15	26.00	3.15	7.5	12.12
Piassa to Megenagna	MD	14	26.00	4.25	7.5	16.35
Piassa to Megenagna	MD	16	24.00	3.20	7.5	13.33
Megenagna to Piassa	MD	14	25.00	4.12	7.5	16.48
Megenagna to Piassa	MD	16	29.00	3.57	7.5	12.31
Jemmo to Piassa	PM	16	27.00	6.10	13.0	22.59
Piassa to Jemmo	PM	13	43.00	5.77	13.0	13.42
Jemmo to Piassa	PM	18	67.00	7.52	13.0	11.22
Jemmo to Piassa	PM	17	68.00	7.75	13.0	11.40
Average						14.05

#### 4.5 Bus Loading Area Capacity

Dwell Time Comparison of the Multiple Regression model with Transit Capacity and Quality of Service Manual (TCQSMs) 2<sup>nd</sup> edition formula was done to compare the results with the manual formula and the regression models developed in this research. Average recommended time values were taken from Table 4.17 below for single alighting boarding passengers and for time of opening and closing doors.

Average number of passengers boarding and alighting the bus and average number of standees was taken from the general dwell time model of Equation 4.5 below.

$$t_d = P_a * t_a + P_b * t_b + t_{oc} \dots \dots \dots \text{Equation 4.5}$$

Where

$t_d$  is dwell time;

$P_a$  is number of passenger alighting;

$t_a$  is time taken by an alighting passenger;

$P_b$  is number of passenger boarding;

$t_b$  is time taken by one boarding passengers; and

$t_{oc}$  is door opening and closing time.

TCQSM 2<sup>nd</sup> edition suggests a 2-5 seconds for door opening and closing time.

Table 4.18 below presents the: comparison of dwell times calculated using TCQSM formula and the overall dwell time model developed. As can be seen from the comparisons the dwell time from the developed model is as twice as the dwell time from TCQSM formula. This implies that the dwell time calculations from manuals cannot be taken without modification for local conditions.

Table 4.17: Passenger Service Times with multiple channel passenger movement  
TCQSMs 2<sup>nd</sup> edition

Available Channel	Door	Default Passengers Service Time (s/p)		
		Boarding	Front Alighting	Rear Alighting
1		2.5	3.3	2.1
2		1.5	1.8	1.2
3		1.1	1.5	0.9
4		0.9	1.1	0.7
STDEV		0.76	0.84	0.62

Table 4.18: Comparison of dwell times calculated using TCQSM formula and the overall dwell time model developed.

Pa	Pb	Ns	$t_a$ (s/p)	$t_b$ (s/p)	$t_{oc}$ (s)	Td	Overall regression model
							DT=7.03+3.32Pb+1.54Pa+0.05Ns
3.24	4.01	27.80	1.35	1.3	3.5	13.09 sec	26.7 sec

#### 4.6 Calculation of Bus Stop Capacity

A bus stop is a location where buses stop to load and unload passengers and consists one or more loading areas or berths. Bus stop vehicle capacity is related to the vehicle capacity of the individual loading areas at the stop, the number of loading areas provided, and the design of the loading areas. The number of loading areas provided should be sufficient to accommodate the number of buses scheduled to use the stop. However, block lengths, driveway locations, and/or the need to maintain on-street parking may constrain the size of the bus stop. In addition, having more than three loading areas at a stop can potentially be confusing to passengers, as they will not know where to wait for a bus, and can lead to longer dwell times, when passengers must walk to the back of the queue of buses to board.

Clearance Time, the sum of the time the bus starts up and travels its own length and the time it takes to get suitable gap in the traffic. Various studies have examined the components of clearance time, with total clearance times ranging from 9 to 20 seconds. The time required for a bus to start up and travel its own length to clear a stop is about 10 seconds and the average interval between acceptable gaps (assumed to be 7 seconds in the absence of other information). (TCQSM and HCM 2000)

Another term in calculating the bus loading area/berths capacity is the failure rate concept which sets how often a bus should arrive at a stop only to find all loading areas occupied. In downtown areas, design failure rates of 7.5 to 15% are recommended for estimating capacity. This represents a trade-off between maintaining bus travel speeds and achieving the higher capacities required in downtown areas. The upper limit, 15%, represents bus stop failure (queues forming behind the bus stop) for about 10 minutes out of the hour. It also represents the point where bus travel speeds begin to drop rapidly. Taking 7.5% failure rate,  $z$  which is the standard normal variable corresponding to the desired failure rate is equal to 1.44 (TCQSM)

Using average dwell time and critical time of 10sec and 15sec and assuming  $g/C$  ratio 0.5 and 1.0 for morning, midday and evening period the individual loading area capacity is calculated as follows:

$$B_1 = \frac{3600\left(\frac{g}{C}\right)}{t_c + t_d\left(\frac{g}{C}\right) + t_{om}} = \frac{3600\left(\frac{g}{C}\right)}{t_c + t_d\left(\frac{g}{C}\right) + zC_v t_d} \dots \dots \dots \text{Equation 4.3}$$

$$z = \frac{t_i - t_d}{s} \dots\dots\dots \text{Equation 4.4}$$

Where

- Bl= loading area bus capacity (bus/h);
- 3600= number of seconds in one hour
- g/C= green time ratio
- t<sub>c</sub>= Clearance time (s)
- t<sub>d</sub>= average dwell time (s)
- z= standard normal variable that corresponds to the desired failure rate
- Cv= coefficient of variation

Table 4.18 below presents bus loading area capacity for Addis Ababa buses for three time periods and subsequently Figure 4.9 shows a bus stop with two loading areas/berths around the British Embassy

Table 4.18: Result of Bus loading Area Capacity (Buses per Hour) Using the Average Dwell Time of the three time periods (Morning, Mid-day and Evening)

Time of Day	Average Dwell Time (seconds)	Clearance Time (g/C=0.5 Signalized)		Clearance Time (g/C=1.0 Unsignalized)	
		10 s	15s	10 s	15s
Morning	25.36	32.00	29.00	52.00	48.0
Midday	18.79	41.00	37.00	68.00	62.00
Evenging	32.79	27.00	26.00	44.00	41.00



Fig 4.8: A bus stop with two loading areas/berths around British Embassy

#### 4.7 Level of Service Bus Stops and routes

The level of service of bus stops and routes is based on the following criterion as stated by the (TCRP Report 26) HCM Criteria.

- Number of buses per hour;
- Number of passengers per seat ratio. 1 means all seats are taken; and
- Number of passengers per hour..

Procedure

- ❖ Compute the capacity of bus loading areas/berths.
- ❖ Count the number of buses per hour.
- ❖ Calculate the number of passengers per seat ration.

Based on the ratio of the number of passengers who get seats and those who are standing the, level of service of Addis Ababa city buses is **Level of Service E**. Table 4.19 below presents the passenger service volumes for planning purposes.

Table 4.19: Suggested bus Passenger service volumes for planning purposes (hourly flow rates based on 50 seats bus) and Level of Service for Arterial streets.

Level of Service	Buses Per Hour Per Lane	Level of Service (Passengers/seat)				
		A 0.00-0.50	B 0.51-0.75	C 0.76-1.00	D 1.01-1.25	E 1.26-1.50
Urban Arterial Streets (Passengers)						
A	=<25	625	940	1,250	1,560	1,875
B	26-45	1,125	1,690	2,250	2,810	3,375
C	46-80	2,000	3,000	5,000	5,000	6,000
D	81-105	2,625	3,940	6,560	6,560	7,875
E	106-135	3,375	5,060	8,440	8,440	10,125

Source: TCRP report 26 A-3

### 4.8 Bus Stop Vehicle Capacity

The number of loading areas provided at bus stop should be sufficient so that the scheduled buses could use it properly. Bus stop vehicle capacity depends on the number of the individual loading areas capacity and the number of effective loading areas.

$$B_s = N_{el} * B_l \dots \dots \dots \text{Equation 4.8}$$

Where

Bs= bus stop vehicle capacity (buses/hour)

Nel= effectivel number of loading areas

Bl= individual loading area capacity (buses/hour)

Table 4.20 shows the efficiency of multiple linear loading areas at bus stops as stated in the TCQSM.

Table 4.20: Efficiency of Multiple Linear Loading Areas at Bus Stops

Online Loading area					Offline Loading Area	
Random Arrivals			Platooned Arrivals		All Arrivals	
Loading Area#	Efficiency %	Cumulative # of Effective Loading Areas	Efficiency %	Cumulative # of Effective Loading Areas	Efficiency %	Cumulative # of Effective Loading Areas
1	100	1.00	100	1.00	100	1.00
2	75	1.75	85	1.85	85	1.85
3	70	2.45	80	2.65	80	2.65
4	20	2.65	25	2.90	65	3.25
5	10	2.75	10	3.00	50	3.75

Source: TCQSM: 4-14.

Most of Addis Ababa city bus stops followed linear loading areas with two loading areas. Linear loading areas are a type of bus stop arrangements in which the loading areas are arranged so that buses stop linearly. So  $N_{el}$  equals 1.85 since the loading area is offline(off traffic). Table 4.21 below presents the bus stop vehicle capacity.

Table 4.21: Bus Stop Vehicle Capacity (buses per hour) for two loading areas ( $N_{el}=1.85$ )

Time of Day	Average Dwell Time (sec)	Clearance Time (g/C=0.5 Signalized)		Clearance Time (g/C=1.0 Unsignalized)	
		10 s	15s	10 s	15s
Morning	25.36	59.2	53.65	96.2	88.8
Midday	18.79	75.85	68.45	125.8	114.7
Evening	32.79	49.95	48.1	81.4	75.85

Two bus stops were selected for checking if the provided loading areas were enough to handle the prevailing number of buses using that bus stop. The bus stops are located around Arat Kilo and the Winget roundabout. Both stops are located near intersection and the time of bus count was done during evening and morning peak period to account for the worst conditions of use of the bus stops. Summary of the counts is presented in Table 4.18 below.

Table 4.18 Case Study Result around Arat Kilo and Winget Bus Stop

Time	Location of stop	Number of buses per hour using stop (counted on field)	Number of buses per lane	Number of loading areas	Capacity of stop (buses per hour)
Morning (1:47-2:47)	Near intersection, no signal	46 upstream	23	3	127
Morning (1:47-2:47)	Near intersection, no signal	35 downstream	18	3	127
Evening(4:06-5:06)	Near intersection, no signal	19 upstream	10	1	41
Evening(4:06-5:06)	Near intersection, no signal	20 downstream	10	1	41

$$B_s = N_{el} * B_l = 2.65 * 48.00 = 127 \text{ buses per hour}$$

$$B_s = N_{el} * B_l = 1.0 * 41.00 = 41 \text{ buses per hour}$$

So, the provided stops are enough based on field data count and capacity calculations using average dwell time. The level of service of bus stops at Arat Kilo and Winget roundabouts, based on the number of buses per lane, is **level of service A**.

#### 4.9 Bus Users Questionnaire Results

A total of 60 bus users response is analyzed here and the main results of the respondents answers are presented below. Out of 60 respondents 37 are male and 23 are females. Most of the respondents have educational status of Diploma or Degree. 52 of the 60 respondents use buses as a means of transportation either always (19 times) or sometimes (25 times). Here are the main results of the questionnaire the bus users pinpointed.

- Based on the comfort level of the bus, Sheger Bus is selected as a number one comfortable bus by 34 respondents and the DD (Double Decker) is selected second by 14 bus users. The low floor level and the other appliances installed inside the buses are better than the single and articulated Anbassa buses.

- On waiting time for buses, 30 bus users wait for buses for less than 30 minutes while 19 users wait for between 30 minutes and one hour of time. This indicates that the frequency of the buses making the trip is less.
- Regarding Dwell Time, all the factors mentioned contributes for the increase in dwell time of the buses during bus loading and unloading of passengers is responded by 45 bus users. Poor fare collection system and too much standing passengers are responded next to that. The factors mentioned were the following: too much boarding passengers, too much alighting passengers, poor fare collection system, and too much standing passengers. As indicated in the descriptive statistics part the bus dwell time for outside fare collection scheme is twice that of inside fare collection scheme.
- Regarding how to encourage passengers to use mass transportation: 42 respondents choose all of the suggested solutions for increase the use of mass transportation and 11 out of 60 respondents choose to increase the loading areas/bus stops of the buses. But the performance study of the loading areas of the bus stops indicates that the provided number of loading areas in the bus stop is enough.

## CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

The objective of this research was to identify the most significant factors which contribute to an increase of bus dwell time. Calculation of bus stop loading area capacity, average bus dwell time comparison with the total travel time of the buses is also made.

In view of the above, the study showed that many determinant factors contribute to the variation and increase of dwell time such as: number of passengers boarding and alighting, bus type, location of bus stop, fare collection system, time of the day, floor level of the bus, number of the doors are the selected factors. Out of the aforementioned factors, number of passengers boarding and alighting, time of the day, fare collection schemes are the main factors to estimate dwell time.

The coefficient of variation of dwell time of the Addis Ababa city buses ranges from 0.85 to 1.00 which is too high indicating less reliable bus transport based on dwell time analysis.

The collected data and the developed models may only apply for the stated nine routes and cannot be used on other routes. Eight hundred sixty eight (868) dwell time data were collected; excluding the terminus stops data which is not required for dwell time analysis.

The bus dwell time of the studied buses along the stated routes took on the average 14% of the total travel time. This percentage is too large when it is compared with other urban centers and need to be decreased in order for transport to be adequate and reliable to passengers.

Using the average dwell times, calculations were done on two stop locations located near Arat Kilo and Winget roundabout, whether the provided loading areas were enough or not. It is evident that the two provided loading areas are enough for the two bus stops and the two loading areas are Level of Service of A. this shows that the provided number of loading areas for the bus stops are enough.

Finally results of the questionnaire analysis indicates that dwell time is increasing due to too much boarding, alighting and standing passengers and due to poor fare collection

system of buses. Bus users also suggested that in order to use mass transportation introduction of more modern buses, awareness creation to buses, and more loading and unloading areas or bus stops are required.

## 5.2 Recommendations

Based on the results of the analysis, the following recommendations are forwarded:

- Modern Fare Collection Scheme: The old/conventional way of fare collection system has to be changed in order to reduce the dwell time and the total travel time of the buses. In this regard, modern fare collection mechanism like smart cards, Prepay, electronic fare collection systems, Magnetic Swipe, contactless fare collecting technologies like Automatic Fare Collection system (AFC) and RFID etc. need to be installed.
- Giving appropriate bus stop information on the whereabouts of buses using GPS system and make passengers wait based on that information is the most appropriate instead of using the waiting method for passengers until the bus is full. The GPS system has two benefits: buses do not waste time waiting for passengers; passengers will choose to use buses or not based on the time table on the bus stop.
- Addis Ababa city buses should work together to provide a better transport service for Addis Ababa passengers focusing on decreasing the dwell time and for a better performance and reliability. Schedules should consider the peak period passenger movements and should avoid unnecessary dwell time delay.
- Bus loading areas should not be used by other vehicles especially for longer period of times. If otherwise, a back queue will be formed and congestion results and the overall system of movement will be disturbed along that road. So the bus stops shouldn't be utilized by other vehicles.
- Off line stops (pull outs or bus bays) should be considered at longer dwell time stops to avoid traffic delays to other vehicles.
- Increasing service frequency so that all passengers may have a seat should also be considered.

### **5.3 PROPOSED FUTURE RESEARCH AREAS**

- Detailed performance analysis of bus stops, stations and terminals.
- Modern fare collection systems for Addis Ababa city mass transport.
- Study on total travel time of buses and interaction with other vehicles.
- Developing a bus arrival algorithm which uses real time information and bus priority signal system design for Addis Ababa.

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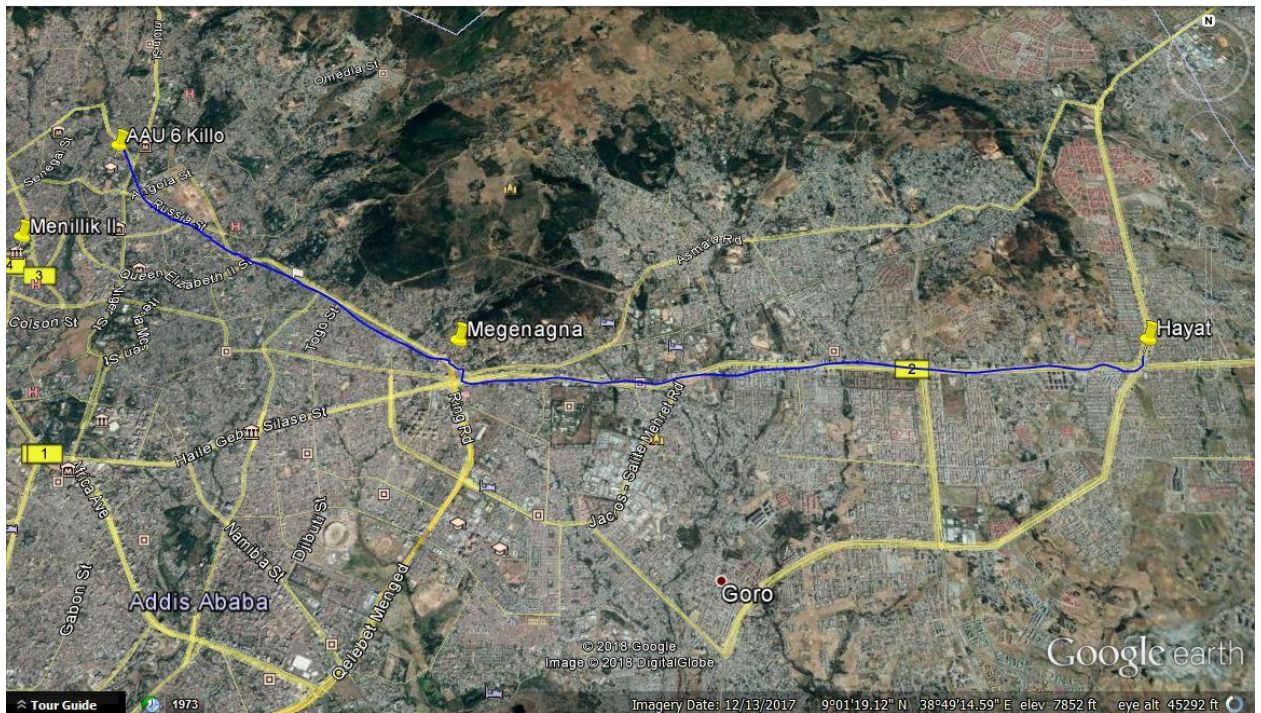
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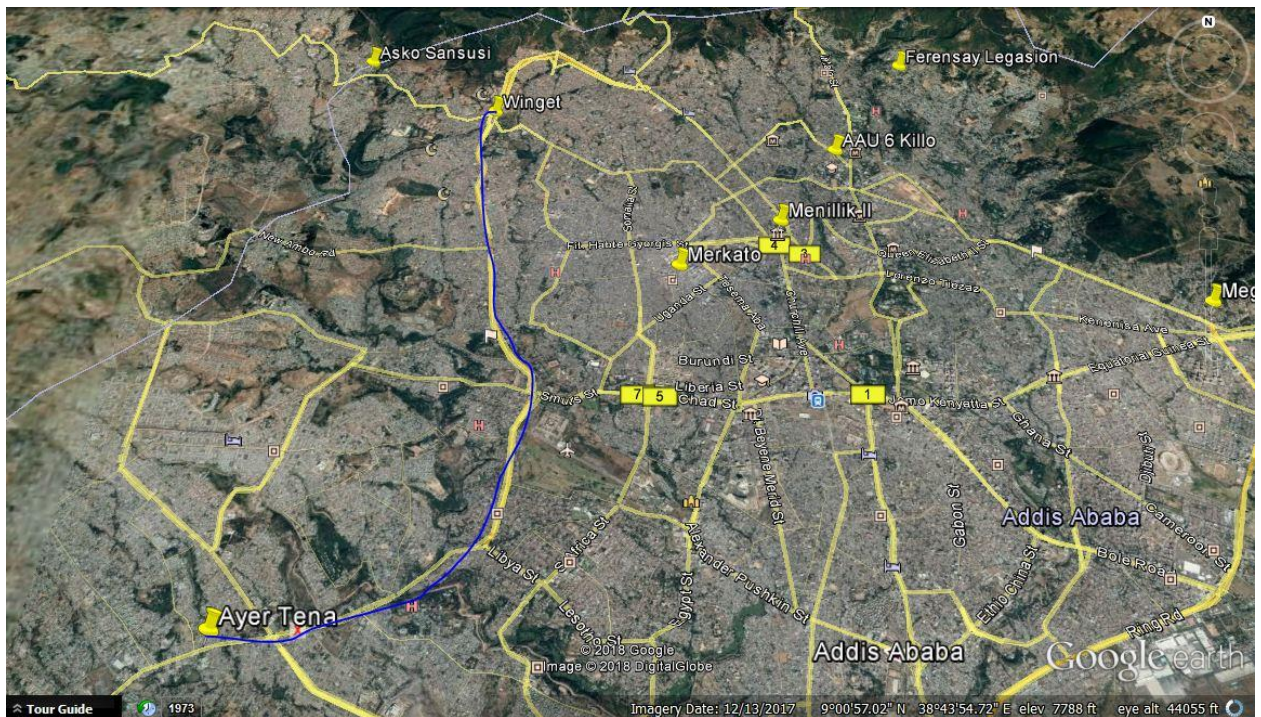
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APPENDIX A: Studied Routes



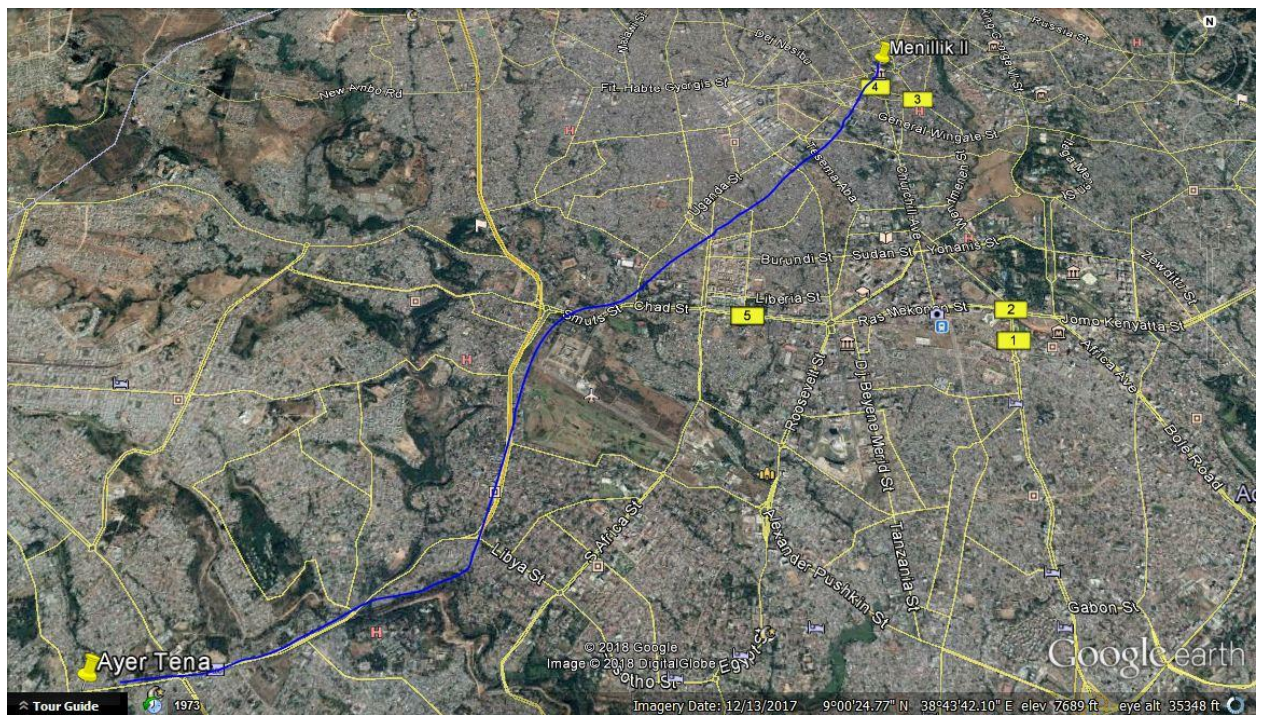
*Route from Sidist Killo to Hayat condominium*



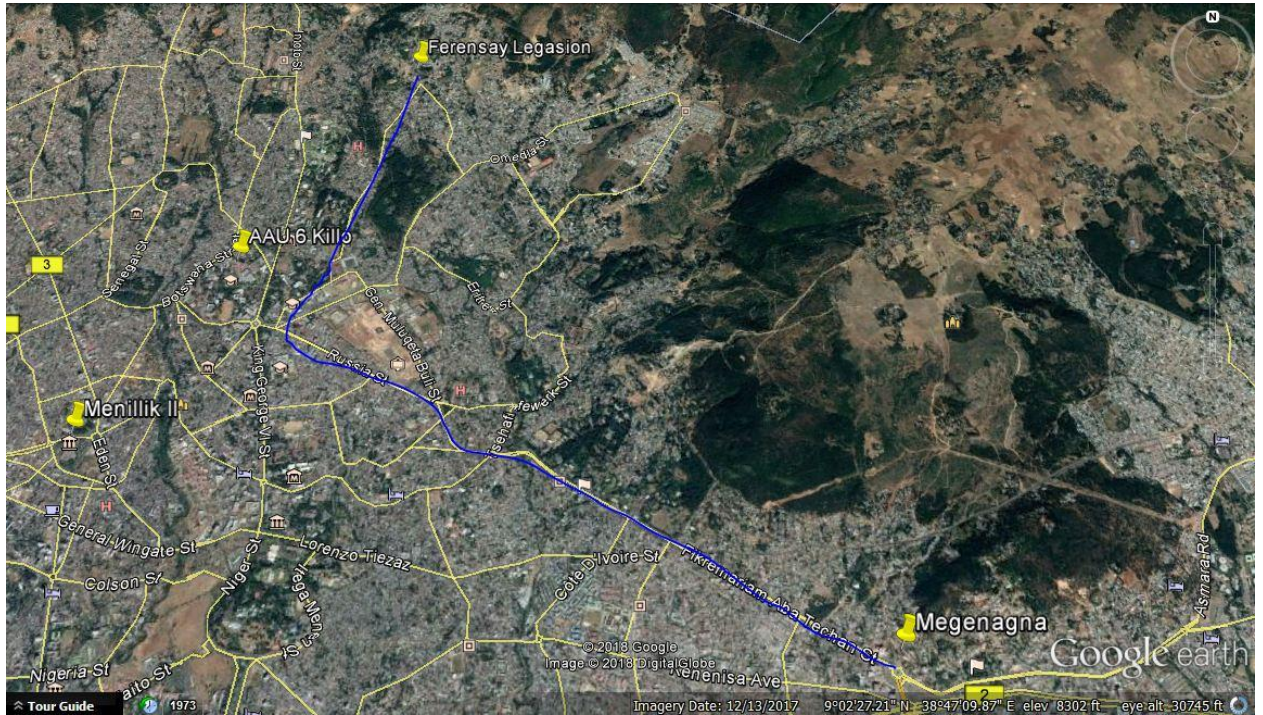
*Route from Ayer Tena to Winget Roundabout*



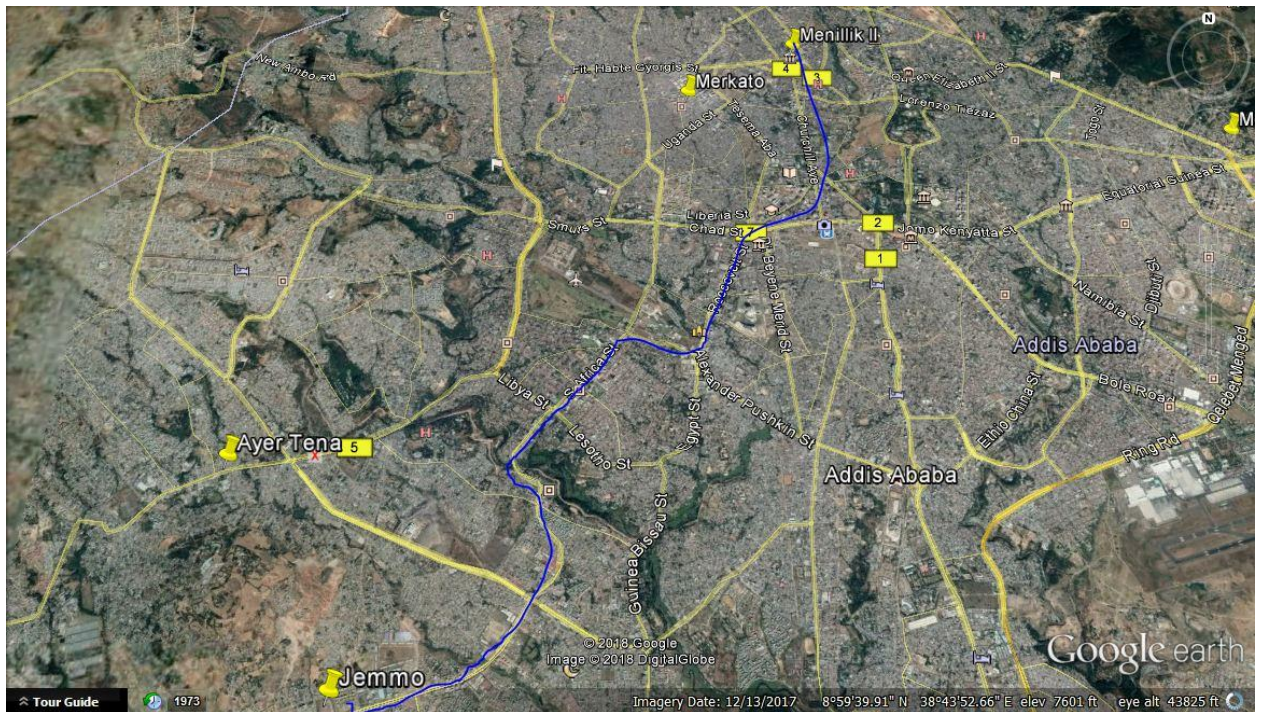
*Route from Mebrat condominium to Menillik Square*



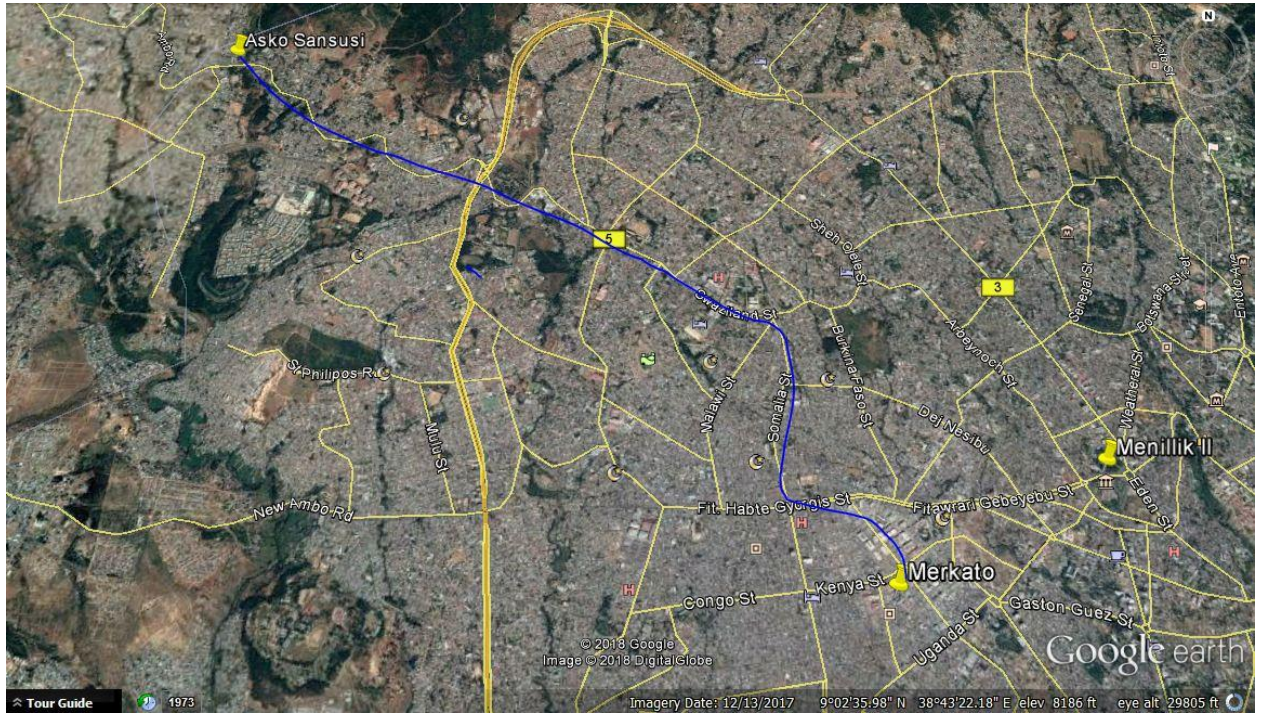
*Route from Ayer Tena to Menillik Square*



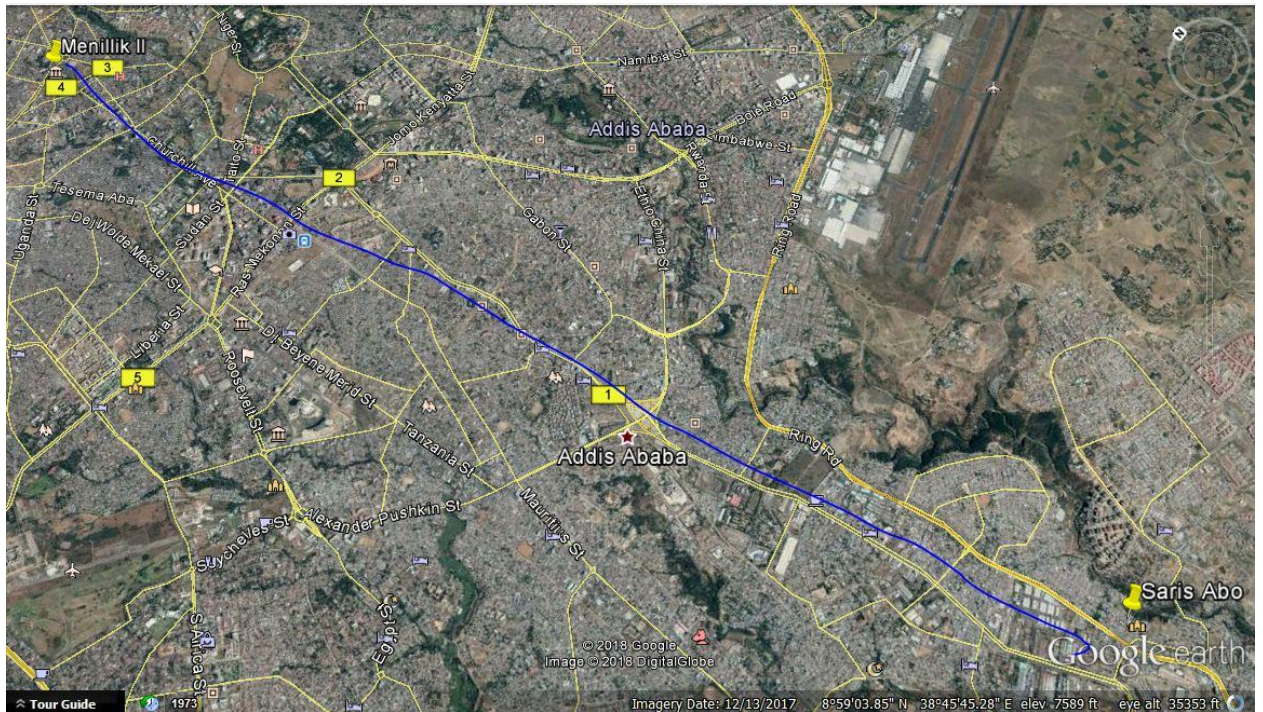
*Route from Megenagna to Ferensay Legasion*



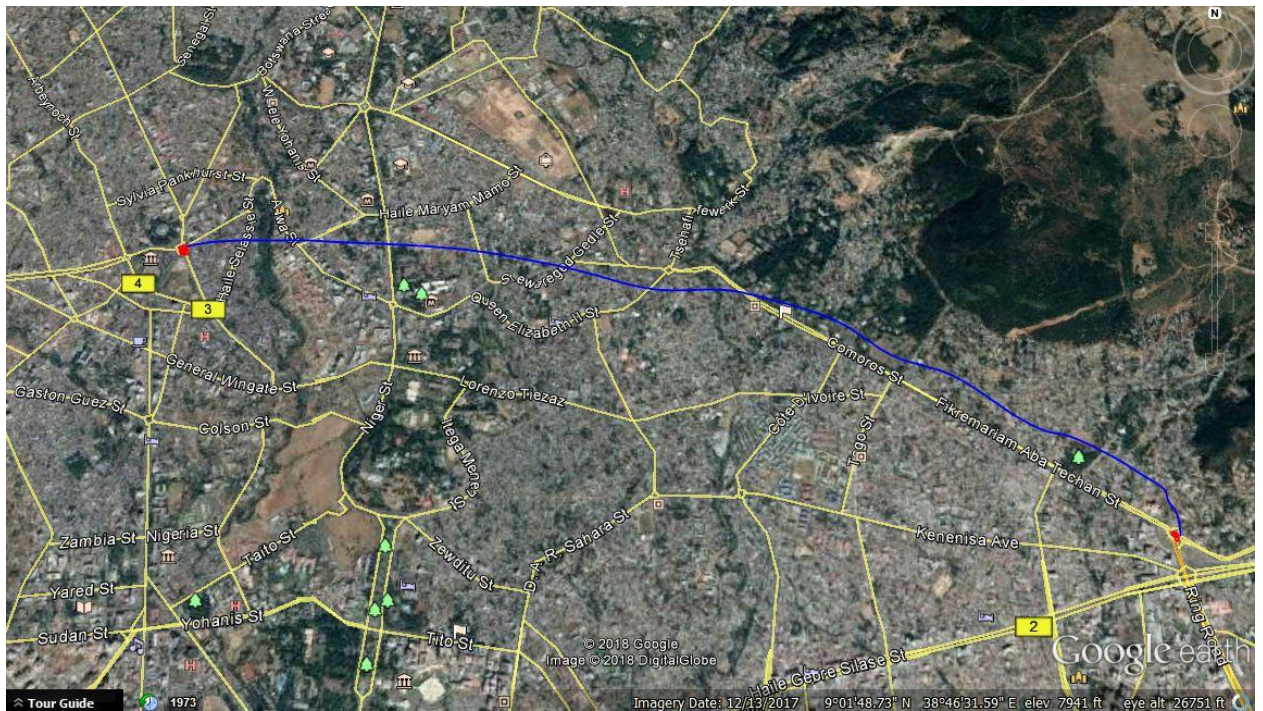
*Route from Jemmo condominium to Menillik Square*



*Route from Sansusi to Merkato*



*Route from Saris Abo to Menilik Square*



Route from Piassa to Megenagna

APPENDIX B Data Collecting Sheet

Dwell Time Data Collecting Sheet								
Name of Bus		Bus Type	Floor	# of Door		Bus Capacity		
Starting Time			End Time		AM	MD	PM	
Route	Origin		Through		Destination			
	Elapsed DT	(Boarding Passenger) $P_b$	(Alighting Passenger) $P_a$	Standeers $N_s$	Location of Stop(MB/NI)	Stop Type(CS/BB)	Number of App. lane	Fare Collection (inside/outside)
1								
2								
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**APPENDIX C: Descriptive Statistics**

Table Descriptive Statistics for variables collected for Articulated bus

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	24.38	Mean	3.25	Mean	3.57	Mean	39.12
Standard Error	1.28	Standard Error	0.31	Standard Error	0.27	Standard Error	2.42
Median	18.50	Median	1.00	Median	2.00	Median	28.50
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	20.86	Standard Deviation	5.11	Standard Deviation	4.39	Standard Deviation	39.24
Sample Variance	435.08	Sample Variance	26.16	Sample Variance	19.23	Sample Variance	1539.74
Kurtosis	9.02	Kurtosis	18.12	Kurtosis	3.50	Kurtosis	0.79
Skewness	2.71	Skewness	3.39	Skewness	1.84	Skewness	1.22
Range	132.00	Range	45.00	Range	21.00	Range	149.00
Minimum	1.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	133.00	Maximum	45.00	Maximum	21.00	Maximum	149.00
Sum	6435.00	Sum	858.00	Sum	942.00	Sum	10328.00
Count	264.00	Count	264.00	Count	264.00	Count	264.00
Confidence Level(95.0%)	2.53	Confidence Level(95.0%)	0.62	Confidence Level(95.0%)	0.53	Confidence Level(95.0%)	4.76

Table Descriptive Statistics for variables collected for Double Decker bus

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	23.05	Mean	3.33	Mean	3.45	Mean	13.48
Standard Error	1.53	Standard Error	0.30	Standard Error	0.29	Standard Error	1.13
Median	17.00	Median	2.00	Median	2.00	Median	7.00
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	21.03	Standard Deviation	4.13	Standard Deviation	3.85	Standard Deviation	15.50
Sample Variance	442.45	Sample Variance	17.04	Sample Variance	14.79	Sample Variance	240.26
Kurtosis	13.57	Kurtosis	1.93	Kurtosis	1.75	Kurtosis	-0.29
Skewness	3.16	Skewness	1.59	Skewness	1.37	Skewness	0.90
Range	145.00	Range	18.00	Range	18.00	Range	55.00
Minimum	5.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	150.00	Maximum	18.00	Maximum	18.00	Maximum	55.00

Sum	4356.00	Sum	630.00	Sum	624.00	Sum	2548.00
Count	189.00	Count	189.00	Count	181.00	Count	189.00
Confidence Level(95.0%)	3.02	Confidence Level(95.0%)	0.59	Confidence Level(95.0%)	0.56	Confidence Level(95.0%)	2.22

Table Descriptive Statistics for variables collected for Sheger bus

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	27.86	Mean	3.39	Mean	4.68	Mean	20.30
Standard Error	2.16	Standard Error	0.40	Standard Error	0.42	Standard Error	1.46
Median	17.00	Median	2.00	Median	3.00	Median	16.00
Mode	13.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	29.36	Standard Deviation	5.38	Standard Deviation	5.72	Standard Deviation	19.91
Sample Variance	862.11	Sample Variance	28.92	Sample Variance	32.71	Sample Variance	396.41
Kurtosis	7.17	Kurtosis	7.59	Kurtosis	6.53	Kurtosis	-0.90
Skewness	2.48	Skewness	2.64	Skewness	2.19	Skewness	0.54
Range	172.00	Range	27.00	Range	37.00	Range	65.00
Minimum	3.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	27.00	Maximum	37.00	Maximum	65.00
Sum	5155.00	Sum	628.00	Sum	866.00	Sum	3755.00
Count	185.00	Count	185.00	Count	185.00	Count	185.00
Confidence Level(95.0%)	4.26	Confidence Level(95.0%)	0.78	Confidence Level(95.0%)	0.83	Confidence Level(95.0%)	2.89

Table Descriptive Statistics for variables collected for Morning Period

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	25.36	Mean	3.05	Mean	4.44	Mean	32.62
Standard Error	1.38	Standard Error	0.29	Standard Error	0.33	Standard Error	1.71
Median	18.00	Median	1.00	Median	3.00	Median	25.00
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	24.19	Standard Deviation	5.01	Standard Deviation	5.69	Standard Deviation	29.93
Sample Variance	584.94	Sample Variance	25.07	Sample Variance	32.41	Sample Variance	895.95
Kurtosis	13.09	Kurtosis	21.89	Kurtosis	8.08	Kurtosis	2.98
Skewness	3.19	Skewness	3.86	Skewness	2.44	Skewness	1.57
Range	172.00	Range	45.00	Range	38.00	Range	142.00
Minimum	3.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	45.00	Maximum	38.00	Maximum	142.00

Sum	7784.00	Sum	937.00	Sum	1349.00	Sum	10014.00
Count	307.00	Count	307.00	Count	304.00	Count	307.00
Confidence Level(95.0%)	2.72	Confidence Level(95.0%)	0.56	Confidence Level(95.0%)	0.64	Confidence Level(95.0%)	3.36

Table Descriptive Statistics for variables collected for Mid-Day Period

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	18.79	Mean	2.49	Mean	2.97	Mean	18.06
Standard Error	1.00	Standard Error	0.21	Standard Error	0.22	Standard Error	1.19
Median	15.00	Median	1.00	Median	2.00	Median	9.00
Mode	15.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	17.25	Standard Deviation	3.69	Standard Deviation	3.75	Standard Deviation	20.42
Sample Variance	297.39	Sample Variance	13.59	Sample Variance	14.08	Sample Variance	416.87
Kurtosis	27.01	Kurtosis	7.46	Kurtosis	6.54	Kurtosis	-0.50
Skewness	4.14	Skewness	2.54	Skewness	2.25	Skewness	0.92
Range	174.00	Range	24.00	Range	23.00	Range	67.00
Minimum	1.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	24.00	Maximum	23.00	Maximum	67.00
Sum	5563.00	Sum	737.00	Sum	869.00	Sum	5347.00
Count	296.00	Count	296.00	Count	293.00	Count	296.00
Confidence Level(95.0%)	1.97	Confidence Level(95.0%)	0.42	Confidence Level(95.0%)	0.43	Confidence Level(95.0%)	2.34

Table Descriptive Statistics for variables collected for Evening Period

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	32.79	Mean	4.29	Mean	4.60	Mean	38.04
Standard Error	1.74	Standard Error	0.35	Standard Error	0.32	Standard Error	2.16
Median	24.00	Median	2.00	Median	3.00	Median	37.00
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	28.06	Standard Deviation	5.64	Standard Deviation	5.17	Standard Deviation	34.84
Sample Variance	787.40	Sample Variance	31.81	Sample Variance	26.75	Sample Variance	1213.53
Kurtosis	4.43	Kurtosis	4.50	Kurtosis	6.22	Kurtosis	0.91
Skewness	1.95	Skewness	2.02	Skewness	1.92	Skewness	1.01
Range	170.00	Range	32.00	Range	37.00	Range	149.00

Minimum	5.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	32.00	Maximum	37.00	Maximum	149.00
Sum	8558.00	Sum	1119.00	Sum	1191.00	Sum	9929.00
Count	261.00	Count	261.00	Count	259.00	Count	261.00
Confidence Level(95.0%)	3.42	Confidence Level(95.0%)	0.69	Confidence Level(95.0%)	0.63	Confidence Level(95.0%)	4.25

Table Descriptive Statistics for variables collected for Inside Fare Collection method

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	22.89	Mean	3.59	Mean	2.91	Mean	25.81
Standard Error	0.95	Standard Error	0.18	Standard Error	0.19	Standard Error	1.25
Median	17.00	Median	2.00	Median	1.00	Median	20.00
Mode	12.00	Mode	1.00	Mode	0.00	Mode	0.00
Standard Deviation	20.15	Standard Deviation	3.73	Standard Deviation	3.93	Standard Deviation	26.52
Sample Variance	405.95	Sample Variance	13.91	Sample Variance	15.48	Sample Variance	703.32
Kurtosis	15.10	Kurtosis	6.68	Kurtosis	6.93	Kurtosis	4.71
Skewness	3.20	Skewness	2.28	Skewness	2.31	Skewness	1.75
Range	174.00	Range	26.00	Range	26.00	Range	149.00
Minimum	1.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	26.00	Maximum	26.00	Maximum	149.00
Sum	10253.00	Sum	1607.00	Sum	1280.00	Sum	11561.00
Count	448.00	Count	448.00	Count	440.00	Count	448.00
Confidence Level(95.0%)	1.87	Confidence Level(95.0%)	0.35	Confidence Level(95.0%)	0.37	Confidence Level(95.0%)	2.46

Table Descriptive Statistics for variables collected for Outside Fare Collection method

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	48.43	Mean	9.03	Mean	3.62	Mean	58.15
Standard Error	4.97	Standard Error	1.02	Standard Error	0.57	Standard Error	4.19
Median	33.00	Median	8.00	Median	2.00	Median	54.00
Mode	31.00	Mode	2.00	Mode	0.00	Mode	0.00
Standard Deviation	40.98	Standard Deviation	8.39	Standard Deviation	4.73	Standard Deviation	34.54
Sample Variance	1679.26	Sample Variance	70.33	Sample Variance	22.33	Sample Variance	1193.23
Kurtosis	1.08	Kurtosis	4.32	Kurtosis	3.08	Kurtosis	-0.11

Skewness	1.28	Skewness	1.67	Skewness	1.80	Skewness	0.53
Range	172.00	Range	45.00	Range	20.00	Range	138.00
Minimum	3.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	45.00	Maximum	20.00	Maximum	138.00
Sum	3293.00	Sum	614.00	Sum	246.00	Sum	3954.00
Count	68.00	Count	68.00	Count	68.00	Count	68.00
Confidence Level(95.0%)	9.92	Confidence Level(95.0%)	2.03	Confidence Level(95.0%)	1.14	Confidence Level(95.0%)	8.36

Table Descriptive Statistics for variables collected for Low Floor Buses

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	25.43	Mean	3.36	Mean	4.07	Mean	16.85
Standard Error	1.32	Standard Error	0.25	Standard Error	0.26	Standard Error	0.94
Median	17.00	Median	2.00	Median	3.00	Median	12.50
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	25.58	Standard Deviation	4.78	Standard Deviation	4.92	Standard Deviation	18.12
Sample Variance	654.10	Sample Variance	22.86	Sample Variance	24.16	Sample Variance	328.29
Kurtosis	9.79	Kurtosis	6.65	Kurtosis	7.35	Kurtosis	-0.50
Skewness	2.81	Skewness	2.36	Skewness	2.19	Skewness	0.77
Range	172.00	Range	27.00	Range	37.00	Range	65.00
Minimum	3.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	27.00	Maximum	37.00	Maximum	65.00
Sum	9511.00	Sum	1258.00	Sum	1490.00	Sum	6303.00
Count	374.00	Count	374.00	Count	366.00	Count	374.00
Confidence Level(95.0%)	2.60	Confidence Level(95.0%)	0.49	Confidence Level(95.0%)	0.51	Confidence Level(95.0%)	1.84

Table Descriptive Statistics for variables collected for Raised Floor buses

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	25.29	Mean	3.13	Mean	3.92	Mean	38.75
Standard Error	1.03	Standard Error	0.22	Standard Error	0.23	Standard Error	1.51
Median	18.00	Median	1.00	Median	2.00	Median	36.50
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	22.82	Standard Deviation	4.93	Standard Deviation	5.05	Standard Deviation	33.51

Sample Variance	520.72	Sample Variance	24.28	Sample Variance	25.50	Sample Variance	1123.12
Kurtosis	11.07	Kurtosis	16.70	Kurtosis	9.20	Kurtosis	1.18
Skewness	2.85	Skewness	3.36	Skewness	2.50	Skewness	1.11
Range	174.00	Range	45.00	Range	38.00	Range	149.00
Minimum	1.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	45.00	Maximum	38.00	Maximum	149.00
Sum	12394.00	Sum	1535.00	Sum	1919.00	Sum	18987.00
Count	490.00	Count	490.00	Count	490.00	Count	490.00
Confidence Level(95.0%)	2.03	Confidence Level(95.0%)	0.44	Confidence Level(95.0%)	0.45	Confidence Level(95.0%)	2.97

Table Descriptive Statistics for variables collected for Two or less Number of lanes road

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	24.75	Mean	3.08	Mean	3.99	Mean	27.19
Standard Error	1.38	Standard Error	0.27	Standard Error	0.26	Standard Error	1.59
Median	17.00	Median	2.00	Median	3.00	Median	20.00
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	25.85	Standard Deviation	5.04	Standard Deviation	4.77	Standard Deviation	29.81
Sample Variance	668.45	Sample Variance	25.44	Sample Variance	22.71	Sample Variance	888.58
Kurtosis	12.62	Kurtosis	18.11	Kurtosis	9.24	Kurtosis	3.41
Skewness	3.23	Skewness	3.57	Skewness	2.46	Skewness	1.67
Range	172.00	Range	45.00	Range	37.00	Range	145.00
Minimum	3.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	45.00	Maximum	37.00	Maximum	145.00
Sum	8738.00	Sum	1088.00	Sum	1383.00	Sum	9597.00
Count	353.00	Count	353.00	Count	347.00	Count	353.00
Confidence Level(95.0%)	2.71	Confidence Level(95.0%)	0.53	Confidence Level(95.0%)	0.50	Confidence Level(95.0%)	3.12

Table Descriptive Statistics for variables collected for Three or more Number of lanes road

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	25.77	Mean	3.32	Mean	3.99	Mean	30.76
Standard Error	1.01	Standard Error	0.21	Standard Error	0.23	Standard Error	1.33
Median	18.00	Median	2.00	Median	2.00	Median	24.00
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00

Standard Deviation	22.79	Standard Deviation	4.74	Standard Deviation	5.16	Standard Deviation	30.07
Sample Variance	519.43	Sample Variance	22.51	Sample Variance	26.59	Sample Variance	903.92
Kurtosis	7.80	Kurtosis	7.84	Kurtosis	7.90	Kurtosis	1.93
Skewness	2.42	Skewness	2.45	Skewness	2.32	Skewness	1.26
Range	174.00	Range	32.00	Range	38.00	Range	149.00
Minimum	1.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	32.00	Maximum	38.00	Maximum	149.00
Sum	13093.00	Sum	1687.00	Sum	2018.00	Sum	15624.00
Count	508.00	Count	508.00	Count	506.00	Count	508.00
Confidence Level(95.0%)	1.99	Confidence Level(95.0%)	0.41	Confidence Level(95.0%)	0.45	Confidence Level(95.0%)	2.62

Table Descriptive Statistics for variables collected for Mid-Block Stops

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	24.28	Mean	3.15	Mean	3.49	Mean	29.45
Standard Error	1.16	Standard Error	0.24	Standard Error	0.20	Standard Error	1.34
Median	16.00	Median	1.00	Median	2.00	Median	22.00
Mode	12.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	25.40	Standard Deviation	5.19	Standard Deviation	4.32	Standard Deviation	29.32
Sample Variance	644.98	Sample Variance	26.98	Sample Variance	18.67	Sample Variance	859.55
Kurtosis	11.43	Kurtosis	15.98	Kurtosis	4.61	Kurtosis	2.13
Skewness	3.04	Skewness	3.44	Skewness	1.97	Skewness	1.34
Range	174.00	Range	45.00	Range	25.00	Range	148.00
Minimum	1.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	175.00	Maximum	45.00	Maximum	25.00	Maximum	148.00
Sum	11628.00	Sum	1508.00	Sum	1658.00	Sum	14107.00
Count	479.00	Count	479.00	Count	475.00	Count	479.00
Confidence Level(95.0%)	2.28	Confidence Level(95.0%)	0.47	Confidence Level(95.0%)	0.39	Confidence Level(95.0%)	2.63

Table Descriptive Statistics for variables collected for Near Intersection Stops

<i>Dwell Time</i>		<i>Passenger Boarding</i>		<i>Passenger Alighting</i>		<i>Number of Standees</i>	
Mean	26.61	Mean	3.36	Mean	4.57	Mean	28.92
Standard Error	1.13	Standard Error	0.22	Standard Error	0.29	Standard Error	1.57

Median	19.00	Median	2.00	Median	3.00	Median	22.00
Mode	13.00	Mode	0.00	Mode	0.00	Mode	0.00
Standard Deviation	22.22	Standard Deviation	4.41	Standard Deviation	5.67	Standard Deviation	30.75
Sample Variance	493.77	Sample Variance	19.47	Sample Variance	32.16	Sample Variance	945.79
Kurtosis	8.57	Kurtosis	3.68	Kurtosis	8.54	Kurtosis	2.85
Skewness	2.51	Skewness	1.90	Skewness	2.43	Skewness	1.52
Range	147.00	Range	26.00	Range	38.00	Range	149.00
Minimum	3.00	Minimum	0.00	Minimum	0.00	Minimum	0.00
Maximum	150.00	Maximum	26.00	Maximum	38.00	Maximum	149.00
Sum	10246.00	Sum	1292.00	Sum	1743.00	Sum	11135.00
Count	385.00	Count	385.00	Count	381.00	Count	385.00
Confidence Level(95.0%)	2.23	Confidence Level(95.0%)	0.44	Confidence Level(95.0%)	0.57	Confidence Level(95.0%)	3.08

**APPENDIX D: Multiple Linear Regression Models**Table SUMMARY OUTPUT Articulated*Regression Statistics*

Multiple R	0.7
R Square	0.51
Adjusted R Square	0.50
Standard Error	14.7
Observations	264

## ANOVA

	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	58259.73671	19419.91224	89.89717533	0.000
Residual	260	56166.13829	216.0236088		
Total	263	114425.875			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper</i>
Intercept	9.91	1.51	6.58	0.000	6.94	12.88
Pb	2.40	0.18	13.15	0.000	2.04	2.76
Pa	1.94	0.21	9.36	0.000	1.53	2.34
Ns	-0.01	0.02	-0.25	0.801	-0.05	0.04

Table SUMMARY OUTPUT Double Decker bus*Regression**Statistics*

Multiple R	0.8
R Square	0.60
Adjusted R Square	0.59
Standard Error	13.5
Observations	189

## ANOVA

	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	49668.81774	16556.27258	91.3980944	0.000
Residual	185	33511.75369	181.1446145		
Total	188	83180.57143			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>
Intercept	4.68	1.69	2.77	0.006	1.35
Pb	3.82	0.25	15.28	0.000	3.33
Pa	1.79	0.26	6.89	0.000	1.28
Ns	-0.02	0.07	-0.30	0.763	-0.15

Table SUMMARY OUTPUT Sheger bus

*Regression**Statistics*

Multiple R	0.8
R Square	0.71
Adjusted R Square	0.67
Standard Error	16.8
Observations	185

## ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	107455.7078	35818.56925	126.69	0.00
Residual	181	51171.91386	282.7177561		
Total	184	158627.6216			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	5.21	2.17	2.40	0.017	0.93	9.49
Pb	4.13	0.24	17.40	0.000	3.66	4.60
Pa	1.46	0.22	6.68	0.000	1.03	1.89
Ns	0.09	0.06	1.37	0.171	-0.04	0.22

Table SUMMARY OUTPUT Morning

*Regression Statistics*

Multiple R	0.8
R Square	0.60
Adjusted R Square	0.56
Standard Error	16.0
Observations	307

## ANOVA

	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	100981.5758	33660.53	130.74	0.000
Residual	303	78010.72392	257.4611		
Total	306	178992.2997			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	8.88	1.63	5.44	0.000	5.67	12.08
Pb	3.40	0.19	18.06	0.000	3.03	3.78
Pa	1.25	0.16	7.66	0.000	0.93	1.57
Ns	0.02	0.03	0.60	0.551	-0.04	0.08

Table SUMMARY OUTPUT MID-DAY

<i>Regression Statistics</i>	
Multiple R	0.8
R Square	0.60
Adjusted R Square	0.58
Standard Error	11.2
Observations	296

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	51003.67	17001.22	135.17	0.000
Residual	292	36726.76	125.7766		
Total	295	87730.43			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	4.62	1.09	4.23	0.000	2.47	6.77
Pb	2.99	0.18	16.72	0.000	2.64	3.35
Pa	1.54	0.18	8.75	0.000	1.19	1.88
Ns	0.12	0.03	3.78	0.000	0.06	0.19

Table SUMMARY OUTPUT EVENING PERIOD

<i>Regression Statistics</i>	
Multiple R	0.72
R Square	0.52
Adjusted R Square	0.51
Standard Error	19.68
Observations	261

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
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Regression	3	105138.9212	35046.31	90.44	0.000
Residual	257	99584.48881	387.4883		
Total	260	204723.41			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	9.77	2.31	4.23	0.000	5.22	14.32
Pb	3.34	0.22	15.15	0.000	2.90	3.77
Pa	1.84	0.24	7.71	0.000	1.37	2.31
Ns	0.01	0.04	0.24	0.807	-0.06	0.08

Table SUMMARY OUTPUT INSIDE FARE COLLECTION

<i>Regression Statistics</i>	
Multiple R	0.733
R Square	0.537
Adjusted R Square	0.534
Standard Error	13.754
Observations	448.000

## ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3.000	97474.365	32491.455	171.767	0.000
Residual	444.000	83986.830	189.160		
Total	447.000	181461.194			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	5.321	1.152	4.617	0.000	3.056	7.586
Pb	3.419	0.176	19.394	0.000	3.073	3.765
Pa	1.440	0.168	8.577	0.000	1.110	1.770
Ns	0.046	0.025	1.873	0.062	-0.002	0.094

Table SUMMARY OUTPUT Outside Fare Collection

<i>Regression Statistics</i>	
Multiple R	0.7
R Square	0.50
Adjusted R Square	R
Standard Error	30.4

Observations	68
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ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	53261.74304	17753.91	19.17758	0.000
Residual	64	59248.88931	925.7639		
Total	67	112510.6324			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	21.68386	8.595940313	2.52257	0.014	4.511496706	38.85623
Pb	3.276433	0.44615649	7.343686	0.000	2.385133019	4.167733
Pa	0.944231	0.790928108	1.193827	0.237	0.635829266	2.524292
Ns	-0.10762	0.108154943	-0.99502	0.323	0.323680266	0.108448

Table SUMMARY OUTPUT Low Floor buses

<i>Regression Statistics</i>	
Multiple R	0.80
R Square	0.65
Adjusted R Square	0.64
Standard Error	15.24
Observations	374

ANOVA						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	3	158014.5	52671.5	226.7069	0.000	
Residual	370	85963.2	232.33			
Total	373	243977.7				

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	4.64	1.33	3.49	0.001	2.02	7.26
Pb	3.99	0.17	23.40	0.000	3.65	4.32
Pa	1.59	0.16	9.84	0.000	1.27	1.90
Ns	0.06	0.04	1.39	0.167	-0.03	0.15

Table SUMMARY OUTPUT Raised Floor buses

<i>Regression Statistics</i>						
Multiple R		0.7				
R Square		0.50				
Adjusted R Square		0.50				
Standard Error		16.2				
Observations		490				

<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	127001	42333.6 6	161.20	0.000
Residual	486	127630.7	262.614 6		
Total	489	254631.7			

	<i>Coefficient</i>	<i>Standard</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper</i>
	<i>s</i>	<i>Error</i>				<i>95%</i>
Intercept	8.22	1.31	6.29	0.000	5.65	10.79
Pb	2.82	0.15	18.45	0.000	2.52	3.13
Pa	1.52	0.15	10.44	0.000	1.23	1.80
Ns	0.06	0.02	2.61	0.009	0.01	0.10

Table SUMMARY OUTPUT Two or Less Number of lane road

<i>Regression Statistics</i>						
Multiple R		0.79				
R Square		0.62				
Adjusted R Square		0.62				
Standard Error		15.98				
Observations		353				

<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	146224.3	48741.44	190.98	0.000
Residual	349	89069.23	255.21		
Total	352	235293.6			

	<i>Coefficients</i>	<i>Standard</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper</i>
		<i>Error</i>				<i>95%</i>

Intercept	4.82	1.42	3.39	0.001	2.02496752	7.61
Pb	3.62	0.17	20.69	0.000	3.2729175	3.96
Pa	1.60	0.18	8.89	0.000	1.24429996	1.95
Ns	0.09	0.03	3.14	0.002	0.03473049	0.15

Table SUMMARY OUTPUT Three or More number of lanes

<i>Regression Statistics</i>						
Multiple R	0.72					
R Square	0.52					
Adjusted R Square	0.51					
Standard Error	15.92					
Observations	508					

<i>ANOVA</i>						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	
Regression	3	135617.5	45205.85	178.3723	0.000	
Residual	504	127731.4	253.44			
Total	507	263349				

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	8.92	1.22	7.29	0.000	6.52	11.33
Pb	3.09	0.15	20.42	0.000	2.79	3.39
Pa	1.51	0.14	10.97	0.000	1.24	1.78
Ns	0.02	0.02	0.82	0.414	-0.03	0.07

Table SUMMARY OUTPUT Mid-Block Bus Stops

<i>Regression Statistics</i>						
Multiple R	0.8					
R Square	0.60					
Adjusted R Square	0.59					
Standard Error	16.3					
Observations	479					

<i>ANOVA</i>						
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>	

Regression	3	181394.3	60464.77	226.3129	0.000
Residual	475	126907.3	267.1733		
Total	478	308301.6			

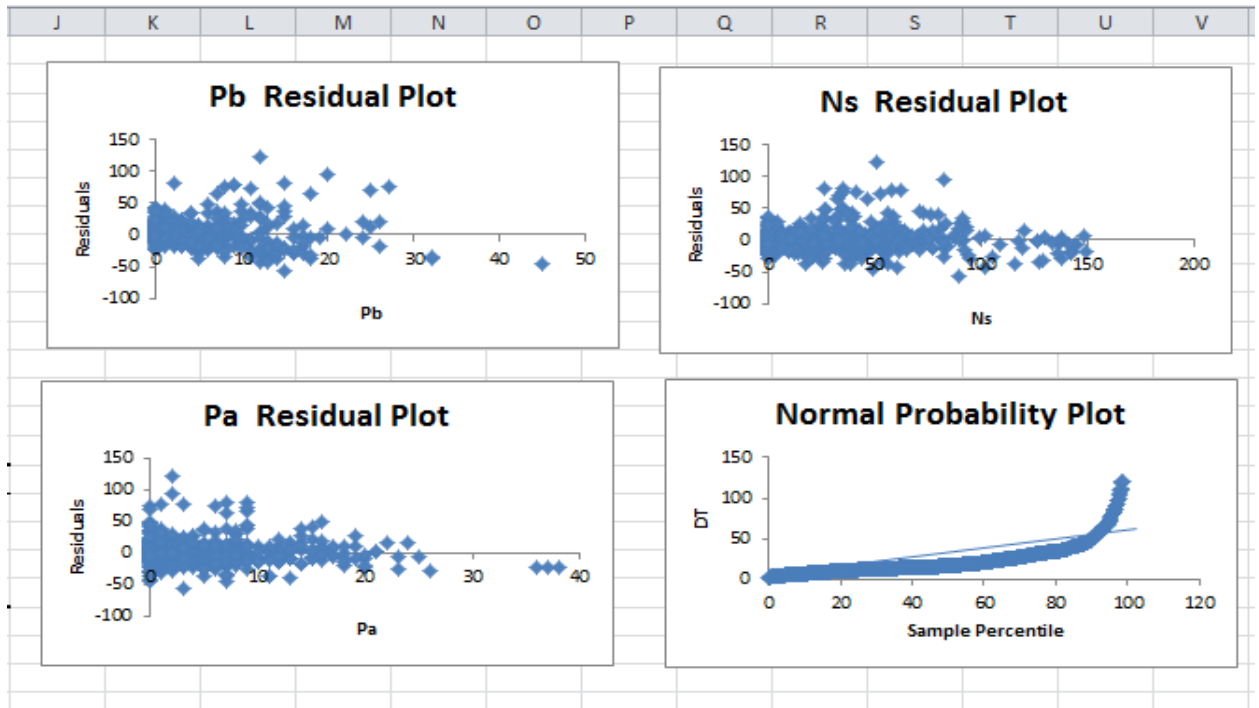
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	5.44	1.26	4.33	0.000	2.97	7.91
Pb	3.38	0.15	22.92	0.000	3.09	3.67
Pa	1.66	0.17	9.60	0.000	1.32	2.00
Ns	0.08	0.03	3.17	0.002	0.03	0.13

Table SUMMARY OUTPUT Near Intersection Bus stops

<i>Regression Statistics</i>	
Multiple R	0.72
R Square	0.52
Adjusted R Square	0.51
Standard Error	15.54
Observations	385

<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	97611.32	32537.11	134.75	0.000
Residual	381	91998.02	241.46		
Total	384	189609.3			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	8.81	1.38	6.37	0.000	6.09	11.53
Pb	3.22	0.18	17.51	0.000	2.86	3.58
Pa	1.44	0.14	10.26	0.000	1.17	1.72
Ns	0.02	0.03	0.62	0.537	-0.04	0.07



Residual and Normal Probability plots for the Overall model

## Appendix E Questionnaire

Good Day!

The response the questioners will assist me in assessing the level of service of Addis Ababa City buses transportation and customers satisfaction of the city bus enterprises. The following questions are only used for research purposes only and would not be used for other purposes.

Thanks beforehand!

I. Respondents Status: Encircle

II. Sex of Respondent

A. Male

B. Female

III. Educational Level

A. Grade 12 or Below

B. Diploma or Diploma student

C. Degree or Degree student

D. Second Degree

1. Do you use buses for transportation?

A. Yes

B. No

2. How often do you use buses for transportation?

- A. Always
  - B. Usually
  - C. Sometimes
  - D. Never
3. Which bus type is **comfortable** in your opinion?
- A. Sheger Bus
  - B. Anbessa Bus
  - C. Articulated Bus/18m Bus
  - D. Double Decker Bus
4. How much **time** do you spend waiting for buses in the bus stop?
- A. Less than 30 minute
  - B. between 30 minute and 1 hour
  - C. more than 1 hour
  - D. don't know
5. Is the **bus stop signs** appropriately located and do they have an important appliances for passengers?
- A. Appropriately located but not have important appliance
  - B. Not appropriately located but have important appliance
  - C. Appropriately located and have important appliance
  - D. Neither appropriately located nor have important appliances
6. Do buses get appropriate **spaces** in the traffic for loading and unloading and return to operation easily?
- A. Usually
  - B. Sometimes
  - C. Never
7. What should be done to encourage passengers use mass transportation like buses?
- A. Introduce more buses
  - B. awareness creation to passengers to use buses
  - C. more bus loading areas/bus stops required
  - D. all
8. Which factor contributes too much for **taking time** for loading and unloading passengers?
- A. Due to too much boarding passengers
  - B. Due to too much alighting passengers
  - C. Poor fare/bill collection system
  - D. Due to too much standing passengers
  - E. all
9. Fill the Number Inside the space please!

Variables	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
	1	2	3	4	5

Location of bus stop is suitable for passengers					
You get appropriate information on the bus stop					
Buses are punctual					
Inside of the bus is safe and secure					
Seats are available on the bus					
The prices of the bus are fair.					