



**ADDIS ABABA UNIVERSITY**  
**ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAiT)**  
**SCHOOL OF GRADUATE STUDIES**  
**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**Evaluating Quality of Service on Public Bus Transportation and Improvement  
Strategy in Addis Ababa: (A Case Study on Sheger Mass Transport Enterprise)**

**BY:**

**Mesfin Tagagne**

**A Thesis Submitted to the School of Graduate Studies of Addis Ababa University  
In partial fulfillment of the requirements for the degree of Master of Science in Civil  
Engineering (Road and Transport Engineering)**

**Advisor**

**Dr. Alemayehu Ambo**

**March 2018**

**Addis Ababa, Ethiopia**



Addis Ababa University

School of Graduate Studies School of Civil and Environmental Engineering

**Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa: (A Case Study on Sheger Mass Transport Enterprise)**

**By**

**Mesfin Tagagne**

**A Thesis Submitted to the School of Graduate Studies of Addis Ababa University  
In partial fulfillment of the requirements for the degree of Master of Science in Civil  
Engineering (Road and Transport Engineering)**

Approval by Board of Examiners

Dr. _____	_____	_____
Advisor	Signature	Date
Dr. _____	_____	_____
Internal Examiner	Signature	Date
Mr. _____	_____	_____
External Examiner	Signature	Date
Dr. _____	_____	_____
Chair Person	Signature	Date

## **DECLARATION**

I certify that this research work titled “Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa: (A Case Study on Sheger Mass Transport Enterprise)” is my own work carried out under the supervision of Dr. Alemayehu Ambo. The work has not been presented elsewhere for assessment. All sources of materials used for this thesis have been properly acknowledged

Name: Mesfin Tagagne

Signature: \_\_\_\_\_

Place: Addis Ababa Institute of Technology, Addis Ababa University

Addis Ababa.

Date of Submission: March 2018

## **ACKNOWLEDGMENT**

First of all I would like to express my deepest gratitude to my advisor Dr. Alemayehu Ambo for his continuous guidance and encouragement starting from the research proposal to the completion of the study.

My gratitude also goes to all the staffs of the Sheger Mass Transport Enterprise, particularly to field supervisors; bus drivers and ticketers who gave me the required assistances in acquiring available information and data related to this research.

I would also like to give my special thanks to the staff members of the Transport Program Management Office; Addis Ababa City Roads Authority; Addis Ababa City Administration Transport Authority and Addis Ababa Traffic Management Agency for their assistances in providing pertinent data for this study.

Lastly but not least, I would like to thank my family and friends that have been supporting me throughout the study.

## **ABSTRACT**

In cities like Addis Ababa, an increase in size and number of population generate increased travel demand. Currently, different transit agencies are trying to meet the travel demand in the City; however, there is a concern on the quality of services provided.

The aim of this study is to evaluate the quality of services of the public bus transportation system on three major routes of the Sheger Mass Transport Enterprise (SMTE) in Addis Ababa and come up with improvement strategies that would increase the quality of services. The study were done using a case study of Sheger Mass Transport Enterprise that is operating regularly along three major routes during the study period. Namely: Shiromeda - Mexico (Route 1); Mexico - Jemo 2 (Route 2) and Piasa - Saris Abo (Route 3).

Both primary and secondary data collection mechanisms were used during the study. Primary data were obtained through observation and on-board field measurements. The on-board data collection were undertaken manually in two periods. The quality of service analyses were done by using objective measures represented by numerical value. The Highway Capacity Manual (HCM) provides procedures in calculating transit quality of service measures from the passengers' point-of-views at transit stops (service frequency and passenger loading) and route segments (hours of service and service reliability). The study also utilized the Transit Capacity and Quality of Service Manual (TCQSM) multimodal level of service (LOS) analysis and Excel Spreadsheet.

The findings of study revealed that the variation of headways and passenger loading vary depending on the period and direction of travel. The study also demonstrated that on average the existing transit LOS score regarding Route 1 and Route 3 were 3.73 and 4.00 respectively. Therefore, the LOS grade for Route 1 and Route 3 are D on most segments; whereas Route 2 has an average existing transit LOS score of 3.03. The LOS grade on Route 2 was found to be C on most segments. In view of the foregoing, the study developed improvement strategies and recommendation that would be helpful for transportation policy makers and public bus transportation service providers in the city of Addis Ababa.

**Key Words:** - Public transport, Quality of service, HCM, TCQSM, Sheger Mass Transport Enterprise

## **Table of Contents**

<b>Content</b>	<b>Page</b>
ACKNOWLEDGMENT .....	I
ABSTRACT.....	II
Table of Contents.....	III
List of Figures.....	VI
List of Tables .....	VII
ACRONYMS.....	IX
CHAPTER ONE.....	1
INTRODUCTION .....	1
1.1 Background of the study.....	1
1.2 Statement of the problem.....	2
1.3 Research objectives.....	3
1.3.1 General objective.....	3
1.3.2 Specific objectives.....	3
1.4 Research questions.....	3
1.5 Significance of the study.....	3
1.6 Conceptual framework.....	4
1.7 Research design .....	4
1.8 Scope and limitations.....	5
1.9 Thesis organization.....	6
CHAPTER TWO.....	7
LITERATURE REVIEW .....	7
2.1 Background of the study.....	7
2.2 Urban transportation .....	7
2.2.1 Urban transportation system in Addis Ababa.....	8
2.2.2 Urban transportation problems.....	9
2.2.3 Urban transportation modes .....	12
2.2.3.1 Walking .....	13
2.2.3.2 Cycling.....	13
2.2.3.3 Road transportation.....	14
2.2.3.4 Rail transportation .....	14

2.3	Public transportation .....	15
2.3.1	Composition of public transportation modes in Addis Ababa .....	15
2.4	Quality of service in public transportation.....	19
2.4.1	Quality of service indicators in public bus transportation system .....	19
2.4.2	Quality of service measure in public bus transportation system.....	22
2.4.3	Subjective measures to evaluate quality of service in public bus transportation system.....	22
2.4.4	Objective measures to evaluate quality of service in public bus transportation system .....	23
2.5	Measures to improve quality of service in public bus transportation .....	24
CHAPTER THREE .....		28
MATERIALS AND RESEARCH METHODOLOGY .....		28
3.1	Research approach .....	28
3.2	Description of study area .....	28
3.2.1	Bus stop stations and direction of travel on Route 1 .....	32
3.2.2	Bus stop stations and direction of travel on Route 2.....	32
3.2.3	Bus stop stations and direction of travel on Route 3.....	32
3.3	Data sources .....	33
3.4	Data collection mechanisms .....	33
3.4.1	Primary data collection mechanisms.....	33
3.4.1.1	Data collected during first data collection period.....	34
3.4.1.2	Data collected during the second data collection period .....	36
3.4.2	Secondary data collection mechanisms.....	42
3.5	Method of data analysis .....	42
3.5.1	Transit LOS at transit stops.....	43
3.5.1.1	Service frequency .....	43
3.5.1.2	Passenger loads.....	44
3.5.2	Transit LOS at route segment.....	44
3.5.2.1	Hours of service.....	44
3.5.2.2	Reliability .....	45
3.5.2.3	Multimodal transit LOS.....	46
CHAPTER FOUR.....		53
RESULTS AND DISCUSSIONS.....		53
4.1	Introduction.....	53

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

---

4.2 Results of service frequency .....	53
4.3 Results of passenger loading.....	54
4.4 Results of hours of service .....	62
4.5 Results of reliability .....	66
4.6 Results of Multimodal Transit LOS.....	68
CHAPTER FIVE .....	83
CONCLUSIONS AND RECOMMENDATIONS .....	83
5.1 Conclusions.....	83
5.2 Recommendations.....	84
CHAPTER SIX.....	86
PROPOSED FUTURE RESEARCH AREAS .....	86
REFERENCES .....	87
Annexes.....	91

## **List of Figures**

<b>Figure</b>	<b>Page</b>
Figure 1.1: Conceptual framework of the research.....	4
Figure 1.2: Research design.....	5
Figure 2.1: Organizational structure of the Addis Ababa City Administration Transport Bureau. 9	
Figure 2.2: The number of accidents occurred in Addis Ababa in different time of day for the year 2008 and 2009 E.C. ....	10
Figure 2.3: Total number of accidents by injury type for the year 2008 and 2009 E.C. ....	11
Figure 2.4: Percentage of traffic accidents in different areas for the year 2008 and 2009 E.C. ....	11
Figure 2.5: Percentage of traffic accident with road condition for the year 2008 and 2009 E.C. 12	
Figure 2.6: Right-of-way and transit priority for use in bus improvement strategies.....	26
Figure 3.1: Map of Addis Ababa and location of sub – cities .....	29
Figure 3.2: Operational route map of Sheger Mass Transport Enterprise in Addis Ababa.....	29
Figure 3.3: Route map of the study area .....	31
Figure 3.4: Trip direction for two-way trip along route 1.....	32
Figure 3.5: Trip direction for two-way trip along route 2.....	32
Figure 3.6: Trip direction for two-way trips along route 3. ....	33
Figure 3.7: Sources of data .....	33
Figure 4.1: Variation of passenger loading with time of day from Shiromeda to Mexico. ....	54
Figure 4.2: Variation of passenger loading with time of day from Mexico to Shiromeda. ....	55
Figure 4.3: Variation of passenger loading with time of day from Mexico to Jemo 2. ....	56
Figure 4.4: Variation of passenger loading with time of day from Jemo 2 to Mexico. ....	57
Figure 4.5: Variation of passenger loading with time of day from Piasa to Saris Abo .....	58
Figure 4.6: Variation of passenger loading with time of day from Saris Abo to Piasa. ....	58
Figure 4.7: Variation of headway with time for the route from Mexico to Shiromeda.....	63
Figure 4.8: Percentage of headway occurrence on route 2 along Northbound direction.....	64
Figure 4.9: Percentage of headways occurred on route 2 along Southbound direction.....	64
Figure 4.10: Variation of headways with time of day from Jemo 2 to Mexico.....	65
Figure 4.11: Variations of headways with time of day from Saris Abo to Piasa.....	65

## **List of Tables**

<b>Table</b>	<b>Page</b>
Table 2.1: The supply of public transportation facilities and the number of passenger served in Addis Ababa in 2016 G.C .....	16
Table 2.2: Average waiting time (minutes) of passengers to get public transport services.....	16
Table 3.1: Population of Addis Ababa by sub- city for the years 2000 and 2010 E.C.....	29
Table 3.2: Travel fares of the Sheger Mass Transport Enterprise. ....	30
Table 3.3: Total number of passengers at each stop station for a given transit vehicle operating from Shiromeda to Mexico.....	35
Table 3.4: Headway for each stop station for the route from Mexico to Shiromeda.....	35
Table 3.5: Segment ID, length and width of road cross – section from Shiromeda to Mexico....	37
Table 3.6: Segment ID, length and width of road cross – section from Mexico to Shiromeda....	38
Table 3.7: Segment ID, length and width of road cross – section from Mexico to Jemo 2.....	38
Table 3.8: Segment ID, length and width of road cross – section from Jemo 2 to Mexico.....	39
Table 3.9: Segment ID, length and width of road cross – section from Piasa to Saris Abo.....	39
Table 3.10: Segment ID, length and width of road cross – section from Saris Abo to Piasa.....	40
Table 3.11: Vehicle classification and corresponding PCEs .....	41
Table 3.12: Morning peak hour traffic volume for the route from Shiromeda to Mexico. ....	41
Table 3.13: Acquired secondary data and corresponding sources .....	42
Table 3.14: Quality of service indicators used for LOS analysis .....	43
Table 3.15: Service frequency LOS thresholds for urban schedule transit service. ....	43
Table 3.16: Passenger load LOS thresholds .....	44
Table 3.17: Hour of service LOS thresholds .....	45
Table 3.18: Headway adherence LOS thresholds.....	46
Table 3.19: Variables for pedestrian environmental score .....	51
Table 3.20: Thresholds for transit LOS values .....	52
Table 4.1: Service frequency LOS for the study routes.....	53
Table 4.2: Transit stop LOS score and LOS grade for route 1 along Southbound direction.....	59
Table 4.3: Transit stop LOS score and LOS grade for route 1 along Northbound direction.....	59
Table 4.4: Transit stop LOS score and LOS grade for route 2 along Southbound direction.....	60
Table 4.5: Transit stop LOS score and LOS grade for route 2 along Northbound direction.....	60
Table 4.6: Transit stop LOS score and LOS grade for route 3 along Southbound direction.....	61
Table 4.7: Transit stop LOS score and LOS grade for route 3 along Northbound direction.....	62

Table 4.8: Hour of service LOS on the study routes.....	62
Table 4.9: Actual arrival time of buses at the Sarbet stop station along Southbound direction ...	66
Table 4.10: Results of Headway Adherence LOS for the route from Mexico to Jemo 2. ....	67
Table 4.11: Results of Headway Adherence LOS for the route from Jemo 2 to Mexico. ....	67
Table 4.12: Results of headway factor for all routes under study .....	68
Table 4.13: Results of passenger load weighting factor and perceived amenity time rate for route 1 along Southbound direction.....	70
Table 4.14: Results of average wait time for route 1 during morning peak hour period.....	71
Table 4.15: Average passenger trip length for route 1.....	71
Table 4.16: Average passenger trip length for route 2.....	72
Table 4.17: Average passenger trip length for route 3.....	72
Table 4.18: Input data and results of transit wait-ride score from Shiromeda to Mexico.....	74
Table 4.19: Input data and results of road cross –section adjustment factor for route 1 along Southbound direction. ....	76
Table 4.20: Input data and results of transit LOS for route from Shiromeda to Mexico.....	77
Table 4.21: Existing and improved transit LOS for segment from Shiromeda to Mexico. ....	78
Table 4.22: Existing and improved transit LOS for segment from Mexico to Shiromeda. ....	78
Table 4.23: Existing and improved transit LOS for segment from Mexico to Jemo 2.....	79
Table 4.24: Existing and improved transit LOS for segment from Jemo 2 to Mexico.....	80
Table 4.25: Existing and improved transit LOS from Piasa to Saris Abo segment.....	81
Table 4.26: Existing and improved transit LOS for segment from Saris Abo to Piasa. ....	82

## **ACRONYMS**

AACRA: Addis Ababa City Road Authority  
AATA: Addis Ababa Transport Authority  
AATMA: Addis Ababa Traffic Management Agency  
ATS: Alliance Transport Service  
BRT: Bus Rapid Transit  
CSA: Central Statistical Agency  
E.C: Ethiopian Calendar  
G.C: Gregorian Calendar  
GPS: Global Positioning System  
HCM: Highway Capacity Manual  
HCSI: Heterogeneous Customer Satisfaction Index  
HOV: High Occupancy Vehicle  
LED: Light Emitting Diode  
LOS: Level of Service  
LRT: Light Rail Transit  
MoWT: Ministry of Work and Transport  
PSETSE: Public Service Employees Transport Service Enterprise  
PT: Public Transport  
QOS: Quality of Service  
SMTE: Sheger Mass Transport Enterprise  
TCQSM: Transit Capacity and Quality of Service Manual  
UK: United Kingdom  
UN: United Nations

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background of the study**

Addis Ababa is the capital and largest city of the Federal Democratic Republic of Ethiopia. Due to its historical and political importance and economic growth together with its suitability for living the size and population of the city increases significantly. As stated by Tilahun Meshesha (2014) the existing public transportation system in Addis Ababa is critically inadequate to provide service for the increasing travel demand of the city. This is due to insufficient and poor quality of service on public bus transportation. Therefore, the aim of this study is to solve the transportation problem and improve the quality of service on public bus transportation.

Juan and Rocio (2014) found that current researchers and managers in PT sector strive to learn detail about the main factor affecting QOS in their organization to increase customer satisfaction and profitability. As stated by Eboli & Mazzulla (2012) Transit service quality can be evaluated by both objective and subjective measures. Subjective measures are evaluated based on passengers' perceptions. Whereas objective measures represented by disaggregate performance measures expressed as numerical values, which must be compared with fixed standards or past performances.

In the last few years, researchers showed great interest in customer satisfaction and service quality measurement. Mekonnen Mammo (2010) conduct customer satisfaction to evaluate quality of service on Anbessa City Bus Service Enterprise in Addis Ababa.

Eboli & Mazzulla (2012, P.1) reported that “The quality of service in objective measures depends on the operating decisions made by a transit agency within the constraints of its budget, particularly decisions as to where transit service should be provided, how often and how long it is provided, and how it is provided. These decisions in turn, are often guided by the agency's goals and objectives”. Therefore in this thesis the quality of service were evaluated using objective measures. In this regard, the study focused on evaluating the quality of service provided by Sheger Mass Transport Enterprise using Highway Capacity Manual 2000 (HCM 2000) and Transit Capacity

and Quality of Service Manual (TCQSM, 2013). HCM provides four LOS measures for service frequency, hour of service, passenger load and service reliability.

## **1.2 Statement of the problem**

Nowadays the size and population of Addis Ababa is greater than 570 km<sup>2</sup> and 3,378,116 respectively. As the size and number of population increases, the demand for using transportation service also increases. Currently, the demand is accommodated by using different means of transportation service. Among this public bus transportation service is one of them. However, there is a concern on quality of services provided by public bus transportation system in the city.

To accommodate the increasing numbers of passenger demand, transportation services need to be expanded both in size and quality. However, the current supply of transportation service is not proportional to the demand due to limited numbers of buses as well as routes. As stated by Mekonnen Mammo (2010) during peak hours, the demand extremely exceeds the supply of service. The waiting time to get transportation service is high and passengers struggle hard to get the services. Furthermore, buses are overcrowded. It is also too difficult for elderly, pregnant, patient and disabled people to get the service.

As stated by Tilahun Meshesha (2014) the existing public transportation service in Addis Ababa is critically inadequate to provide the required services for the increasing travel demand of the city due to insufficiency of buses, limited number of routes and substandard quality.

Currently there are problems associated with public bus transportation services, which include overcrowding; longer waiting time at stop station; longer travel time, bus bunching and so on. Beirão and Cabral (2007) found that increased private motorization has resulted in increased traffic congestion which in turn resulted in longer travel times for many people. Compare to subjective measure, objective measure is not given due attention to evaluate quality of service on public bus transportation in Addis Ababa. Thus the outcome of this research could be used to develop a standard public transportation system, where people would tend to travel using public transportation instead of private vehicles. In order to eliminate important problems such as congestions on roads; pollution; accidents, and so forth. The research areas is selected to assess the exiting transportation problems in Addis Ababa and to forward possible solutions.

### **1.3 Research objectives**

#### **1.3.1 General objective**

The overall objective of the study is to evaluate the quality of service on public bus transportation services in Addis Ababa considering the Sheger Mass Transport Enterprise (SMTE) as a case study and to come up with possible improvement strategies to enhance the quality of services.

#### **1.3.2 Specific objectives**

The specific objective of the study are:

- To identify the factors that are currently used to measure the quality of services in public bus transportation;
- To evaluate the quality of services provided by the Sheger Mass Transport Enterprise (SMTE); and
- To develop and propose solutions to improve the quality of services provided by SMTE and similarly to recommend solution for other public bus service providers in the City.

### **1.4 Research questions**

The research is envisaged to address the following questions regarding quality of transportation services provided by the SMTE:

- What are the factors used to measure the quality of services in public bus transportation?
- What and how are the quality of services currently provided by SMTE in Addis Ababa?
- What are the challenges faced by the SMTE in providing the required services?
- What are the short - and long - term plans of the Enterprise and how practical are they with respect to international standard?

### **1.5 Significance of the study**

The study is presumed significant mainly for the following three reasons:

- applicability of improvement strategy in public bus transportation services in which case the study attempts to contribute to increase the quality of service, to attract new passengers, to increase the usage of public bus transportation services and solve pertinent problems.
- to help transportation planners and transit agencies to consider good quality services before planning any public transportation activities; and

- to give direction for further study in this area on different routes of the city by different service providers.

## 1.6 Conceptual framework

The figure below illustrates the conceptual framework followed during carrying out this research. Initially, the existing supply and demand of the Sheger company will be obtained and used to examine the quality of the service in order to improve the transportation services of the Enterprise in the future. Figure 1.1 below presents the conceptual framework of the research.

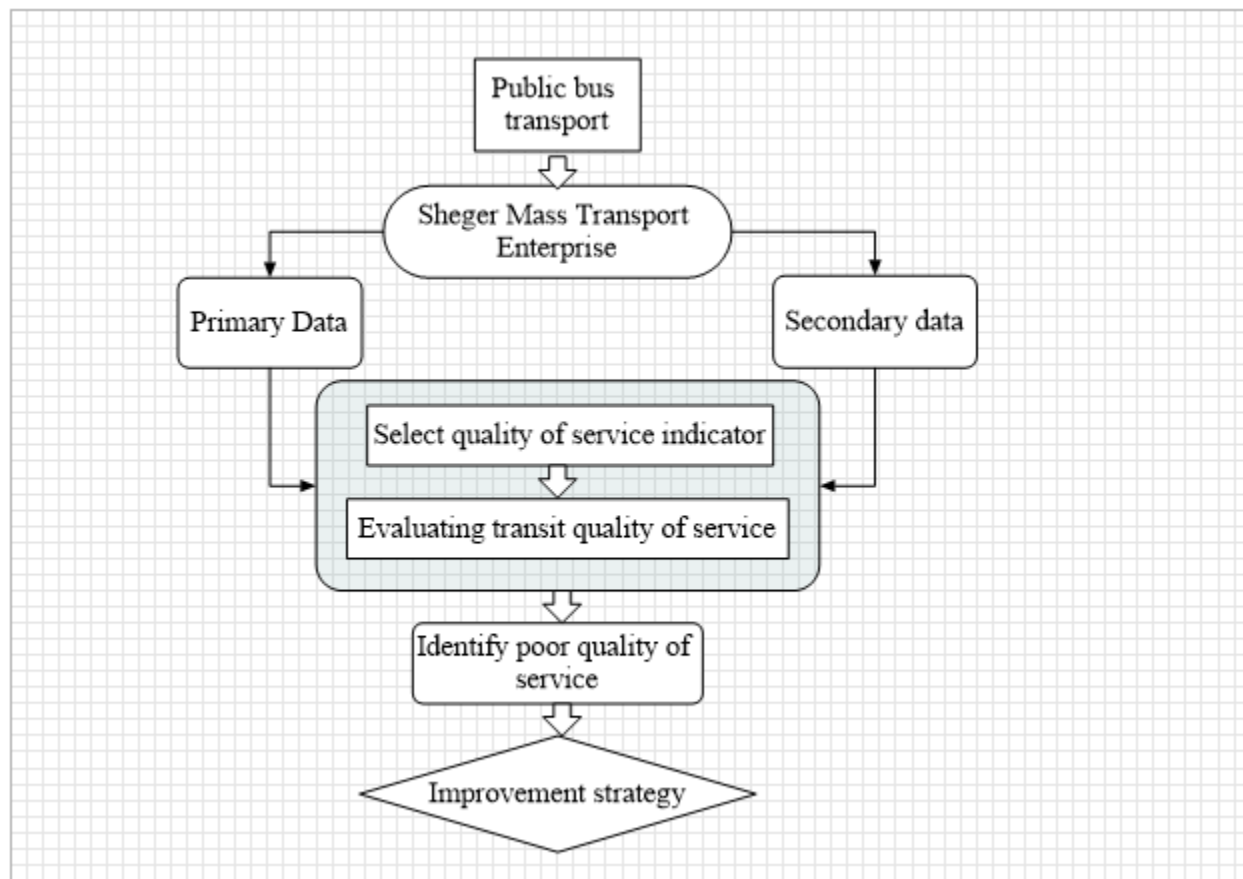


Figure 1.1: Conceptual framework of the research

## 1.7 Research design

The outline of the research design has been illustrated in Figure 1.2 below. The research problem and the objectives were stated above are followed by the literature review. Next, identification of data required to deal with and solve the problem was regarded. Primary data were acquired from field data collection; whereas, secondary data were acquired from different documents available at the office of the subject company and from different literatures. The data were used for SMTE

quality of service analysis. Finally, conclusion were formulated and recommendations forwarded based on the results of analysis for the purpose of development of improvement strategies.

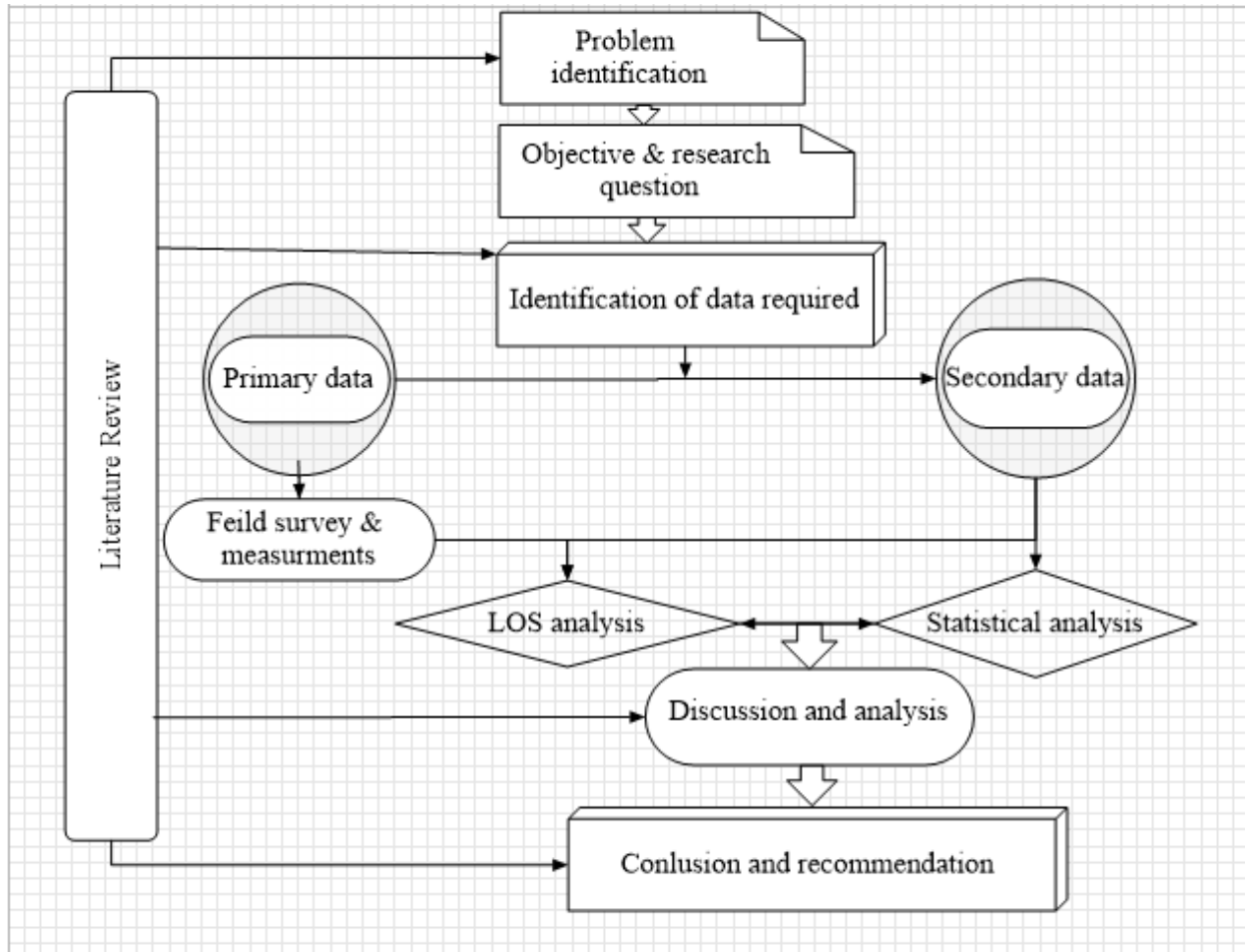


Figure 1.2: Research design

## 1.8 Scope and limitations

The study was carried out to evaluate the quality of service of SMTE on three routes of the city of Addis Ababa and these were; Mexico to Sheromeda; Mexico to Jemo 2 and Piasa to Saris Abo. These routes were providing regular (i.e. both off-peak and peak hour) transportation services during the data collection period. However, it has been envisaged that the results of the study will be applicable to other routes in the city as well.

## **1.9 Thesis organization**

The thesis has been organized into six chapters. Chapter One deals with the introduction part that includes; Background of the Study; Statement of the Problem, Objectives of the Thesis, Significance of the Study; and Scope and Limitation of the Study. Chapter Two provides a brief literature review on public bus transportation service and improvement strategies. Under the literature review, the findings of relevant studies were examined. Description on the study area, data collection process and regarding the methodology is presented in Chapter Three. In Chapter Four, the results of the analysis and discussion are presented. Chapter Five deals with the conclusions and recommendations of the study. Finally, Chapter Six presents proposed future research areas to enhance the results of this study and broaden the area to augment the overall public bus transportation in the City of Addis Ababa.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Background of the study**

In cities like Addis Ababa, public transportation is an important aspect of life for the residents. It provides mobility to those who do not have private cars or to those who prefer public transportation instead of private cars and so it offers access to jobs, education, medical and other social services.

As the number of population and size of the city increases, both freight and passenger transportation demand increases. Currently the passenger transportation demand is served by both public and private transportation service providers. For example, the Anbessa City Bus Enterprise (ACBE); SMTE and Public Service Employees Transport Service Enterprise (PSETSE) are public owned enterprises. In addition, other privately owned enterprises such as Alliance Transport Service (ATS); Higer bus; Kitkit Bus and Mini-bus taxis are providing transportation service to the residents of Addis Ababa City.

Transit agencies are responsible for providing efficient, comfortable and reliable service that is positively perceived by the public. Providing a reliable transit services is necessary to maintain an efficient and attractive system, which increases users' satisfaction and loyalty. (Vuchic, 2005)

#### **2.2 Urban transportation**

Urban transportation is all types of means of transportation used in urban areas. as stated by Mulu Eshete (2015). Urban transportation plays a crucial role in urban development by providing access for people to education, markets, employment, recreation, health care and other key services.

As stated by Pojani and Stead (2015), urban areas both in developed and developing countries, have become increasingly automobile –dominated and less sustainable. Especially in developing countries, cities have experienced a rapid growth in transportation related challenges, including traffic congestion, traffic accidents, pollution, climate change and lack of transportation accessibility for urban poor. Whereas in case of developed countries, some cities are in a trend of reclaiming urban spaces from the automobile dominance and making the urban spaces more

sustainable by improving public transportation services, encouraging non-motorized modes, creating pedestrian zone and limiting the use of private cars.

“In order to return urban places to people and to create more livable cities, decision makers in these cities urgently need to change the direction of urban transportation development toward a more sustainable future. Establishing a sustainable urban transportation system requires a comprehensive and integrated approach to policy and decision making with the aim of developing affordable, economically viable, people-oriented and environment-friendly transportation systems” (Shanghai Manual, 2011. P.2).

In the foreword to the guide, the National Association of City Transportation Officials (NACTO), 2013 chair and former New York transportation commissioner Janette Sadik-Khan said, “For the last century, streets around the world have been built around automobiles. Wide lanes for traffic and little room for people became the rules of the road in most corners of the globe”. However, when urbanization significantly increases, the street in the city should be the place for people. The design guide is based on the principle that streets are public spaces for all users from motorcyclists to pedestrians. This would be done by changing the old road hierarchy which was designed from a functional classification of streets to move traffic and vehicular access [(NACTO), 2013].

### **2.2.1 Urban transportation system in Addis Ababa**

Public and private transportation operators predominantly carry urban transportation users in Addis Ababa. The modes of urban transportation system in Addis Ababa are categorized into motorized and non-motorized traffic. As such, motorized modes of transportation include: light rail transit, public bus, minibus taxis; while non-motorized transportation services include walking and animal carts.

Organizationally, the private and public transportation operations in Addis Ababa comes under the responsibility of the Transport Bureau of the Addis Ababa City Administration Municipal Services and the organizational structure is depicted in Figure 2.1 below.

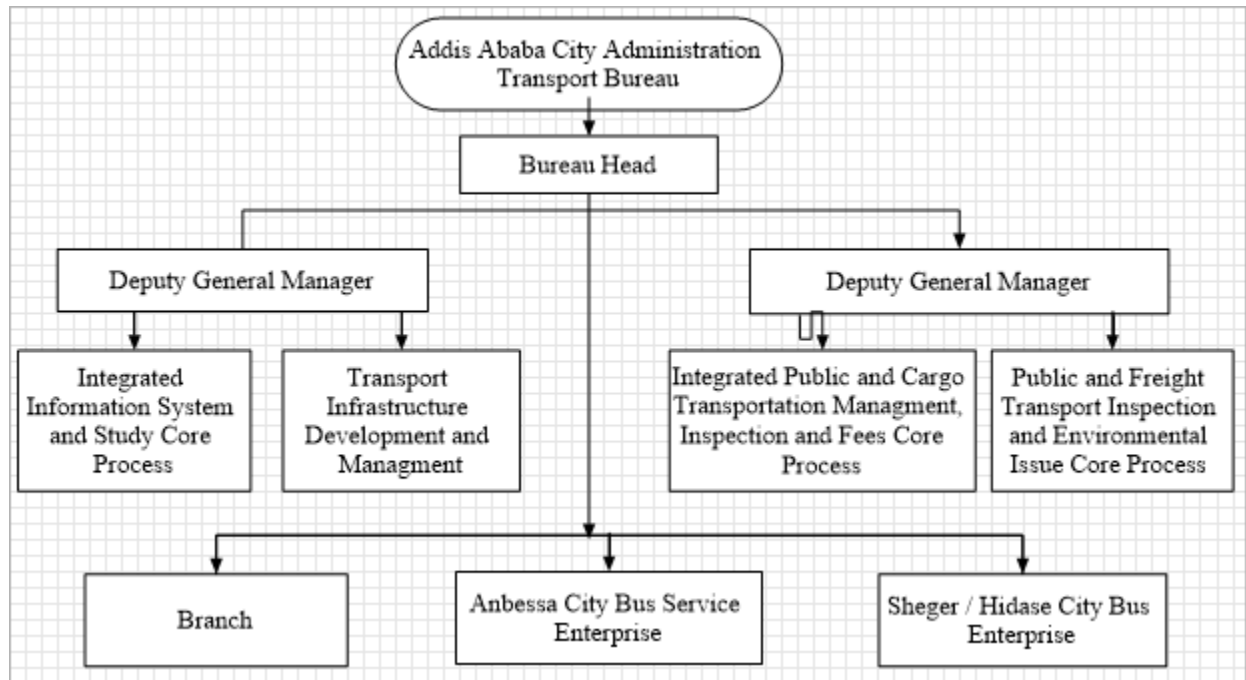


Figure 2.1: Organizational structure of the Addis Ababa City Administration Transport Bureau.

Source: Addis Ababa City Administration Transport Bureau

### 2.2.2 Urban transportation problems

Rodrigue. J. (2014) cited in Jhave. D. (2014) identifies urban transportation problems. These include: traffic congestion and parking difficulties; longer commuting; public transportation inadequacy; difficulty for non- motorized transportation; loss of public spaces; high maintenance costs; environmental impact and energy consumption; accidents and safety; freight distribution and automobile dependency. The urban transportation problems that were discussed by Rodrigue. J. (2014) cited in Jhave. D. (2014) are presented below.

Traffic congestion and parking difficulties is one of the most prevalent transportation problem in urban areas. Traffic congestion increases due to reduction of lane capacity. Some of the causes of traffic congestion in Addis Ababa include: increased traffic demand; traffic accidents; inadequate and poor infrastructure; erratic drivers' behaviors; and on-street parking. Rising automobile mobility can be perceived as a positive consequence of economic development. However, increased private motorization will cause traffic congestion at peak traffic hours.

Especially for people using public transportation, longer commuting is one of the problem of urban transportation in Addis Ababa. The spatial arrangement of residential and workplace in the city

creates one – directional travel demand. Therefore, congested people are spending a large amount of time commuting between their residences and workplaces. Public transportation inadequacy occurred due to higher travel demand during peak hour periods and shortage of supply. Especially during peak hour, public transportation inadequacy creates crowdedness and discomfort for its users.

Difficulties for non-motorized transportation are either the outcome of intense traffic, where the mobility of pedestrians, bicycles and vehicles is impaired, or due to lack of consideration for pedestrians and bicycles in the physical design of infrastructures and facilities. In addition to traffic mobility, urban spaces should also be designed for social interaction and street activities.

Environmental impacts and energy consumption including air pollution and noise affects the quality of life and even the health of urban populations. The emission from large number of automobiles have a negative impact on the environment.

In urban areas, the number of accidents and fatalities are increasing significantly. Accidents are also the causes of recurrent delay in major roads of developing countries. Figure 2.2 below shows the number of accidents occurred in Addis Ababa in different time of day and subsequently, Figure 2.3 below shows the total number of accidents by injury and fatality types for the years 2008 and 2009 E.C.

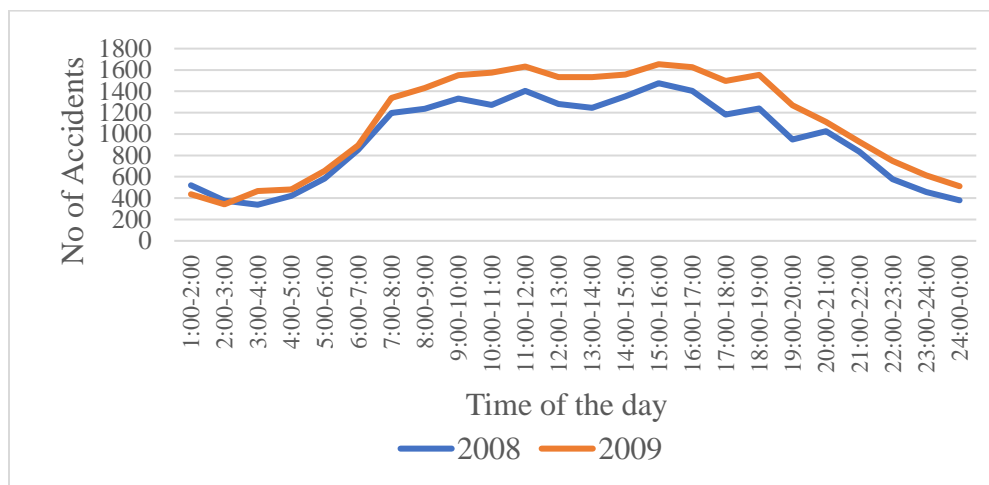


Figure 2.2: The number of accidents occurred in Addis Ababa in different time of day for the year 2008 and 2009 E.C.

Source: Addis Ababa Traffic Management Agency, 2009 E.C

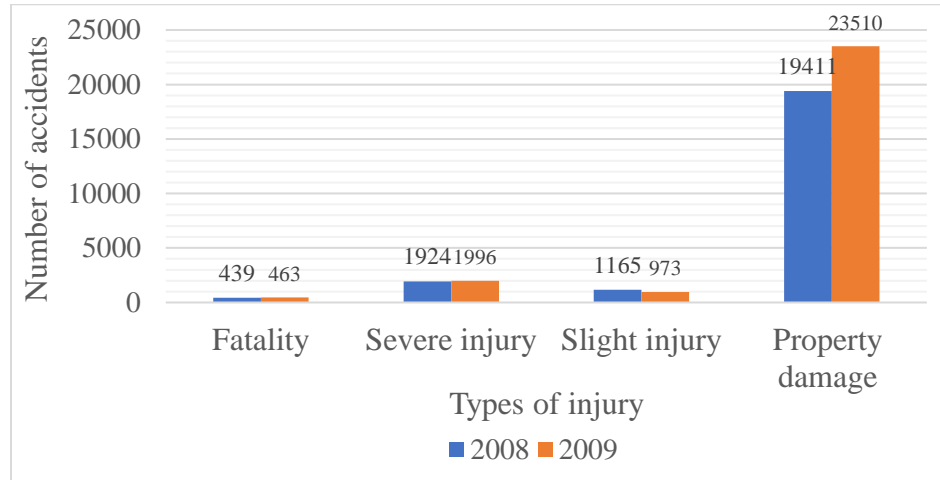


Figure 2.3: Total number of accidents by injury type for the year 2008 and 2009 E.C.

Source: Addis Ababa Traffic Management Agency, 2009 E.C.

Figure 2.3 above shows that larger number of traffic accidents in Addis Ababa result in property damages. Comparing to traffic accident in 2008 E.C. and 2009 G.C. except slight injury all types of injury for the 2009 E.C are higher in number.

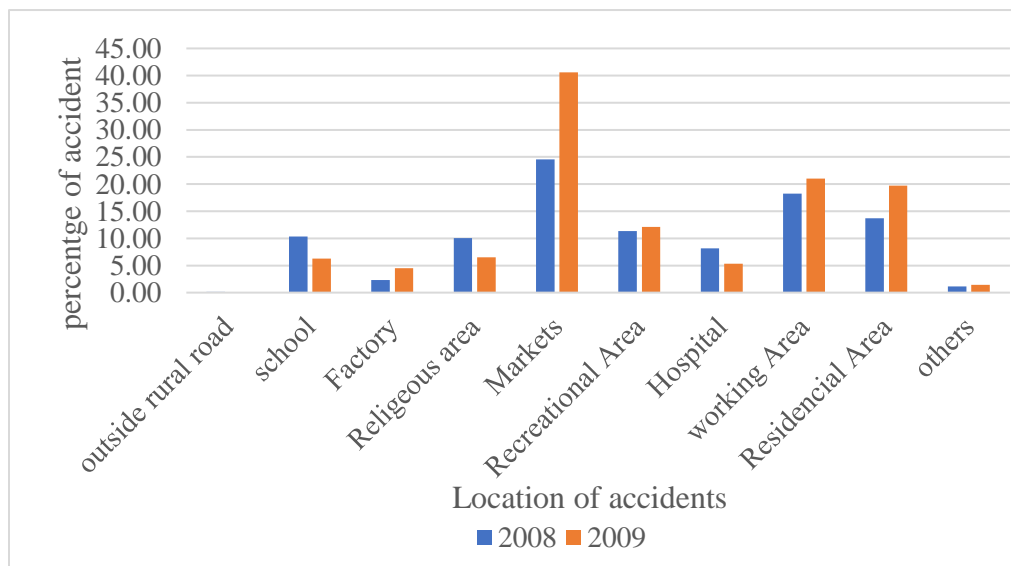


Figure 2.4: Percentage of traffic accidents in different areas for the year 2008 and 2009 E.C.

Source: Addis Ababa Traffic Management Agency, 2009 E.C.

Figure 2.4 above shows that larger percentage of traffic accidents occurred in markets, working areas and residential areas. Comparing the traffic accident in 2008 E.C. and 2009 E.C. in respect of around schools; religious areas and hospitals, it decreases in the latter case. On the other hand,

in areas around factories; markets; recreational areas; working areas and residential areas, the traffic accidents increased in 2009 E.C.

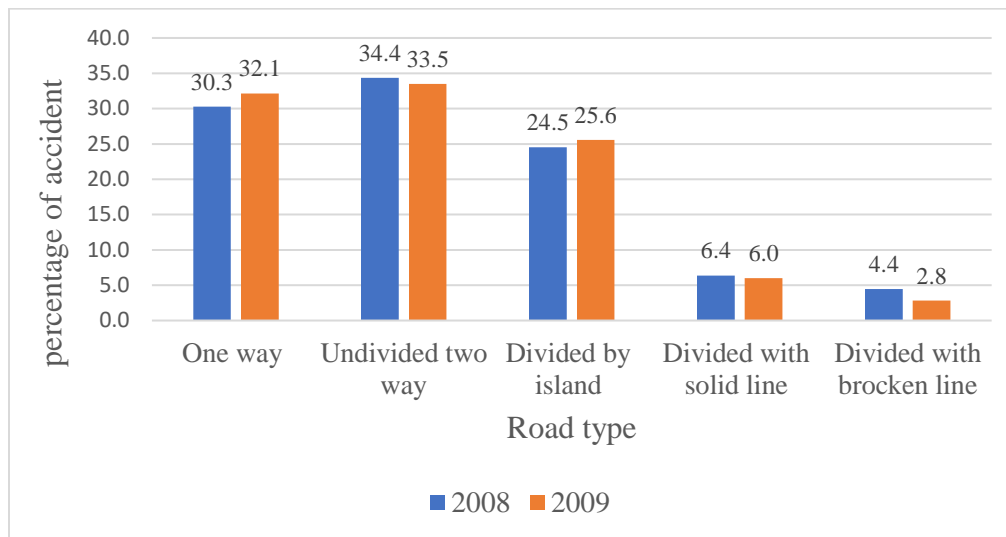


Figure 2.5: Percentage of traffic accident with road condition for the year 2008 and 2009 E.C.

Source: Addis Ababa Traffic Management Agency, 2009 E.C

Therefore, the transportation sector is responsible for public health issues such as air pollution, noise pollution, greenhouse gas emissions and traffic accidents. It is known that transportation helps the growth of economy by linking different stockholders. Similarly, if not well managed, it can retard growth and the efficient delivery of essential social services. (Verma et al, 2014)

### **2.2.3 Urban transportation modes**

Urban transportation is broadly categorized into motorized or non-motorized modes. The choice of a particular mode of urban transportation depends on such factors as accessibility and ease of operation. Non-motorized modes includes animal drawn, walking and bicycle; whereas motorized modes include: railways, airplanes, vehicles and motor cycles. (Mulu Eshete, 2015)

The following aspects can be taken in to account in deciding which public transportation mode is to be preferred. (Transport mode, n.d)

- a) **The ability to meet the passenger demand:** The selected mode should be able to cope with the estimated volume of passengers expected to use the route. This also depends on the corridor width available for the route. If the mode cannot carry the passenger demand within the corridor space available, then either more effective larger mode must be used, the corridor width increased or use of two parallel routes;

- b) **Cost:** The cost should be affordable to all groups of passengers;
- c) **Environment:** Adversary environmental impacts that include; noise and air pollution, projects visual intrusion as well as the consumption of energy should be avoided;
- d) **Journey time:** The magnitude of journey time saving depends on the number of passengers and the value placed on the time saved by each passenger;
- e) **Safety:** The expected relative safety of each mode; usually expressed as the expected number of fatalities, injuries or collisions; and
- f) Less quantifiable aspects which include:
  - comfort;
  - convenience;
  - number of modes/vehicle interchanges required;
  - flexibility;
  - reliability of mode in operation;
  - problems with fare evasion and revenue leakage;
  - sophistication of the operation and system maintenance;
  - availability of adequate trained personnel to perform these functions; and
  - Complexity of implementation.

### **2.2.3.1 Walking**

UN-Habitat (2013) describes walking as a dominant form of mobility in developing countries. Urban planners need to look at land-use and transport planning to provide well-connected and safe pedestrian environments. In most of these countries, pedestrian environment and facilities are not safe. School children and youth often walk long distances along congested corridors to reach schools, exposing them to accident risks and other hardships.

### **2.2.3.2 Cycling**

According to UN-Habitat (2013), cycling is important to enhance access in many cities of developed world. With the appropriate planning and infrastructure, bicycles can be used as feeders to other transportation services. In some cities such as, in the Netherlands, for example, bicycles account for up to 40 percent of the total trips. In smaller Chinese cities, the range is between 70 percent and 80 percent. The role of bicycles in Addis Ababa is insignificant because of topographic inconvenience and lack of dedicated bicycle lane as a part of right of way in most of city's road networks.

### **2.2.3.3 Road transportation**

Road transport plays a vital role in transporting people and goods in different areas of the city. The road network in Addis Ababa, not only links different parts of the city but also provide access to neighboring cities. Pojani & Stead (2015) classified road-based urban transportation mode in to para-transit and buses.

#### **a) Para-transit**

The term para-transit refers to unscheduled public transport services that typically operates using small buses or mini-buses. The most common type of para-transit service is delivered by minibuses. The flexibility of para-transit service has made it a very attractive mode for passengers who often do not have access to private transportation, and have travel distances that are too far to walk. Para-transit can offer more frequent transportation services. They can also penetrate closer to the home: thereby providing a more accessible service. Para-transit operation are free to choose the vehicle type and the route. (Urban Infrastructure, 2015)

#### **b) Buses**

In the road-based domain, there are also varieties of modes. The highest capacity mode is bus rapid transit (BRT) and has some of the attributes of fixed-track services such as dedicated (though not fixed-track) rights-of-way, stations, and high-capacity vehicles. BRT services still contend with general traffic at intersections, which is commonly dealt with through specialized signaling systems and turning lanes. (Urban Infrastructure, 2015)

### **2.2.3.4 Rail transportation**

Rail transit operate exclusively on dedicated rights-of-way and run on a guided track on steel wheels or rubber tires. Such modes includes: Light rail, Rapid rail and Sub-urban Rail transit and are explained as follows. (Transport modes, n.d)

- a) **Light rail transit Trains:** operate in mixed traffic along public streets to semi-metro rail systems on exclusive trucks.
- b) **Rapid rail transit (Metro, subways or underground):** operates on exclusive right-of-ways at high speed and high capacity with passengers' board from high-level platform to facilitate rapid loading.
- c) **Sub-urban rail transit (Commuter rail system):** operates on trucks shared with intercity passenger crews and freight.

## **2.3 Public transportation**

Public transportation is a shared passenger transportation service which is available for use by public for the purpose of travelling from an origin to a destination. Developing countries are characterized by high population density, low income and lack of resources forcing them to depend on public transportation/transit systems, which can transport large number of people at low cost. (Ranawana and Hewage, 2015)

Demelash Abate (2007) pointed out that public transportation is typically more energy efficient than private cars if running at reasonable occupancy rates, but offers less flexibility and typically longer travel times. The conventional bus is the most common public transportation mode in developing countries mainly due to its low running and initial cost, route flexibility and permeability into town and city centers.

In developing countries, the primary importance of public transportation is to move large number of passengers to meet mobility demand. However, existing public transportation supply in developing countries do not satisfy the demand for a number of reasons. This includes: the quality of travel on public transportation is poor; roads are not properly maintained and so are managed; the safety and comfort of people using public transportation is low (Demelash Abate, 2007).

This research is on bus transportation system in Addis Ababa and is focused on conventional bus transportation system and specifics are described below.

### **2.3.1 Composition of public transportation modes in Addis Ababa**

In Addis Ababa, there are different types of public transportation service providers and these include Light Rail transit (LRT), Public Service Employees Transport Service Enterprise (PSETSE), Anbesa City Bus Enterprise (ACBE), Alliance Transport Service (ATS), Sheger Mass Transport Enterprise (SMTE), Higer buses and Minibuses. However, due to the increasing mobility demand, economic activity and rapid urbanization, the quality of public transportation services is low. Table 2.1 below shows the transportation supply and the number of passenger served in Addis Ababa in 2016 G.C.

Table 2.1: The supply of public transportation facilities and the number of passenger served in Addis Ababa in 2016 G.C

No.	Vehicle Types, Numbers and Activities				Number of Passengers per day		No. of routes	
	Types	Total	Active		Average No. of Trips per day	Total		Average per active bus per trip
			No.	%				
1	Anbessa bus	723	440	61	10	396,000	90	124
2	Sheger bus	131	89	68	8	39,160	55	23
3	Higer bus	393	280	71	12	134,400	40	37
4	Kitkit bus	291	191	66	10	76,400	40	303
5	Code -1 taxi	4,830	3,481	72	16	668,352	12	318
6	Code -3 Minibus	6,646	4,392	66	16	843,264	12	303
7	Alliance bus	25	17	68	7	10,710	90	17
8	Light rail	41	18	44	17	97,002	317	2
<b>Total</b>		<b>13,080</b>	<b>8,908</b>			<b>2,265,288</b>		

Source: Research on Public Transport Waiting Time in Addis Ababa Addis Ababa Transport Authority, March 2017.

Note: Some calculations were done by the Author.

According to the Addis Ababa Transport Authority study, public transportation waiting times were established as presented in Table 2.2 below.

Table 2.2: Average waiting time (minutes) of passengers to get public transport services.

N0.	Types of public transportation service provider	Average waiting time (min)
1	Light rail transit	17
2	Anbessa bus	86
3	Sheger bus	24
4	Higer bus	20
5	Minibus	14

Source: (Addis Ababa Transport Authority, March 2017).

The Anbessa City Bus Enterprise is currently giving service with a total of 440 active buses. In 2016, ACBE transported a total of 396,000 passengers per day. According to the Addis Ababa City Administration Transport Authority study, 2017 the waiting time to get ACBE service was

an average of 86 minutes. Related to service provision, the study identified the causes for poor quality services. Poor quality services included: bus is not clean, high passenger loading, lack of modern garages and depots, lack of modern field supervision, lack of skilled personnel, lack of modern and comfortable buses, lack of dedicated bus lane, on street parking, lack of public transportation terminals, poor quality of roads and improper maintenance, traffic congestion and shortage of transit vehicles.

Higer Bus Transport started giving transportation services with 461 buses in 2008 G.C. Currently there are only 280 buses that are giving services along 37 routes in the city. The company transports an average of 134,400 passengers per day. Regarding the service, the bus is operating with high passenger loading which makes them uncomfortable for passengers and making supervision difficult.

Minibus transportation service is provided by both Code 1 minibus and Code 3 supporting minibuses. Code 1 minibuses provide service with a total of 3,481 vehicles along 318 routes and Code 3 supporting minibuses provide service with a total of 4,392 vehicles along 303 routes. Compared to the other public transportation service providers, minibus taxis serve higher number of routes and the waiting time to get the service is small (about 14 minutes).

Based on the information obtained from drivers, the causes for poor quality of service on minibus taxis were; lack of field supervision, unwillingness to give service along their designated routes and lack of coordination between the transportation offices at sub city level. It was also found that the minibus taxis charge tariffs above the normal rates. Lack of awareness regarding public transportation usage, traffic congestion, lack of enough transportation terminals and infrastructures and shortage of supply were some of the causes for poor quality service. In this regard, shorter trip lengths and availability of alternative public transportation services will presumably increase the quality of service and decrease the waiting time to get minibus transportation services.

According to the results of the Addis Ababa Transport Authority study (2017), the study also identified factors which increase waiting time to get minibus service using passengers' views. These includes: shortage of infrastructure; low supply of public transportation; traffic congestion is serious; transportation facilities and infrastructures are not properly maintained; there is lack of continuous field supervision; on-street parking limits smooth traffic flows; and there is high passenger demand during peak hour periods.

According to the results of the Addis Ababa Transport Authority study (2017), the average waiting time to get the SMTE service was 24 minutes. However, the Enterprise is making efforts to reduce waiting time to 10 minutes. Based on the information obtained from SMTE drivers, the causes for high waiting time are: lack of suitable bus terminals; insufficient infrastructures; on street parking; traffic congestion; lack of dedicated bus lanes and illegal activities by assigned public transportation monitors.

The Addis Ababa Light Rail Transit (AALRT) started giving transportation services in October 2015 G.C. with 18 trains along East-West and North-South directions. The AALRT serves an average of 97,002 passengers per day. The average waiting time to get AALRT service is 17 minutes. During peak hour, the average waiting time is 15 minutes. The AALRT administration has long- and short-term plans to decrease the average waiting time to 10-12 minutes.

Initially, the AALRT office had a plan of 6-minute headway. However, due to a number of problems the headway extended up to 16-18 minutes due to lack of spare parts; shortage of electric supply; very high passenger loadings. Continuous rail crossing of vehicle and pedestrian; lack of skilled personnel and shortage of supply.

Compared to Midibuses and Minibuses taxis high occupancy vehicles are preferred due to the following reasons, according to the Addis Ababa City Transport Authority:-

- It involves strong managerial activities;
- It saves time and money;
- It reduces air pollution;
- It reduces traffic congestion;
- It carries high number of passengers;
- It reduces waiting time to get the service; and
- It is sustainable and acceptable by the policy

Similarly, the study summarized the advantages and disadvantages of midi bus and minibus taxi services.

## **2.4 Quality of service in public transportation**

According to Parasuraman et al. (1988), quality is defined as adherence to customer satisfaction, which requires meeting the criteria that customers want. Similarly, Juan al et (2014) stated that current researchers and managers in the public transport (PT) sector strive to learn details about the main factors affecting quality of service (QOS) in their organizations to increase customer satisfaction and profitability. Offering high quality service will encourage a modal shift from private mode to PT mode. Consequently, it promotes sustainable mobility. Measuring customer satisfaction enables transit agencies to know the quality of service provided. If customers are satisfied with the quality of the bus services, they will continue to use the bus service.

### **2.4.1 Quality of service indicators in public bus transportation system**

A review of literature on transit performance reveals that different authors use different service quality attributes to assess customer satisfaction; for example, Friman & Gärling (2001) classified service quality attributes into four broad categories which include; reliability of the system, treatment by employee, simplicity of information, and design. The criteria which affect the overall satisfaction are therefore based on literature reviews and they can be specified after an interaction between the analyst and the concerning company (Mihelis et al., 2001).

In the following, service quality determinants of: service availability, service reliability, comfort, cleanliness, safety and security, fare, information, customer care and environmental impacts that were dealt with by Eboli & Mazzulla ( 2012 ) are discussed below:.

#### **2.4.1.1 Service Availability**

Transit service availability can be used as a measure of quality of service. Availability measures are discussed below:

##### **a) Frequency at transit Stops**

Service frequency measures how often transit service is provided. It determines the number of times an hour a user has access to the transit mode. It is also a measure of the convenience of transit service that helps riders to determine how long one wait for a transit vehicle (HCM, 2000). Service frequency resulted to be the attribute with the highest weight on the overall transit service quality (Eboli and Mazzulla, 2008).

As stated in HCM (2000), urban scheduled transit service includes all scheduled services within a city as well as services between cities within a larger metropolitan area. Deviated-route bus service

is included in the category, because the basic service is scheduled even if specific stops are not. The service frequency, LOS measure for urban scheduled transit service is headway and is determined at a given bus stop.

**b) Span of service**

Hour of service is the number of hours during a day that transit service is provided along a route, segment of a route, or between two locations. (HCM, 2000). Hours of service can vary by day of the week, by route, and even by stop. Then, an indicator can be calculated as an average value of the number of hours per day in different days and/or for different routes/stops. The length of service in a day can affect the convenience of using transit system and constrain the types of trips that the passengers are able to make by transit. (Eboli and Mazzulla, 2012)

**2.4.1.2 Service reliability**

Several performance metrics can be used to assess the reliability of transit system. These include on-time arrivals, travel-time adherence, run-time adherence, and customer satisfaction. (Arhin, 2013). In addition, the Transit Capacity and Quality of Service Manual (TCQSM, 2013) defined service reliability in two categories: on-time performance and headway adherence. Reliability affects the waiting time of passengers at a stop for a bus to arrive. Reliability also affects total trip time of a passenger. As stated by Chang (1988), effective scheduling and utilization of vehicle capacity increase the reliability of service and provide significant benefits to transit agencies and passengers alike.

**a) On-time performance**

On-time performance can be evaluated by considering the percentage of transit vehicles departing from or arriving to a location on time. (Eboli and Mazzulla, 2012). Many transportation service agencies provide a range around the schedule time within which the transit bus is considered to be on time. Generally, on-time arrival depends on the types of routes; locations and condition of stop stations; traffic composition on that route, number of people boarding and alighting and ticketing system. (Arhin, 2013).

**b) Headway regularity**

Headway can be defined as the evenness of intervals between transit vehicles (Eboli and Mazzulla, 2012). Different studies provide different methods for determining headway regularity. According

to the HCM (2000), headway adherence is calculated by dividing standard deviation of headways with schedule headway. Similarly, the headway adherence (coefficients of variation of headways)  $C_{vh}$  was calculated by dividing the standard deviation of headways with the average headway (TCQSM, 2013).

#### **2.4.1.3 Comfort**

The most frequently used indicator for evaluating comfort during the journey is degree of crowding on bus. According to Eboli and Mazzulla (2011), degree of crowding was calculated on the basis of the number of passengers per run and the number of offered seats per run. Passenger load (PLOS) is based on two measures: Passenger load can be defined by passengers per seat when the transit vehicle designed for mostly seated passengers. For transit vehicle designed for mostly standing passengers average passenger standing area per passenger can be used to describe the level of crowding on board the vehicle. (TCQSM, 2013)

Threshold values for overcrowding are based on seating capacity, travel demand, headway, and an acceptable maximum number of standees. Overcrowding thresholds also vary by length of route, frequency of service and time of day. (Arhin, 2013)

#### **2.4.1.4 Cleanliness**

The indicators regarding cleanliness refer to the physical condition of vehicles and facilities, and specifically it includes cleanness of interior and exterior of vehicle, shelter and benches. (Eboli and Mazzulla, 2012).

#### **2.4.1.5 Safety and security**

Safety and security indicates the degree of safety from crime or accidents and the feeling of security resulting from psychological factors; therefore, this aspect refers not only to safety from crimes while riding or at bus stops and from accidents, but also to safety related to the behavior of other persons and to the bus operation. (Eboli and Mazzulla, 2012)

#### **2.4.1.6 Fare**

The service aspect regarding fare includes characteristics of the monetary cost of the journey by bus, like the cost of a one-way ride, the cost of a transfer, the availability of discounted fares (e.g. for students), the availability of volume discounts (e.g. for monthly passes), the cost of parking at bus stops. (Eboli and Mazzulla, 2012)

#### **2.4.1.7 Information**

Another service aspect affecting transit service quality is linked to the availability of information pertinent to the planning and execution of a journey. Passengers need to know how to use transit services, where the access are located; where to get off in the proximity of their destination, whether any transfers are required; and when transit services are scheduled to depart and arrive. Without this information, potential passengers will not be able to use transit services. (TCQSM, 2003. P.124)

#### **2.4.1.8 Customer care**

Customer care includes those elements needed to make easier and more pleasant journey, like courtesy and knowledge of drivers, courtesy and helpfulness of ticket agents and personnel appearance, (Eboli and Mazzulla, 2012).

#### **2.4.1.9 Environmental Impacts**

Environmental impacts due to bus system includes: emissions, noise, visual pollution, vibration, dust, dirt, odor and waste should be considered. Environmental protection can be maintained by using ecological vehicles. (Eboli and Mazzulla, 2012).

### **2.4.2 Quality of service measure in public bus transportation system**

As stated by Eboli and Mazzulla (2012), transit service quality can be evaluated by subjective and objective measures. Subjective measures are evaluated based on passengers' perceptions, whereas objective measures are numerical values which are represented by disaggregate performance measures which must be compared with fixed standards or past performances. Definitively, both subjective and objective transit performance measures support transit agencies for monitoring, evaluating, and implementing improvements in service. (Eboli and Mazzulla, 2012).

### **2.4.3 Subjective measures to evaluate quality of service in public bus transportation system**

Subjective measures are evaluated based on customer satisfaction. Customer satisfaction represents a measure of company performance according to customer needs (Hill et al. 2003). In this case, customers express their opinions about the services provided.

As stated by Eboli and Mazzulla (2009) subjective measure show some advantages compared to the other adopted methods for measuring service quality, because it can be easily applied by the transit operators. However, this type of measure have strong subjectivity of transit users'

judgments; the failure to take non-users' perceptions into account and users' judgments are too heterogeneous. However, Heterogeneous Customer Satisfaction Index (HCSI) introduces heterogeneity into user judgments, because importance and satisfaction rates are corrected according to dispersion from the average value.

In the last few years, researchers showed great interest in customer satisfaction and service quality measurement. In this regard, Mekonnen M, (2010) conducted customer satisfaction to evaluate quality of service on ACBSE in Addis Ababa. Accordingly, he stated some customer dissatisfaction factors such as; low service frequency, schedule unreliability, excessive waiting time, long walking distance to get the service and overcrowding.

The United Kingdom (UK) Department for Transport (2003) also conducted studies regarding customer need in public transportation. High frequency of service, services that are reliable and fares that offer value for money are revealed as important needs of UK public transportation users. The report also stated about the importance of understandable timetable information in bus stop and in local newspaper in order to make them aware of the existence of the service. Simple ticketing arrangement is also important in order to make them use public transportation.

Researches were conducted regarding customer satisfaction with an aim to identify unattractive and substandard factors in public transportation. For instance, Edvarsson (1998) found that driver incompetence, lack of punctuality and information were important factors causing dissatisfaction.

Beirão (2007) conducted in depth interviews in Porto, Portugal to find out dissatisfying factors and customers reported that wasted time, too crowded, lack of comfort, time uncertainty, lack of control, unreliability, long waiting times, need to transfer, unable to change route to avoid traffic congestion and lack of flexibility.

#### **2.4.4 Objective measures to evaluate quality of service in public bus transportation system**

Objective performance measures are quantitative measures expressed as a numerical value that must be compared with a fixed standard or past performance (Eboli and Mazzulla, 2012).

In order to evaluate and monitor service quality, performance standards should be established for each objective measure. Alternatively, the performance indicators can be expressed in a format that provides built-in interpretation. As a result six levels of service letters are designated from A

to F, with level of service (LOS) A representing the best operating conditions and LOS F the worst. (Eboli and Mazzulla, 2012)

The Highway Capacity Manual 2000 (HCM 2000) provides a broad range of Level-of-Service (LOS) measures for all the modes, including auto, transit, bicycle, and pedestrian modes.

The TCQSM (2013) also introduces a new approach to measure performance of transit service using a two-dimensional LOS framework covering two service quality dimensions (availability and comfort/convenience) for three levels (stops, route segments, and the whole system). Xin et al (2005) applied the TCQSM to evaluate the quality of service along a highway corridor. The author uses four LOS measures: service frequency, hour of service, service coverage and transit – auto travel time.

The study conducted by Bhuyan & Nayak (2013) shows that TCQSM methodology for evaluating the LOS of a transit system is straightforward and relatively easy to apply and cover the importance aspects of quality of service concerns by passengers, transit operators and planners.

## **2.5 Measures to improve quality of service in public bus transportation**

Improving bus system helps transportation planners and transportation service providers to improve the current and future mobility needs, increase customer satisfaction and profitability of transportation industry. Through sustainable transportation and transportation demand management, many Canadian communities have taken actions to improve the sustainability of their urban system and reshape their transportation system to address the congestion issue, respond to their community needs and provide travelers and commuters with convenient, reliable, clean, safe and sustainable transportation options (Gris Orange 2012).

Mekonnen M, (2010) pointed out some measures to improve the ACBE and these includes: importing additional number of buses to increase the service coverage and reduce overcrowding; designing better routes to improve interchangeability between services and minimize the walking distance to and from the bus stops; providing other alternative mass public transport services by encouraging private sectors to participate on transportation industry.

Monzon et al. (2013) shows benefit of real time passenger information system on Madrid and Bremerhaven cities. As a result, both bus punctuality and user's perception of public transportation increases.

Improving bus service means providing a reliable and convenient alternative service to wide range of commuters. Gris Orange (2012) categorized the measures to improve the bus service into five main categories. These include:

- Network planning and service;
- Branding and marketing;
- Right-of-way and transit priority;
- Bus stop and bus station; and
- Vehicle.

**a) Network planning and services**

Planning for improved bus service is more effective when it relies on a comprehensive and strategic approach. Developing a shared accountability system is a key factor to ensure the coordination among transit authorities, public and private agencies, and the compatibility between transit networks. (Gris Orange, 2012).

Increased reliability refers to greater schedule adherence, increased number of routes ensuring an equitable city coverage, higher service frequency during both peak hours and non-peak hours. Assessing performance on a regular basis helps to adapt and accommodate the need of bus system. Improved route coordination between transit networks facilitate transfer and connection between the networks helps to reduce the waiting time at transfer points of the network. (Gris Orange, 2012).

**b) Branding and Marketing**

Branding and marketing strategies have become a strategic component of transit improvement projects to attract new passengers and retain current riders. These include: comprehensive marketing strategy, branding devise, market research, social marketing, advertising, strategic partnership and pricing strategies. (Gris Orange, 2012.)

Figure 2.6 below presents the right-of-way and transit priority for use in bus improvement strategies.

**c) Right of way and transit priority**

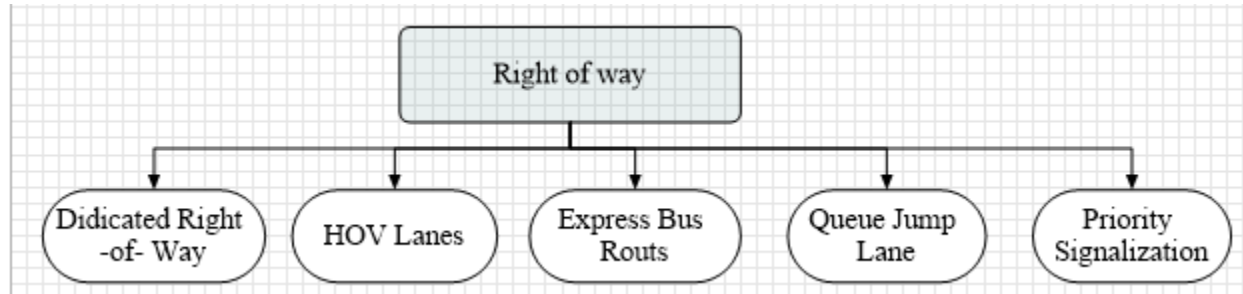


Figure 2.6: Right-of-way and transit priority for use in bus improvement strategies.

Source: Gris Orange, (2012)

- **Dedicated right-of-way**

Dedicated right-of-way lanes are exclusively and permanently reserved lanes for the use of transit vehicles. They are segregated from regular routes by curbs or physical barriers, allowing transit vehicles to remain independent from regular traffic. It reduces traffic congestion, faster travel time for commuters and increase the reliability of the service.

- **High Occupancy Vehicle (HOV) Lanes**

Bus lanes are integrated lanes on surface street where buses have preferential treatment and may share the road with other (HOV), taxis, and hybrid cars (occasionally). The lane may be separated by a line or special signalization. These lanes are likely to be reserved for a limited time during peak hours. Buses using this lane can be expected to follow regular traffic at crossings or can benefit from transit priority signalization at traffic lights. Gris Orange, (2012)

- **Express bus routes**

Express buses carry commuters from one major trip generator to another and make very few stops. They generally drive directly to a given destination and benefit from their own dedicated road space, maximizing travel speed and service reliability. Gris Orange, (2012)

- **Queue Jump Lane**

A queue jump lane is a reserved lane on the section of the road closest to the intersection, which allows buses to avoid long queues at intersections. Queue jump lane is a cost-effective alternative to increase bus speed and reduce travel time. Gris Orange, (2012)

- **Priority signalization**

Transit priority signalization consists of various techniques and control strategies giving buses preferential treatment by allowing them to override regular traffic signals. Gris Orange, (2012)

- **Bus stop and bus station**

Bus stops and stations should be carefully designed because of their impacts on both the convenience and the attractiveness of using a bus service. (Gris Orange 2012).

- **Vehicle**

Vehicles should be carefully selected because of their impacts on travel time, service reliability, and operating or maintenance costs. Gris Orange, (2012).

## **CHAPTER THREE**

### **MATERIALS AND RESEARCH METHODOLOGY**

#### **3.1 Research approach**

The study approach includes: study area description, sources of data, data collection mechanisms and method of data analysis. Both primary and secondary data collection mechanisms are discussed. This study is a descriptive research type which uses a case study of the Sheger Mass Transport Enterprise (SMTE), a private entity which is actively operating in Addis Ababa City. Three routes of the operational lines of SMTE were considered in the study and these include: Shiromeda - Mexico (Route 1); Mexico - Jemo 2 (Route 2) and Piasa - Saris Abo (Route 3).

#### **3.2 Description of study area**

Addis Ababa is the capital and the largest city of the Federal Democratic Republic of Ethiopia. According to the 2007 population census, it had a population of 2,738,248. With an average annual growth rate of 2.1 %, this number would have increased to around 3,378,116 in 2017/18.

Due to its historical, cultural and political significance, the city is a seat for various embassies, international and regional organizations. The city is located at the center of the country on an elevation of 2,300 meters (7,500 ft) and latitude and longitude of 9°1'48"N 38°44'24"E. The city rises to over 3,000 meters (9,800 ft) at Entoto Mountain in the North and has lowest elevation around Bole International Airport with 2,326 meters (7,631 feet) above sea level in the south. Currently, the size and population of Addis Ababa is increasing significantly due to migration from rural areas and natural increment phenomena. The area of the city has been expanded to over 540 square kilometers (km<sup>2</sup>) and is divided into 10 administrative Sub-cities and further divided into 116 Woredas. ("History of Addis Ababa", n.d.).

Depending on the population density, residential places can be classified into higher density at the central area and lower density at the periphery (Yetnayet Ayalneh, 2012). The central sub-cities have relatively equal distribution of population even though these areas only count for 7.8 % of the City's area and their population accounts for 32.5 % of the city's residents. Table 3.1 below presents the 2000 and 2010 E.C population of the sub-cities.

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa : ( A Case Study on Sheger Mass Transport Enterprise)*

Table 3.1: Population of Addis Ababa by sub- city for the years 2000 and 2010 E.C.

No	Sub-city	No of woredas	Population 2000 E.C	Population 2010 E.C	Percentage of area	Area (km <sup>2</sup> )	Population density
1	Lideta	10	201,613	248,726	1.7	9.18	27,094
2	Cherkos	11	220,991	272,632	2.8	14.62	18,648
3	Arada	10	212,009	261,551	1.9	9.9	26,419
4	Addis Ketema	10	255,092	314,701	1.4	7.41	42,470
	<b>Central Area Total</b>	<b>41</b>	<b>889,705</b>	<b>1,097,610</b>	<b>7.8</b>	<b>41</b>	<b>28,658</b>
5	Gullele	10	267,381	329,862	5.7	30.18	10,930
6	Yeka	13	346,484	427,450	16.3	85.98	4,972
7	Bole	14	308,714	380,854	23.2	122.08	3,120
8	Nefas Silk Lafto	12	316,108	389,976	13.0	68.3	5,710
9	Kolfe Keraniyo	15	428,654	528,821	11.6	61.25	8,634
10	Akaki Kality	11	181,202	223,545	22.4	118.08	1,893
	<b>Peripheral Area Total</b>	<b>75</b>	<b>1,848,543</b>	<b>2,280,507</b>	<b>92.2</b>	<b>486</b>	<b>5,876</b>
	<b>Grand Total</b>	<b>116</b>	<b>2,738,248</b>	<b>3,378,116</b>	<b>100</b>	<b>527</b>	

Source: -Addis Ababa Population by sub-city (2007 Census report)

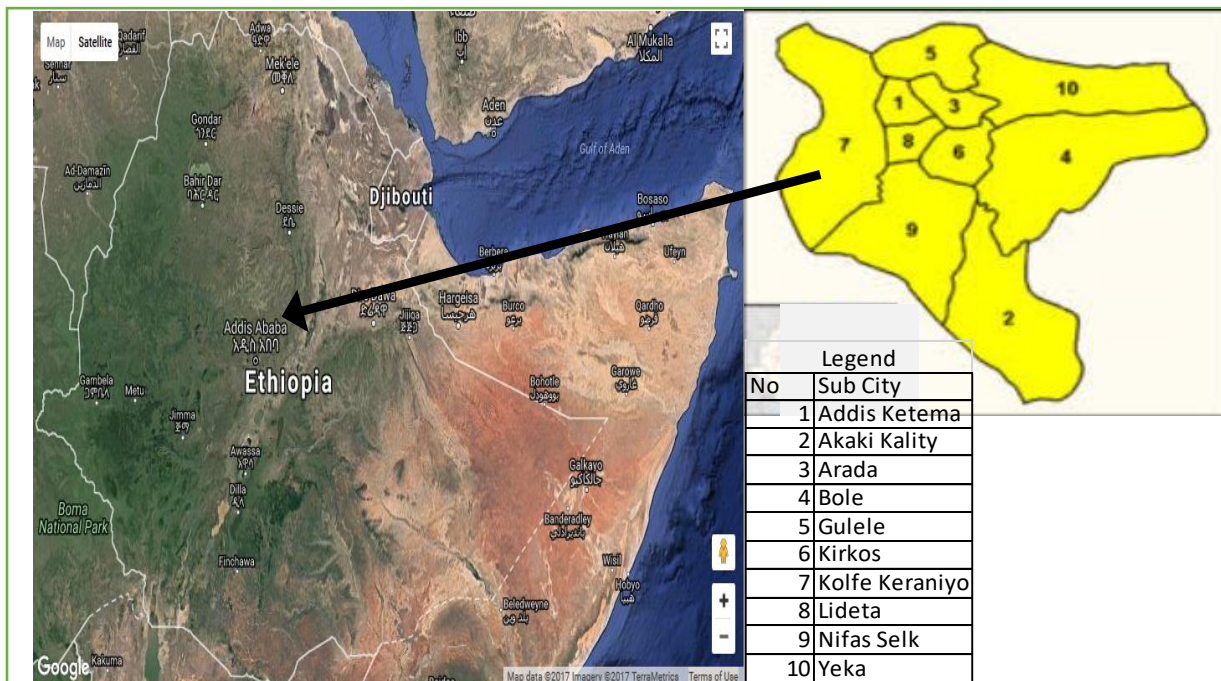


Figure 3.1: Map of Addis Ababa and location of sub – cities

The Sheger Mass Transport Enterprise was launched to provide public transportation service on free trial on May 28, 2016 with 10 buses for 10 days. During this period, 112,000 passengers were acquiring the service on the route from Mexico to Shiromeda. Each bus is 12.5 m in length with a capacity of 70 passengers - 40 seated and 30 standing. The buses are equipped with global positioning systems (GPS), security cameras, televisions, e-ticketing and other facilities to help passengers with disabilities, pregnant women and children for entering the bus easily (Sheger Bus Banner, 2009).

The fares depend on distance coverage. Tables 3.2 and Figure 3.2 show travel fares and operational routes of the enterprise respectively.

Table 3.2: Travel fares of the Sheger Mass Transport Enterprise.

Distance travel in KM	Price in Birr
Up to 4 KM	1.5
From 4.1 Km – 6 KM	2.0
From 6.1 Km – 9 KM	3.0
From 9.1 KM – 10 KM	3.5

Source: Sheger Bus Banner (2009)

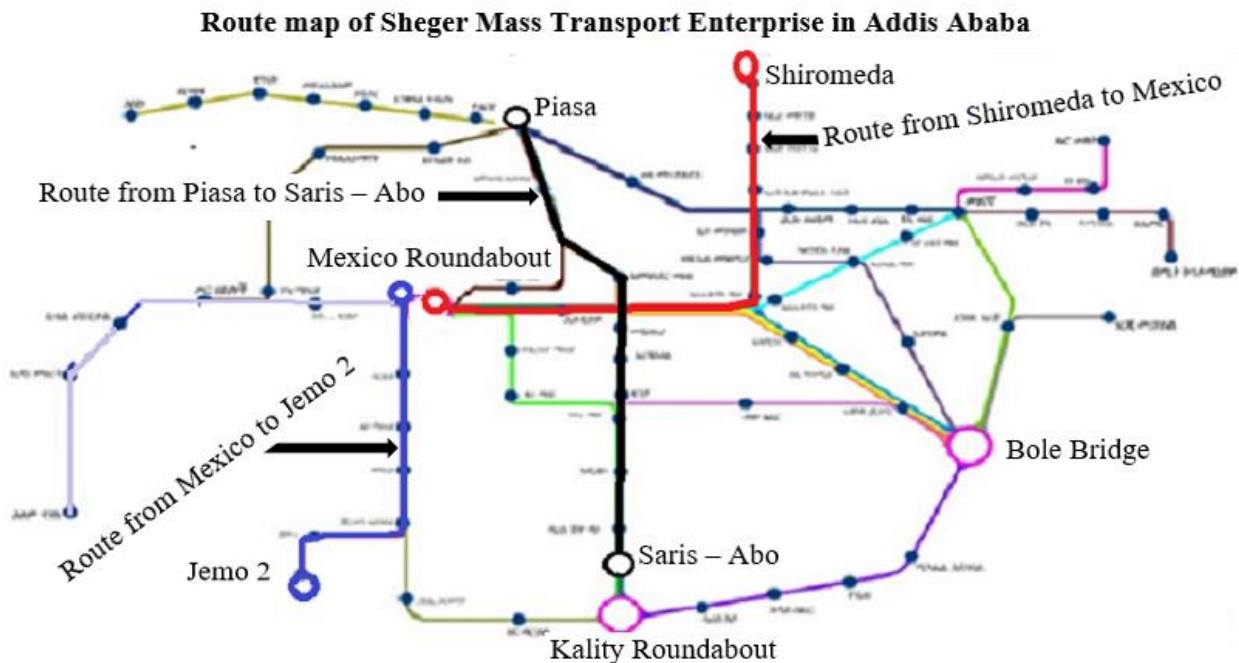


Figure 3.2: Operational route map of Sheger Mass Transport Enterprise in Addis Ababa.

Source: Sheger Mass Transport Enterprise (2009)

In the near future, the Sheger Mass Transport Enterprise will introduce new services, including the City's first school bus service and Bus Rapid Transit (BRT) system. The BRT will be a high quality public transportation system with an aim to provide faster, more comfortable and cost-effective service through a dedicated bus lane. The Enterprise is making efforts to reduce the passengers' waiting time to 10 min. (Sheger bus banner, 2009).

This study was conducted on three operational routes of Sheger Mass Transport Enterprise that the Enterprise was operating on regular basis. The routes includes: Mexico - Shiromeda; Mexico – Jemo 2 and Piasa - Saris Abo. These routes were selected to identify the problems and come up with possible solutions to solve the transportation problems that currently exist regarding the Enterprise's operations on these routes. It is presumed that the recommendations as well as the solutions will be replicated on other routes in the city. The study area of the Enterprise's bus operational lines, considered in this case study is presented in figure 3.3 below.

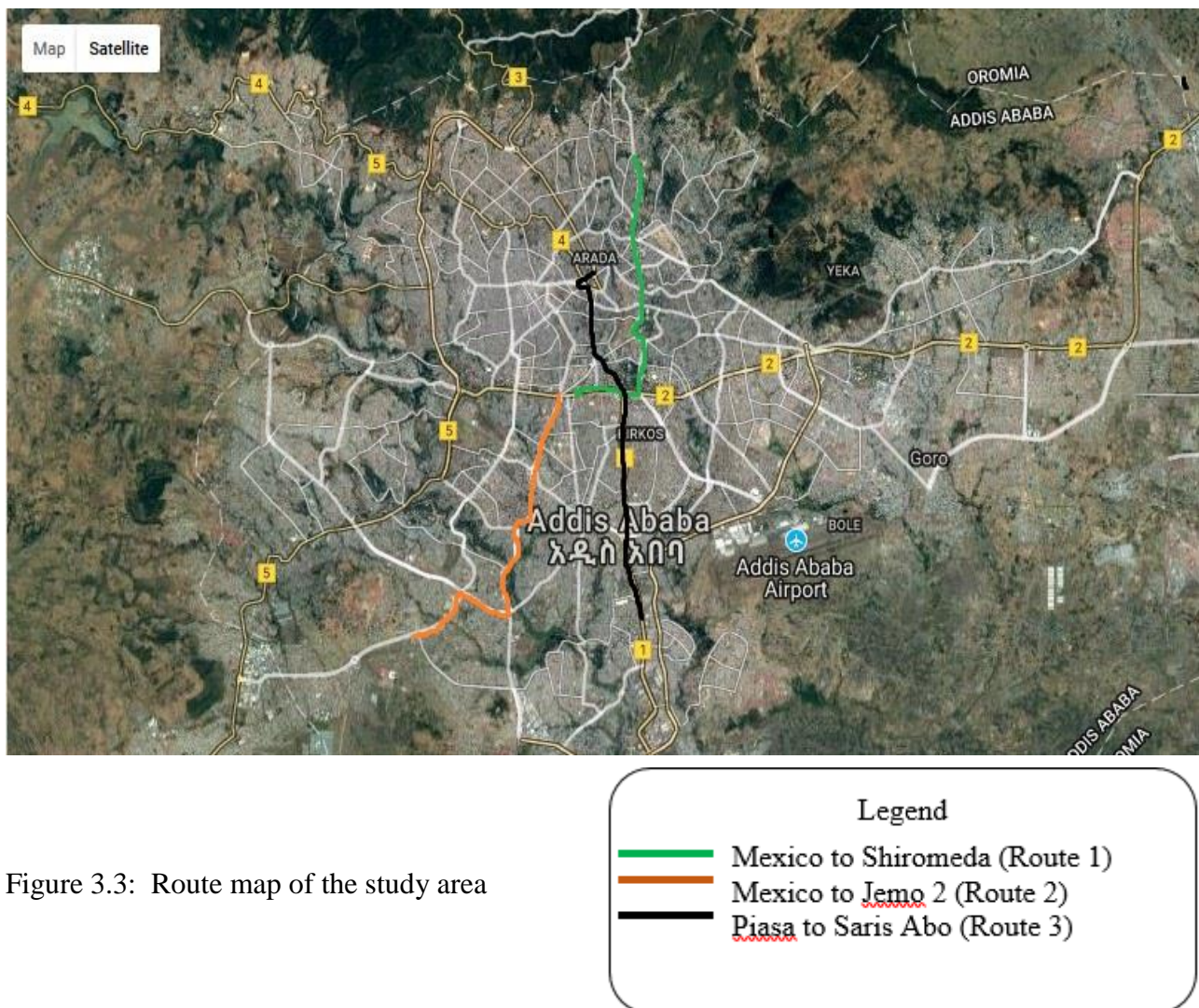


Figure 3.3: Route map of the study area

### 3.2.1 Bus stop stations and direction of travel on Route 1

This route has starting and ending stations at Mexico and Shiromeda in two directions. The first direction is Southbound along Shiromeda → Sidist Kilo → Arat Kilo → Estifanos → Stadium → Mexico and the second direction is Northbound along Mexico → Estifanos → Arat Kilo → Sidist Kilo → Teferi Mekonen → Shiromeda. Figure 3.4 below illustrates the directions for two-way trips along route 1.

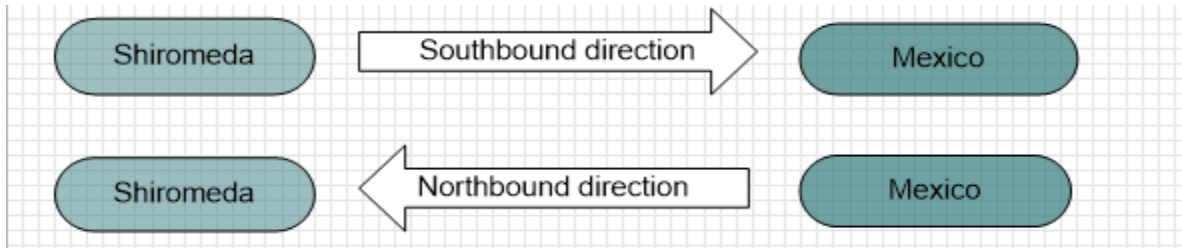


Figure 3.4: Trip direction for two-way trip along route 1

### 3.2.2 Bus stop stations and direction of travel on Route 2

This route has starting and ending stations at Mexico and Jemo 2 in two directions. The first direction is Southbound along Mexico → Sarbet → Abo Mazoria → Mekanisa → Germen Adebabay → Micheal Adebabay → Jemo 1 → Jemo 3 → Jemo 2. The second direction is Northbound along Jemo 2 → Jemo 3 → Jemo 1 → Micheal Adebabay → Germen Adebabay → Mekanisa → Abo Mazoria → Sarbet → Mexico. Figure 3.5 below shows the two way trip direction on route 2.

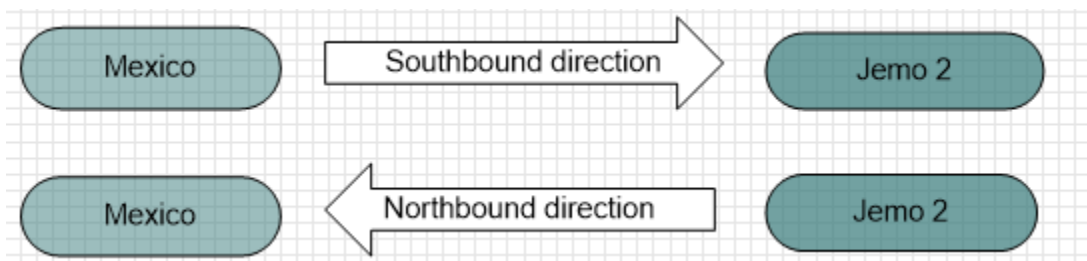


Figure 3.5: Trip direction for two-way trip along route 2

### 3.2.3. Bus stop stations and direction of travel on Route 3

This route has starting and ending stations at Piasa and Saris Abo in two directions. The first direction is Southbound along Piasa → Tewodros Adebabay → Tikur Anbesa → Ambassador →

Riche → Tele Garage → Agona → Gotera Shell → Kadisco → Adey Ababa → Saris Abo. The Northbound direction goes along Saris Abo → Adey-Ababa → Kadisco → Gotera Shell → Agona → Tele Garage → Riche → Ambassador → Tikur Anbesa → Tewodros Adebabay → Piasa.

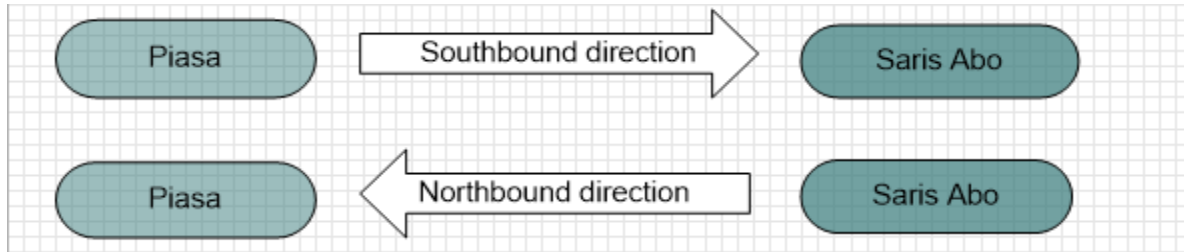


Figure 3.6: Trip direction for two-way trips along route 3.

### 3.3 Data sources

The study considered both primary and secondary data. Primary data were obtained through field surveys and measurements; whereas, secondary data were acquired from pertinent literatures available by different government institutions, transport company publications and from relevant websites. Figure 3.7 below figuratively presents the data sources.

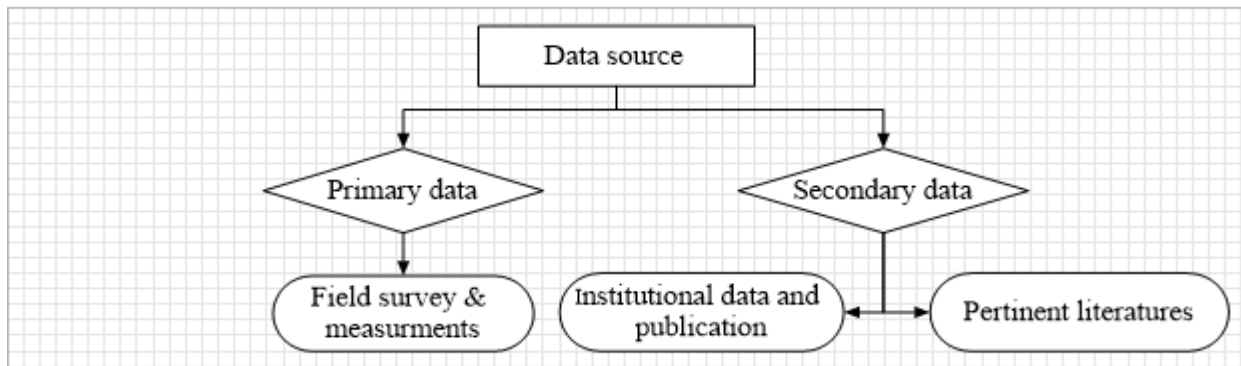


Figure 3.7: Sources of data

### 3.4 Data collection mechanisms

#### 3.4.1 Primary data collection mechanisms

Initially, it was planned to acquire enough information and was expected to be achieved through the subject routes observations. During observations, there were chances to communicate with passengers and staff members on prevailing service provision and operational problems of the SMTE. Primary data were obtained through on - board field measurements. The on-board data

collection was recorded manually during working days. The data collection process took place in two periods. The first one was performed between 14/06/09 and 22/06/2009 E.C. for route 1 the on-board data collection was conducted for four days starting from 14/06/09 (Tuesday) and ending on 17/06/09 (Friday). During this period, 10 buses were provided transportation services. For Route 2 the on-board data collection was conducted for five days beginning from 14/06/09 (Tuesday) and ending on 18/06/09 (Saturday). During this period, 11 buses were provided. Finally, on Route 3 the on-board data were collected for six days starting on 16/06/09 (Thursday) and ending on 22/06/09 (Wednesday). During this period, 6 buses were provided transportation services.

#### **3.4.1.1 Data collected during first data collection period**

The data collected during the first period were used for determining transit LOS at stop stations and transit segments. During this period, data recording sheets were used which incorporated: date, route name, name of bus stop station, name of data recorder, actual arrival time, actual departure time, number of people boarding and alighting at each stop. Accordingly, the following data were obtained from the first data collection period for all routes.

##### **a) Passenger loading**

Passenger loading can be expressed in terms of passenger per seat if the vehicle is designed for maximum seating capacity. The total number of passenger in each bus at each stop station can be calculated as cumulative number of passengers boarding and alighting at each stop station. Similarly, passenger-loading data that were obtained as a secondary source were used to crosscheck with the primary data. Table 3.3 below shows the total number of passenger at each stop station for a given transit vehicle traveling from Shiromeda to Mexico during morning peak hour periods. Similarly, the results of passenger loading for all vehicles at each stop stations during the study period were calculated. Table: 3.3 below presents the total number of passengers at each stop station for a given transit vehicle traveling from Shiromeda to Mexico.

Table: 3.3 Total number of passengers at each stop station for a given transit vehicle operating from Shiromeda to Mexico

Stop station	Actual arriving time	No of passenger boarding	No of passenger alighting	Cumulative Number of passenger
Shiromeda	8:19 AM	77	0	77
6 kilo	8:24 AM	33	9	101
4 kilo	8:31 AM	4	48	57
Estifanos	8:40 AM	0	22	35
Stadium	8:46 AM	0	11	24
Mexico	8:57 AM	0	24	0

**b) Headway**

Headway can be defined as the time difference between two successive vehicles. The actual arrival time of each vehicle at each bus stop station were used to determine the headway between the two successive vehicles. Table 3.4 below shows morning peak hour period headway on the route from Mexico to Shiromeda using the data collected on 15/06/2009 E.C. the actual arrival time of each vehicle at each stop stations were recorded and used for determination of headway at each stop station. The headway for the remaining peak hour period, route and days were evaluated using similar way.

Table 3.4: Headway for each stop station for the route from Mexico to Shiromeda.

Morning peak hour period (a.m)						
Actual arrival time of buses (a.m)	Headway at each stop station					
	Mexico	Estifanos	Arat Kilo	Sidist Kilo	Teferi Mekonnen	Shiromeda
6:27	6:27	6:33	6:38	6:41	6:44	6:47
6:30	3	8	12	13	15	18
6:58	28	24	11	20	18	15
7:28	30	32	33	34	35	36
7:33	5	10	14	15	17	20
7:39	6	4	3	3	2	2
8:03	24	24	24	24	24	22

Actual arrival time of buses (a.m)	Morning peak hour period (a.m)					
	Headway at each stop station					
	Mexico	Estifanos	Arat Kilo	Sidist Kilo	Teferi Mekonnen	Shiromeda
8:15	12	8	4	2	0	1
8:50	35	39	43	45	47	47
9:00	10	10	10	10	10	11
9:10	10	9	8	7	7	6
9:15	5	5	9	11	12	11
9:20	10	6	2	1	1	4
10:43	83	83	82	81	79	75

#### **3.4.1.2 Data collected during the second data collection period**

The second data collection period were takes place between 01/07/09 and 08/07/2009 E.C. During this period, traffic counts and road geometric measurements were obtained manually on working days. Accordingly, only morning and afternoon peak hour period traffic counts were recorded and used for LOS analysis. During this time the length of the segment, transit travel time, sidewalk width, width of outside through lane, width of shoulder/bicycle lane and proportion of on-street parking occupied and outside lane traffic volumes were collected.

##### **a. Length of the segment**

A street segment is defined as the length of street between intersections where traffic on the street may have to stop due to traffic control (i.e., signalized intersections, roundabouts, intersections where the street is STOP or YIELD controlled) and the intersection at the downstream end of the segment. Each direction of travel on the street was analyzed separately. (TCQSM, 2013. P.43). On Route 1, eight and nine segments were considered to evaluate the transit LOS at route segment along Southbound and Northbound directions respectively. The lengths of segments were measured on the field.

##### **b. Transit travel time**

The time taken to traverse each segment were recorded for both morning and afternoon peak hour periods and average values of two days travel time data were used to calculate the travel speed of

transit vehicles. Therefore, average transit speed was calculated by dividing the length of the segment by the time required to traverse the segment.

**c. Width of road cross-section elements**

Width of road cross–section elements used in transit LOS analysis includes: sidewalk width, width of outside through lane, and width of shoulder / bicycle lane. During the data collection period, it was found that each road segment did not have shoulder/ bicycle lane. Therefore, only width of sidewalks and outside through lane were obtained from field measurements. Similarly, road geometric data, which were obtained as a secondary source are used to crosscheck the values with the primary data measured on the field. Length, average travel time and width of transit segment cross – section elements are presented in the Table 3.5, 3.6, 3.7, 3.8, 3.9 and 3.10 below.

Table 3.5: Segment ID, length and width of road cross – section from Shiromeda to Mexico.

Morning peak hour period					
Segment ID	Segment Location	Length (mi)	Average travel time (min)	Width of outside through lane (ft)	Width of sidewalk (ft)
SM 1	Shiromeda → Sidist Kilo	1.21	4.52	11.48	11.48
SM 2	Sidist Kilo → Kedeste Mariam	0.50	4.02	11.48	13.12
SM 3	Kedeste Mariam → Arat Kilo	0.22	2.54	11.48	11.48
SM 4	Arat Kilo → Niger St, Signal	0.20	3.16	11.48	9.84
SM 5	Niger St, Signal → Estifanos	1.44	6.45	11.48	14.76
SM 6	Estifanos → Stadium	0.49	3.35	11.48	26.24
SM 7	Stadium → Leghar	0.24	4.58	9.84	11.48
SM 8	Leghar → Mexico	0.46	4.40	9.84	9.84

Table 3.6: Segment ID, length and width of road cross – section from Mexico to Shiromeda.

Morning peak hour period					
Segment ID	Segment Location	Length (mi)	Average travel time (min)	Width of outside through lane (ft)	Width of sidewalk (ft)
MS 1	Mexico → Leghar	0.37	3.05	9.84	9.84
MS 2	Leghar → Stadium	0.40	1.35	9.84	9.84
MS 3	Stadium → Estifanos	0.42	3.50	11.48	26.24
MS 4	Estifanos → Niger St, Signal	1.26	5.15	11.48	31.16
MS 5	Niger St, Signal → Arat Kilo	0.39	1.45	11.48	14.76
MS 6	Arat Kilo → Kedeste Mariam	0.25	2.55	11.48	9.84
MS 7	Kedeste Mariam → Sidist Kilo	0.39	1.45	11.48	11.48
MS 8	Sidist Kilo → Teferi Mekonen	0.59	1.56	11.48	13.12
MS 9	Teferi Mekonen → Shiromeda	0.76	3.20	11.48	11.48

Table 3.7: Segment ID, length and width of road cross – section from Mexico to Jemo 2.

Southbound Direction					
Segment ID	Segment Location	Length (mi)	Average travel time (min)	Width of outside through lane (ft)	Width of sidewalk (ft)
MJ 1	Mexico → Sarbet	1.21	3.33	9.84	9.84
MJ 2	Sarbet → Abo Mazoria	0.86	2.45	11.48	13.12
MJ 3	Abo Mazoria → Mekanisa	0.86	2.20	11.48	13.12
MJ 4	Mekanisa → Germen Adebabay	0.45	1.30	11.48	13.12
MJ 5	Germen Adebabay → Michael Adebabay	1.10	8.20	11.48	6.56
MJ 6	Michael Adebabay → Jemo 1	0.74	2.08	9.84	13.12
MJ 7	Jemo 1 → Jemo 3	1.00	5.39	9.84	13.12
MJ 8	Jemo 3 → Jemo 2	0.86	3.30	9.84	13.12

Table 3.8: Segment ID, length and width of road cross – section from Jemo 2 to Mexico.

Northbound direction					
Segment ID	Segment Location	Length (mi)	Average travel time (min)	Width of outside through lane (ft)	Width of sidewalk (ft)
JM 1	Jemo 2 → Jemo 3	1.12	4.11	9.84	13.12
JM 2	Jemo 3 → Jemo 1	1.00	6.05	9.84	13.12
JM 3	Jemo 1 → Michael Adebabay	0.74	15.10	9.84	14.76
JM 4	Michael Adebabay → Germen Adebabay	1.10	6.15	11.48	6.56
JM 5	Germen Adebabay → Mekanisa	0.45	6.36	11.48	13.12
JM 6	Mekanisa → Abo -Mazoria	0.86	5.45	11.48	13.12
JM 7	Abo -Mazoria → Sarbet	0.86	6.52	11.48	13.12
JM 8	Sarbet → Mexico	1.21	11.43	9.84	11.48

Table 3.9: Segment ID, length and width of road cross – section from Piasa to Saris Abo.

Southbound Direction					
Segment ID	Segment Location	Length (mi)	Average travel time (min)	Width of outside through lane (ft)	Width of sidewalk (ft)
PS 1	Piasa → Churchil ave signal	0.60	6.19	11.48	11.48
PS 2	Churchil ave signal → Tewodros Adebabay	0.30	0.45	11.48	19.68
PS 3	Tewodros Adebabay → Tikure Anbesa	0.43	4.40	11.48	6.56
PS 4	Tikure Anbesa → Ambassador	0.52	5.37	11.48	9.84
PS 5	Ambassador → Stadium	0.52	3.09	11.48	9.84
PS 6	Stadium → Rich	0.23	1.31	9.84	13.12
PS 7	Rich → Tell garage	0.34	3.17	9.84	11.48
PS 8	Tell garage → Agona	0.83	3.47	9.84	11.48
PS 9	Agona → Gotera Shell	0.86	4.10	9.84	11.48
PS 10	Gotera Shell → Kadisco	0.57	1.43	9.84	11.48
PS 11	Kadisco → Adey Ababa	0.57	1.36	9.84	11.48
PS 12	Adey Ababa → Saris Abo	0.48	2.17	9.84	11.48

Table 3.10: Segment ID, length and width of road cross – section from Saris Abo to Piasa

Northbound direction					
Segment ID	Segment Location	Length (mi)	Average travel time (min)	Width of outside through lane (ft)	Width of sidewalk (ft)
SP 1	Saris Abo → Adey Ababa	0.48	3.20	13.00	11.48
SP 2	Adey Ababa → Kadisco	0.57	2.50	9.84	11.48
SP 3	Kadisco → Gotera Shell	0.57	2.55	9.84	11.48
SP 4	Gotera Shell → Agona	0.86	3.00	9.84	11.48
SP 5	Agona → Tell Garage	0.84	4.26	9.84	11.48
SP 6	Tell Garage → Riche	0.33	1.00	9.84	11.48
SP 7	Riche → Stadium	0.34	3.41	9.84	13.12
SP 8	Stadium → Ambassador	0.59	4.79	11.48	9.84
SP 9	Ambassador → Tikure Anbesa	0.51	3.55	11.48	4.26
SP 10	Tikure Anbesa → Tewodros Adebabay	0.34	1.43	11.48	13.12
SP 11	Tewodros Adebabay → Churchil ave signal	0.23	1.54	9.84	0.00
SP 12	Churchil ave signal → Piasa	0.59	1.57	9.84	6.56

**d. Outside lane traffic volume**

Outside lane traffic volume on each route were collected during morning and afternoon peak hour periods for two days. The average value of both days' traffic were used for transit LOS analysis. The total traffic were expressed in terms of passenger car unit (PCU). The values were calculated by multiplying each types of vehicle by the corresponding PCEs to arrive at the volume of traffic. Traffic were categorized into six classes by visual assessment of the vehicle sizes and the corresponding passenger car equivalent (PCEs). (Botswana Roads Department, 2004). Table 3.11 below shows vehicle classification and corresponding PCEs.

Table 3.11: Vehicle classification and corresponding PCEs

No.	Vehicle Type	PCE
1.	Bicycle	0.2
2.	M/cycle	0.5
3.	Car (Passengers Cars, Station wagons, pick-up, M/bus)	1.0
4.	S/Truck (Small buss (18-48 passenger occupancy) and small truck)	2.0
5.	M/Truck (Medium Truck and Large Bus with 48-62 passenger occupancy )	2.5
6.	H/Truck (double cargo city busses and Truck and Trailer)	3.0

Source: Botswana Roads Department, 2004

**e. Number of on - street parking vehicles**

The method of obtaining the total number of on–street parking vehicle in each segment was similar to the method applied in collecting the outside lane traffic volume. The total number of vehicles were expressed in terms of PCU. This includes small cars that have length up to 5m and used in determining the proportion of on-street parking for transit LOS analysis. Table 3.12 below shows total traffic volume in per hour duration and the total number of on-street parking vehicles on Shiromeda to Mexico route during the morning peak hour period. Total traffic volume for the remaining routes are included in the Appendix.

Table 3.12: Morning peak hour traffic volume for the route from Shiromeda to Mexico.

Segment	Morning peak hour period						Total (PCU)/ hr.	Total No of street parked vehicles
	Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck		
SM 1	5	9	385	20	21	8	507	10
SM 2	3	8	305	18	16	7	407	4
SM 3	5	10	491	30	24	8	641	5
SM 4	4	16	539	35	30	5	708	4
SM 5	3	27	808	68	29	16	1,079	0
SM 6	0	54	913	76	40	13	1,231	0
SM 7	2	38	699	54	31	11	937	4
SM 8	2	19	272	18	14	4	365	5

### **3.4.2 Secondary data collection mechanisms**

The secondary data were acquired from different sources: company publication, data prepared by institutions and pertinent literatures. Different literatures were examined as a source of secondary data. Especially transport-related research papers that were prepared either by individuals or by government offices were also used. Arrival and departure times of buses at each end stations, passenger loading, frequency and road geometric data were also used to cross check with the data obtained as a primary data. In addition, relevant documents were collected from different websites. The sources of secondary data and the data types are depicted in Table 3.13 below.

Table 3.13: Acquired secondary data and corresponding sources

No.	Data type	Source
1	Arrival and departure time of buses at each end stations, passenger loading and frequency	Sheger Mass Transport Enterprise
2	Road geometric data	Addis Ababa City Roads Authority
3	Type and number of vehicle in the city, company research publication and consultant studies	Addis Ababa Transport Authority
4	Traffic accident data	Addis Ababa Traffic Management Agency

### **3.5 Method of data analysis**

Based on the type and relevance of data, different analytical techniques were adapted. At first, the causes for poor quality of service were identified using different literatures. The collected data were also analyzed using percentages and Microsoft Excel chart with their descriptions.

The proposed framework presents transit quality of service measures regarding transit availability and convenience for transit stops and route segments. The HCM presents procedures for calculating transit quality of service measures of transit service from the passengers' point-of-view for transit stops and route segments. The manual is popular and well accepted by highway planners and operators. TCQSM also have consistent framework with HCM. The method for evaluating the Multimodal transit LOS provided by different operations were developed and calibrated by Dowling et al (2008a) as published in the NCHRP Report No. 616 of the Transport Research Board.

The data analysis was carried out both at transit stops and on route segments. TCQSM provides calculation steps and excel spreadsheet to evaluate Multimodal transit LOS. The procedure involves calculation of transit wait – ride score and pedestrian environmental score (TCQSM, 2013). Table 3.14 below shows the quality of service indicators used in this research

Table 3.14: Quality of service indicators used for LOS analysis

NO.	Quality of service indicator	Applied at/on	Methodology used
1	Frequency	Transit Stops	HCM 2000
2	Passenger Loading	Transit Stops	HCM 2000
3	Hours of Service	Route Segments	HCM 2000
4	Reliability	Route Segments	HCM 2000
5	Multimodal Transit LOS	Route Segments	TCQSM 3 <sup>rd</sup> edition

### 3.5.1 Transit LOS at transit stops

Transit LOS at transit stops can be evaluated using the two measures described below. These includes service frequency and passenger loading.

#### 3.5.1.1 Service frequency

From the user’s perspective, frequency determines the number of times in an hour a user has access to the transit mode. Service frequency LOS is determined by destination from a given transit stop. HCM (Exhibit 27.1) lists LOS both by headway and the corresponding number of vehicle per hour. Table 3.15 below presents service frequency LOS thresholds for urban schedule transit service.

Table 3.15: Service frequency LOS thresholds for urban schedule transit service.

LOS	Average Headway (min)	veh/h	Comments
A	<10	>6	Passengers don’t need schedule
B	10-14	5-6	Frequent service, passengers consult schedule
C	15-20	3-4	Maximum desirable time to wait if bus/train missed
D	21-30	2	Service unattractive to choice riders
E	31-60	1	Service available during hour
F	>60	<1	Service unattractive to all riders

Source: (HCM, 2000)

### **3.5.1.2 Passenger loads**

From the passenger’s perspective, passenger loads reflect the comfort level of the on-board vehicle portion of a transit trip both in terms of being able to find a seat and in overall crowding levels within the vehicle. From a transit operator’s perspective, a poor LOS may indicate the need to increase service frequency or vehicle size in order to reduce crowding and to provide a more comfortable ride for passengers. The load factor is given in the Exhibit 27.5 of HCM which can be used to estimate the passenger load LOS. Table 3.16 below presents passenger load LOS thresholds in terms of passenger per seat (P/seat) as provided by HCM (2000).

Table 3.16: Passenger load LOS thresholds

LOS	P/seat	Comments
A	0.00-0.50	No passenger need sit next to another.
B	0.51-0.75	Passenger can choose where to sit
C	0.76-1.00	All passenger can sit
D	1.01-1.25	Comfortable standee load for design
E	1.26-1.50	Maximum schedule load
F	>1.50	Crush loads

Source: (HCM, 2000)

## **3.5.2 Transit LOS at route segment**

Transit quality of service on route segment were evaluated using HCM and TCQSM procedures. Hours of service and reliability LOS for the route segment were evaluated using HCM procedure. Similarly, TCQSM provides Multimodal transit LOS calculation steps and excel spreadsheet.

### **3.5.2.1 Hours of service**

Hours of service, also known as “service span,” is simply the number of hours during the day when transit service is provided along a route, a segment of a route, or between two locations. As with Frequency, Hours of service LOS can vary by day or week. For fixed-route service, LOS is based on the number of hours per day. Exhibit 27.4 of HCM presents LOS thresholds for Hours of Service. Table 3.17 below presents the hour of service LOS as provided in Exhibit 27.4 of HCM.

Table 3.17: Hour of service LOS thresholds

LOS	Hours per day	Comments
A	19-24	Night or owl service provided
B	17-18	Late evening service provided
C	14-16	Early Evening service provided
D	12-13	Daytime service provided
E	4-11	Peak hour service/limited midday service
F	0-3	Very limited or no service

Source: (HCM, 2000)

### 3.5.2.2 Reliability

Several performance metrics can be used to assess the reliability of transit system. These include: on-time arrival, travel time adherence, run-time adherence, and customer satisfaction. (Arhin, 2013).

#### Headway adherence

For transit service, scheduled operations at frequencies of six (6) buses/h or less, headway adherence is used to determine reliability. The bunching effect can be measured in terms of headway adherence. The measure is based on the coefficient of variation of headways of transit vehicles serving a particular route arriving at a stop,  $C_{vh}$  which is calculated by Equation 27-1 of HCM.

$$C_{vh} = \frac{\text{Standard deviation of headways}}{\text{Schedule headway}}$$

Where  $C_{vh}$  is coefficient of variation of headways (headway adherence).

Table 3.18 below presents the headway adherence LOS thresholds as provided in Exhibit 27.8 of HCM 2000.

Table 3.18: Headway adherence LOS thresholds

LOS	C <sub>vh</sub>	Passengers and operator perspective
A	0.00-0.10	Service provided like clockwork
B	0.11-0.20	Vehicle slightly off headway
C	0.21-0.30	Vehicle often off headway
D	0.31-0.40	Irregular headways, with sum bunching
E	0.41-0.50	Frequent bunching
F	>0.50	Most vehicles bunched

Source: (HCM, 2000)

### 3.5.2.3 Multimodal transit LOS

The analysis involves calculation of the transit wait – ride score, the pedestrian environmental score and the transit LOS score. Finally, transit LOS letters are assigned for each transit LOS score.

#### Step 1:- Determination of the Transit Wait-Ride Score

The transit wait – ride score involves the calculation of headway factor and a perceived travel time factor. These in turn, are related to traveler responses to changes in headway and changes in travel time. These responses are quantified in terms of elasticities. Transit elasticities reflect the percent change in transit ridership resulting from a 1% change in an attribute of the service (e.g, fare, frequency, travel time, service hours, etc.) (Dowling, 2008). Transit Wait-Ride score were computed using Equation 5.5 of TCQSM.

$$S_{W-r} = f_h f_{tt}$$

Where

$S_{W-r}$  = Transit wait-ride score;

$f_h$  = headway factor; and

$f_{tt}$  = perceived travel time factor.

- **Headway factor**

Calculation of headway factor depends on the frequency of bus service on the study routes. The recommended transit LOS model uses the following frequency elasticity values, based on typical values reported in TCRP Report 95: +1.0 for 1–2 buses/hour, +0.5 for 2–4 buses/hour, +0.3 for 4–

6 buses/hour, and +0.2 for 6 or more buses/hour. Therefore, one can estimate future ridership demand based on a given starting demand and an assumed elasticity. Thus, with an elasticity of +1.0, a route with a ridership of 100 passengers at 60-minute headways. (Dowling, 2008). For any given frequency or headway, one can estimate the ridership relative to a 60-minute headway and, thus, the headway factor (the relative attractiveness of the service) is computed using Equation 5.6 of TCQSM as depicted below:

$$f_h = 4.00e^{\frac{-1.434}{(f+0.001)}}$$

- **Perceived travel time rate**

The perceived travel time factor includes components related to passenger loading, transit vehicle speed, reliability and condition of stop amenities. Load factor is the average ratio of passengers to seats for buses under the study route. For a given load factor the values of the passenger load weighting factor is determined using Equation 5.9 of TCQSM.

$$f_{pl} = \begin{cases} 1.00 & L_f \leq 0.80 \\ 1 + \frac{4(L_f-0.8)}{4.2} & 0.8 < L_f \leq 1.00 \\ 1 + \frac{4(L_f-0.8)+(L_f-1.00)(6.5+[5(L_f-1.00)])}{4.2L_f} & L_f > 1.00 \end{cases}$$

Where

$f_{pl}$  = passenger load weighting factor;

$L_f$  = average passenger load factor (p/seat);

- **Perceived amenity time rate**

The perceived amenity data includes information about the presence of benches and shelter for each stop station in the analysis segment. They can reduce journey time by providing a more comfortable waiting environment. Shelter with benches are counted as both shelters and benches. The percentage of stops in each segment with each type of amenity should be determined. Therefore, the perceived amenity time rate is the time value of various bus stop improvements divided by the mean passenger trip length as provided in Equation 5.10 of TCQSM as depicted below.

$$T_{at} = \frac{1.3P_{sh} + 0.2P_{be}}{L_{pt}}$$

Where

$T_{at}$  = perceived amenity time rate (min/mi);

$L_{pt}$  = average passenger trip length (mi);

$P_{sh}$  = proportion of stops on segment with shelters (decimal); and

$P_{be}$  = proportion of stops on segment with benches (decimal).

The average passenger trip length was used by the method to convert schedule reliability and value for amenity into a perceived travel time rate. The value can be determined by dividing total passenger miles by the total number of boarding passengers.

- **Excess waiting time rate**

The excess waiting time rate for late arrival  $T_{ex}$  is the excess wait time  $t_{ex}$  divided by the average passenger trip length  $L_{pt}$ . Where Excess wait time is the difference between average wait times minus schedule wait time. When departure is not perfectly reliable, the average waiting is longer than half the average headway and is related to the spread in the headway distribution. (TCQSM, 2013). Average wait time was computed using the following formula as provided by Equation 5.4 of TCQSM.

$$t_w = 0.5h_o(1 + C_{vh}^2)$$

Where

$t_w$  = average wait time (min),

$h_o$  = average observed headway (min), and

$C_{vh}$  = coefficient of variation of headways.

The coefficients of variation of headways  $C_{vh}$  was calculated by dividing the standard deviation of headways (representing the range of actual headways) with the average (mean) headway. (TCQSM, 2013. P. 30)

The perceived travel time rate was computed using Equation 5.8 of TCQSM.

$$T_{ptt} = \left( f_{pl} \frac{60}{s} \right) + (2T_{ex}) - T_{at}$$

Where

$T_{ptt}$  = Perceived travel time rate (min/mi), and

$f_{pl}$  = passenger load weighting factor: as a function of the average load on buses.

$S$  = Average travel speed of transit vehicle along the segment (mi/h).

$2$  = wait time factor, converting actual wait times into perceived wait times.

$T_{at}$  = perceived amenity time rate (min/mi); reduction due to the provision of certain bus stop amenities

The perceived travel time factor is calculated using Equation 5.7 of TCQSM.

$$f_{tt} = \frac{(E - 1)T_{btt} - (E + 1)T_{ptt}}{(E - 1)T_{ptt} - (E + 1)T_{btt}}$$

Where

$f_{tt}$  = perceived travel time factor;

$E$  = ridership elasticity with respect to change in the travel time rate (default - 0.40)

$T_{btt}$  = base travel time rate = 6.0 for the CBD of a metropolitan area with 5 million person or more, otherwise = 4.0 (min/mi);

### **Step 2:- Determination of the Pedestrian Environmental Score**

The pedestrian environment score reflects the quality of the pedestrian environment in the vicinity of the transit stop. The pedestrian environmental score includes a constant value and factors relating to traffic volume, traffic speed, and the roadway cross section. (TCQSM, 2013). The pedestrian environmental score is calculated using Equation 5.11 of TCQSM as follows:

$$I_p = 6.0468 + f_w + f_v + f_s \quad \text{Equation 5.11}$$

Where

$I_p$  = pedestrian environmental score;

$f_w$  = cross – section adjustment factor;

$f_v$  = motorized vehicle volume adjustment factor; and

$f_s$  = motorized vehicle speed adjustment factor;

- **Motorized vehicle volume adjustment factor**

The outside lane motorized traffic volume has significant effect on pedestrian feeling of safety. as the frequency of motor vehicle passing pedestrian increases, the pedestrians' feeling of safety decreases.(Landis et al, 2001). The motorized vehicle volume adjustment factor is calculated using Equation 5.13 of TCQSM.

$$f_v = 0.0091 \frac{V_m}{4} \quad \text{Equation 5.13}$$

Where

$V_m$  = outside lane motorized vehicle demand flow rate at mid - segment (i.e. lane closest to the subject sidewalk) (veh/h).

- **Motorized vehicle speed adjustment factor**

The speed of motorized vehicle affects pedestrians' sense of safety. As the speed increases, the pedestrian discomfort increases (Landis et al, 2001). The motorized vehicle speed adjustment factor is calculated using Equation 5.14 of TCQSM.

$$f_s = 4 \left( \frac{S_R}{100} \right)^2 \quad \text{Equation 5.14}$$

Where

$S_R$  = average motorized vehicle running speed in the segment, including delay at the downstream intersection (mi/h).

- **Road cross-section adjustment factor**

Presence of sidewalk and lateral separation between the roadway and sidewalk affects pedestrians' sense of safety and comfort in the roadway environment. As the lateral separation increases, the pedestrian safety also increase. Similarly, when a barrier such as on – street parking, trees and other intervening objects would improve the sense of safety (Landis et al, 2001). The road cross-section adjustment factor is computed using equation 5.12 of TCQSM.

$$f_w = -1.2276 \ln(W_v + 0.5W_1 + 50P_{pk} + W_{buf}f_b + W_{aA}f_{sw}) \quad \text{Equation 5.12}$$

Where

$W_v$  = effective total width of outside through lane, bicycle lane, and shoulder (parking lane) as a function of traffic volume (see exhibit 5-27) (ft);

$W_1$  = effective width of combined bicycle lane and shoulder (ft);

$p_{pk}$  = proportion of on street parking occupied (decimal);

$W_{Buf}$  = buffer width between roadway and available sidewalk (= 0 if sidewalk does not exist) (ft);

$f_b$  = buffer area coefficient =5.37 for any continuous barrier at least 3 ft (0.9m) high that is located between the sidewalk and the outside edge of roadway; otherwise use 1.0

$W_A$  = available sidewalk width = 0.0 if sidewalk does not exist (ft);

$W_{aA}$  = adjusted available sidewalk width =min ( $W_A$ , 10) (ft); and

$f_{sw}$  = sidewalk width coefficient = 6.0-0.3 $W_{aA}$ ;

Table 3.19: Variables for pedestrian environmental score

Condition	Variable when condition are satisfied	Variable when condition are not satisfied
$P_{pk} = 0.0$	$W_t = W_{ol} + W_{bl} + W_{os}^*$	$W_t = W_{ol} + W_{bl}$
$V_m > 160$ veh/h or street is divided	$W_v = W_t$	$W_v = W_t(2 - 0.005 V_m)$
$P_{pk} < 0.25$ or parking is striped	$W_1 = W_{bl} + W_{os}$	$W_1 = 10$

Source: (Exhibit 5.27 of TCQSM)

Notes:

$W_t$  = total width of outside through lane, bicycle lane, and paved shoulder or parking lane (ft);

$W_{ol}$  = width of the outside through lane (ft);

$W_{os}^*$  = adjusted width of paved outside shoulder or parking lane, if curb is present

$W_{os}^* = W_{os} - 1.5 \geq 0.0$ , Otherwise  $W_{os}^* = W_{os}$ (ft);

$W_{os}$  = width of paved outside shoulder or parking lane (ft); and

$W_{bl}$  = width of the bicycle lane (0= if bicycle lane not provided) (ft).

The sidewalk is curb-tight, therefore the buffer width  $W_{Buf}$  is 0 ft. Next, the factor related to the buffering effect of barrier or street trees is considered. There are continuous barrier along the segment; therefore, the buffer area coefficient is  $f_b = 5.37$ .

### Step 3: Determination of the Transit LOS Score

The proposed general form for the transit LOS model is a linear combination of the quality of service accessing the bus stop on foot and the quality of service involved in waiting for and riding the bus. The transit LOS score is computed using equation 5.15 of TCQSM

$$I_t = 6.0 - 1.50S_{w-r} + 0.15I_p \quad \text{Equation 5.15}$$

Where  $I_t$ = the Transit LOS Score

**Step 4: Determine Transit LOS**

Transit LOS is determined by comparing the transit LOS score with the thresholds as depicted in Table 3.20 below.

Table 3.20: Thresholds for transit LOS values

LOS	LOS Score
A	$\leq 2.00$
B	$>2.00 - 2.75$
C	$>2.75 - 3.50$
D	$>3.50 - 4.25$
E	$>4.25 - 5.00$
F	$>5.00$

Source: Exhibit 5.28 of TCQSM

## CHAPTER FOUR

### RESULTS AND DISCUSSIONS

#### 4.1 Introduction

The data collected from different sources were analyzed to meet the objectives of the research. The results obtained through data analysis were illustrated using graphs and tables followed by pertinent descriptions. Accordingly, in this chapter the results and discussions of the quality of service indicators are presented.

#### 4.2 Results of service frequency

In this respect, the results indicate that service frequency is similar for all stops along the study routes. Table 4.1 below shows existing service frequency LOS for the study routes.

Table 4.1: Service frequency LOS for the study routes

No	Route	Peak hour periods			
		Morning		Afternoon	
		Frequency (veh/hr)		Frequency (veh/hr)	
		No.	LOS	No.	LOS
1	From Shiromeda → Mexico	5	B	5	B
2	From Mexico → Jemo 2	6	B	6	B
3	From Piasa → Saris Abo	3	C	3	C

It can be seen in Table 4.1 above that the frequency LOS for the study route were determined using the corresponding number of vehicles per hour. It describes how often the potential users has access to transit service per hour duration. According to the results shown in the same table, the frequency on Route 1 is 5 veh/h. This indicates that the service is relatively frequent with a headway of 11-14 min. Therefore, passengers will usually check scheduled arrival times to minimize their waiting times at the bus stations. Similarly, Route 2 exhibits frequent service with a headway of < 10 min. In this case, passengers do not need to consult schedules.

Compared to Route 1 and Route 2, Route 3 has less frequent service with a headway of 15-20 min. in this case passengers need scheduled service and should check the scheduled arrival times to

minimize their waiting times at bus stations. According to the survey made on all routes, it was found that bus-bunching problem is present which result in variable waiting times for bus and variable passenger loading.

### 4.3 Results of passenger loading

The results of analysis for passenger loading vary between each stop station. Therefore, detail analysis was done using graphs to better illustrate the results. At each stop station cumulative number of passenger retained at each stop station are considered as passenger loading. Variation of passenger loading with time of day for route 1 at each stop stations along Southbound and Northbound direction are shown in the figure 4.1 and 4.2 below respectively.

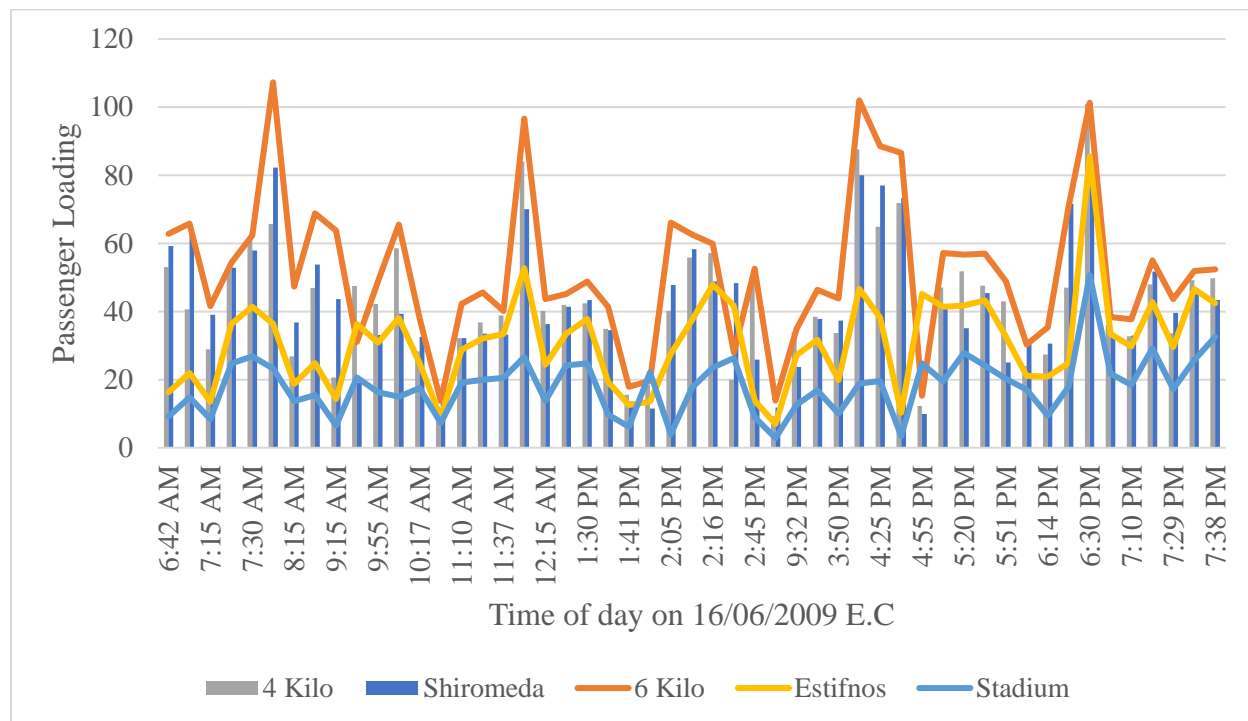


Figure 4.1: Variation of passenger loading with time of day from Shiromeda to Mexico.

It can be seen from Figure 4.1 above that passenger loading for Southbound direction vary from time to time during different times of the day. Compare to other bus stop stations, passenger loading is high at the Sidist Kilo stop station and low at the Stadium bus stop station.

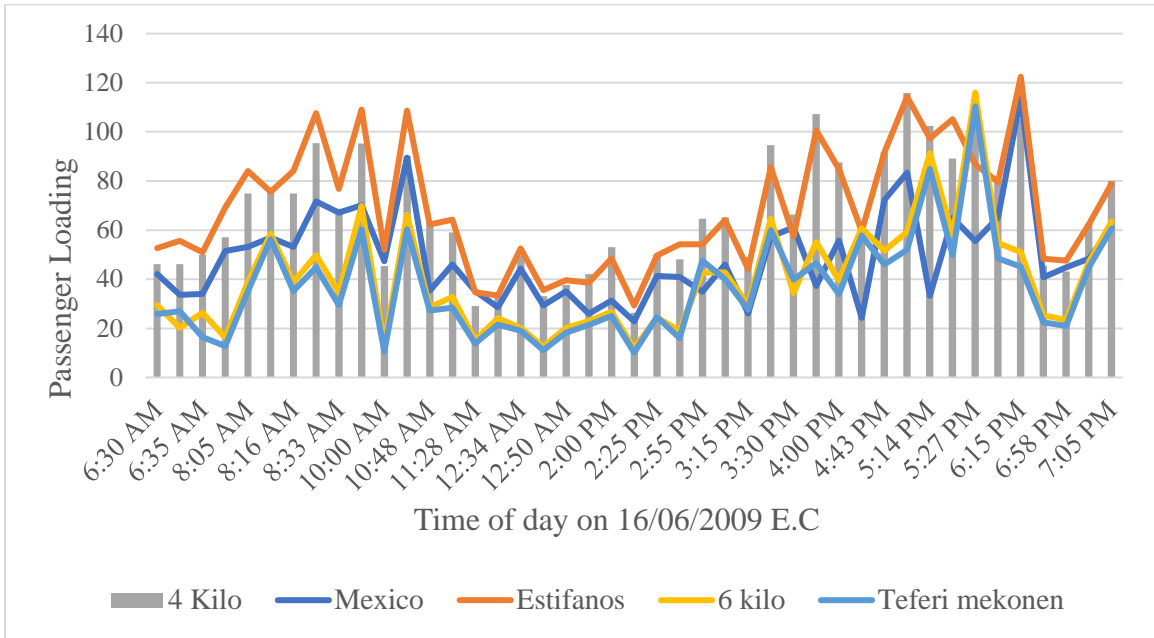


Figure 4.2: Variation of passenger loading with time of day from Mexico to Shiromeda.

Figure 4.2 above clearly indicates that passenger loading for Northbound direction is high during morning and afternoon peak hours. Especially in the afternoon peak hours, high number of passengers move from Mexico to Shiromeda. Compared to other stop stations, passenger loading is low at the Sidist Kilo and Teferi Mekonnen stop stations and maximum number of passenger loadings occur at Estifanos and Arat Kilo bus stop stations. Therefore, special services should be provided to transport the excess passengers.

Similar to the findings discussed above, Figures 4.3 and 4.4 below illustrate variations of passenger loading with time of day on Route 2 along Southbound and Northbound directions respectively. The Sheger transit buses moving along the Southbound direction have a maximum of 67 passengers at Mekanisa bus stop station during the morning peak hour. In addition, it can be seen that around 11:05 am the transit bus has on the average a loaded number of 100 passengers at the Mekanisa bus stop station. The preceding bus at this station left with 32 passenger and the bus that followed come 20-minute later; then, high number of passengers were waiting for this next bus. As a result, the next transit bus carried 100 passengers which was more than three times than the previous one. Similarly, the bus that followed arrived after 10 minutes with only 36 passengers. Therefore, the up and down number of passenger in the graph shows variation of passengers loading due to bunching problems. The passenger loading is high up to Mekanisa bus stop station and decreases smoothly towards the end stop station (Jemo 2).

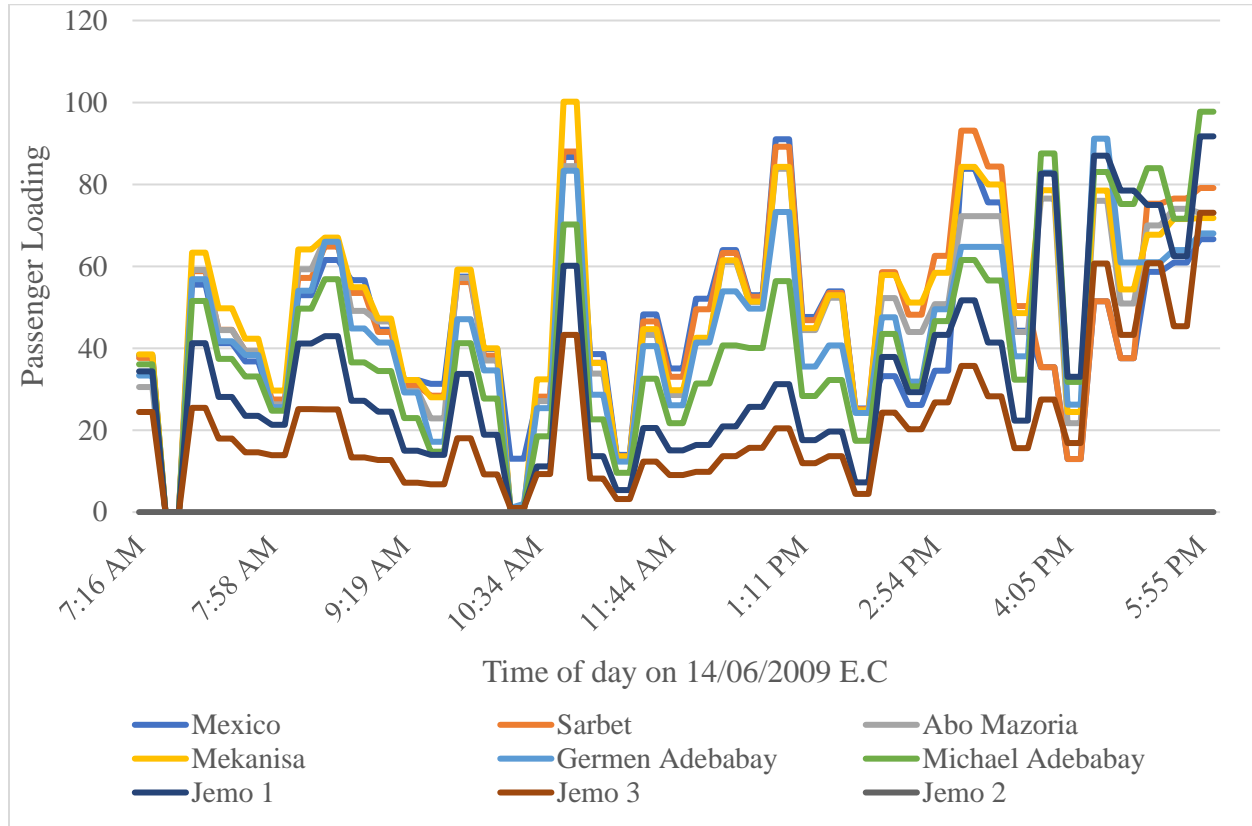


Figure 4.3: Variation of passenger loading with time of day from Mexico to Jemo 2.

Figure 4.4 below shows that the passenger loading on Northbound direction is high and randomly distributed during the morning peak hour; especially from 6:45 am to 10:00 am and there is high variation of passenger loadings. Whereas in the afternoon peak-hour periods, the passenger loading is low and uniformly distributed. The passenger loading in the morning peak hour period increases gradually from Jemo 2 to Michael Adebabay and then gradually decreases from Michael Adebabay stop station to Mexico stop station. In Addis Ababa, most of the residential areas are located at the periphery and large institutions and economic activities are taking place in the central parts of the city. As a result, the passenger loading is high along Northbound during the morning peak hour periods. Similarly, in the afternoon peak hour periods, the passenger loading is high along the Southbound direction.

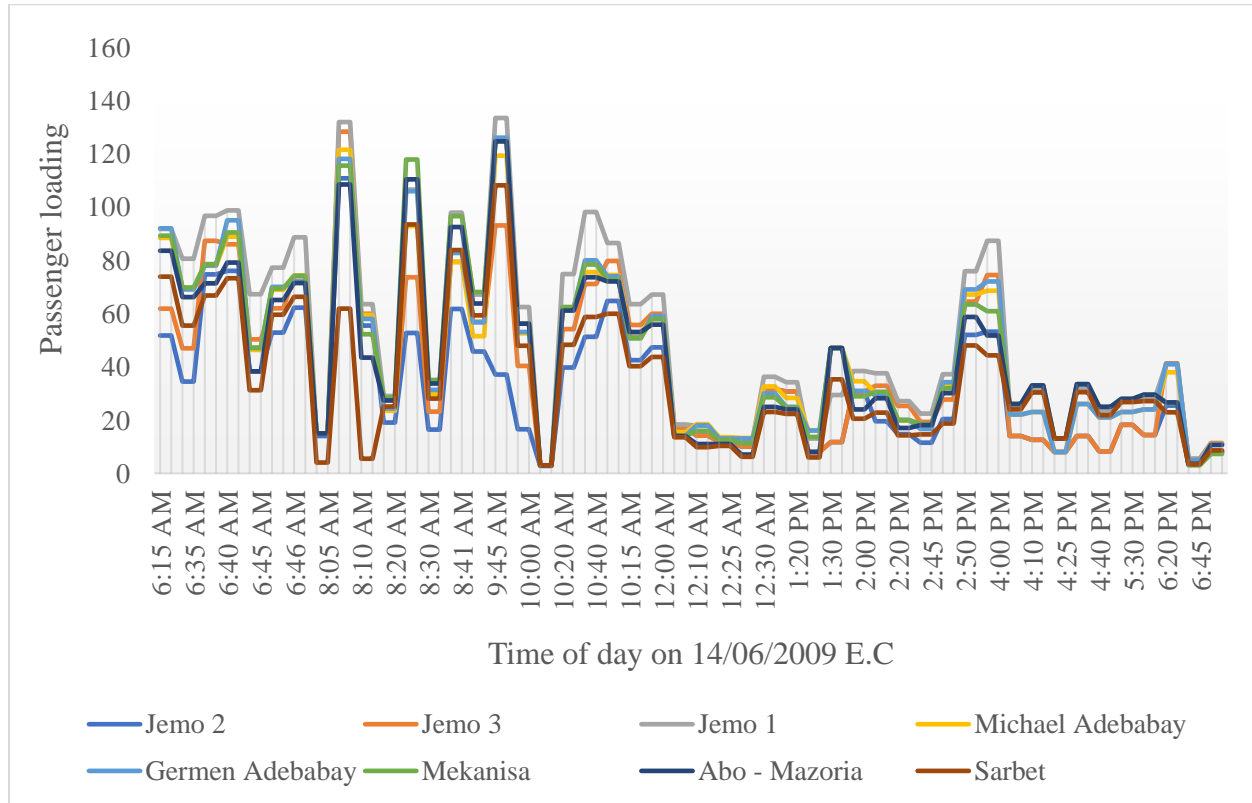


Figure 4.4: Variation of passenger loading with time of day from Jemo 2 to Mexico.

In Figure 4.5 below, it can be seen that passenger loading gradually increases from Piasa stop station up to Tele Garage stop station and decrease towards Saris Abo stop station. It is also shown that during off peak hour periods (10:00 am to 3:00 pm), passenger loadings can be high or low depending on the variation of frequency i.e. passenger demand and headways during these periods. Higher passenger loadings exist in the afternoon peak hour periods compared to morning peak hour period. Figure 4.5 below illustrates the variation of passenger loading with time of day for the route from Piasa to Saris Abo whereas. Figure 4.6 below illustrates the variation of passenger loading from Saris Abo to Piasa

Figure 4.5 below illustrates the variation of passenger loading with time of day for the route from Piasa to Saris Abo.

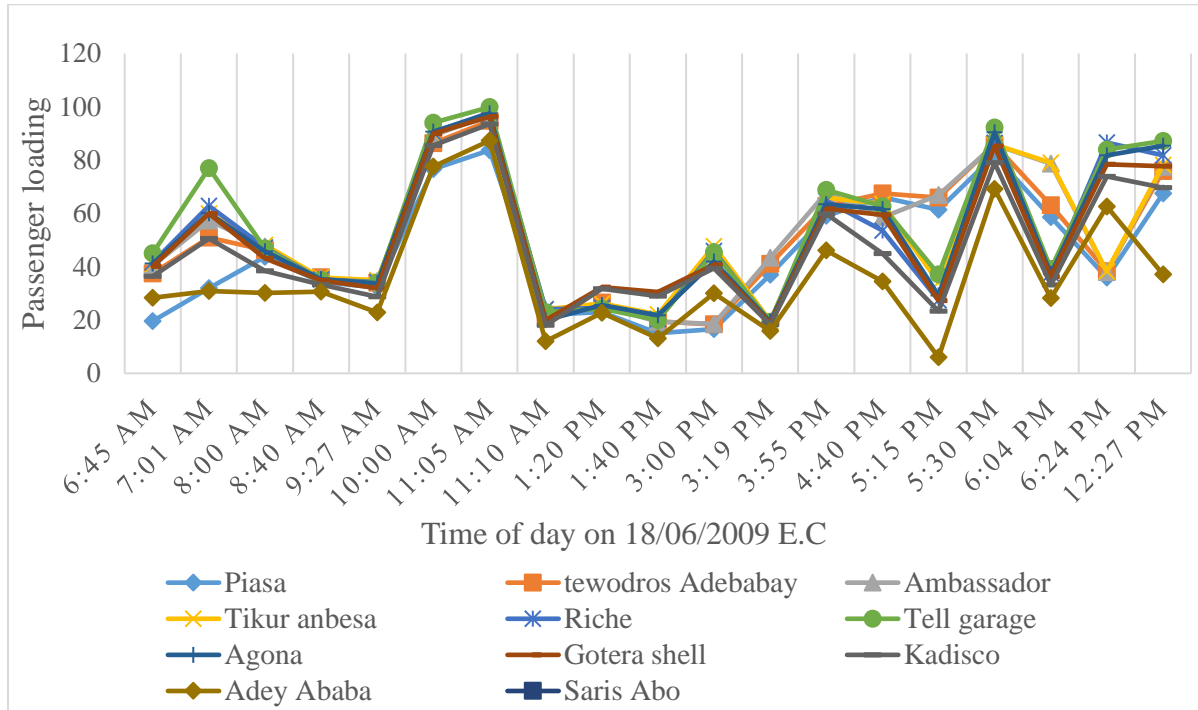


Figure 4.5: Variation of passenger loading with time of day from Piasa to Saris Abo

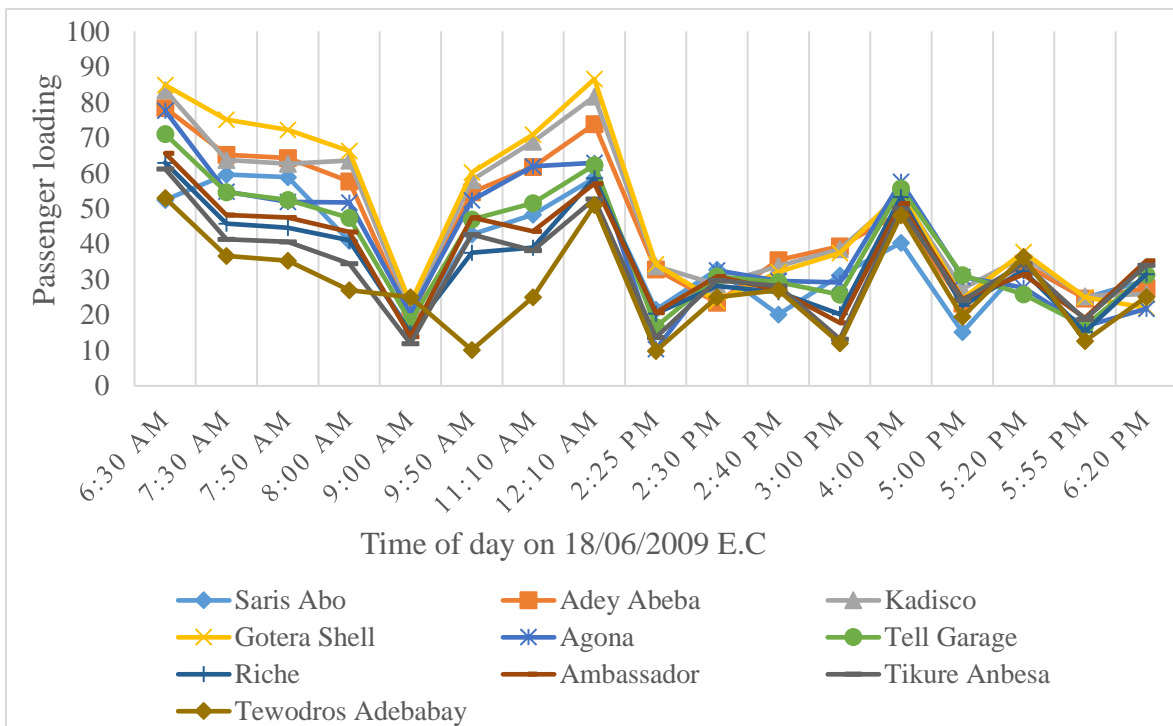


Figure 4.6: Variation of passenger loading with time of day from Saris Abo to Piasa.

Figure 4.6 above shows that passenger loading along northbound direction gradually increases from Saris Abo stop station to Gotera Shell stop station and decreases towards the Piasa stop station. During off peak hour periods i.e. from 10:00 am to 12:00 am passenger loading can reach up to 87. From the graph, it can be found that the headway between the consecutive transit vehicles are 80 and 60 minutes. However, from 2:25 pm to 3:00 pm the passenger loading can reach up to 39 passengers per bus with 5, 10 and 20-minute headway. This shows that for a constant passenger demand smaller headway and higher frequency leads to lower passenger loading.

Table 4.2: Transit stop LOS score and LOS grade for route 1 along Southbound direction

Southbound direction								
Stop Station	Morning Peak hour period				Afternoon peak hour period			
	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade
Shiromeda	5	B	1.45	E	5	B	1.33	E
6 Kilo	5	B	1.78	F	5	B	1.63	F
4 Kilo	5	B	1.38	E	5	B	1.38	E
Estifanos	5	B	0.83	C	5	B	1.08	D
Stadium	5	B	0.50	A	5	B	0.65	B
Mexico	5	B	0.50	A	5	B	0.65	B

Table 4.3: Transit stop LOS score and LOS grade for route 1 along Northbound direction.

Northbound direction								
Stop Station	Morning Peak hour period				Afternoon peak hour period			
	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade
Mexico	5	B	1.30	E	5	B	1.35	E
Stadium	5	B	1.73	F	5	B	2.03	F
Estifanos	5	B	1.53	F	5	B	2.18	F
4 Kilo	5	B	0.78	C	5	B	1.45	E
6 Kilo	5	B	0.70	C	5	B	1.35	E
Shiromeda	5	B	0.70	C	5	B	1.35	E

Table 4.4: Transit stop LOS score and LOS grade for route 2 along Southbound direction.

Southbound direction								
Stop Station	Morning Peak hour period				Afternoon peak hour period			
	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade
Mexico	6	B	1.04	D	6	B	1.54	F
Sarbet	6	B	1.07	D	6	B	1.67	F
Abo-Mazoria	6	B	1.06	D	6	B	1.64	F
Mekanisa	6	B	1.15	D	6	B	1.71	F
Germen Adebabay	6	B	0.98	C	6	B	1.52	F
Michael Adebabay	6	B	0.85	C	6	B	1.52	F
Jemo 1	6	B	0.60	B	6	B	1.13	D
Jemo 3	6	B	0.45	A	6	B	0.97	C
jemo 2	6	B	0.45	A	6	B	0.97	C

Table 4.5: Transit stop LOS score and LOS grade for route 2 along Northbound direction.

Nouthbound direction								
Stop Station	Morning Peak hour period				Afternoon peak hour period			
	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade
Jemo 2	6	B	1.17	D	6	B	0.52	B
Jemo 3	6	B	1.53	F	6	B	0.69	B
Jemo 1	6	B	1.97	F	6	B	0.89	C
Michael Adebabay	6	B	1.72	F	6	B	0.73	B
Germen Adebabay	6	B	1.74	F	6	B	0.73	B
Abo-Mazoria	6	B	1.78	F	6	B	0.75	B
Mekanisa	6	B	1.69	F	6	B	0.76	C
Sarbet	6	B	1.38	E	6	B	0.59	B
Mexico	6	B	1.38	E	6	B	0.59	B

Table 4.6: Transit stop LOS score and LOS grade for route 3 along Southbound direction.

Southbound direction								
Stop Station	Morning Peak hour period				Afternoon peak hour period			
	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade
Piasa	3	C	1.08	D	3	C	1.40	E
Tewodros Adebabay	3	C	1.43	E	3	C	1.55	F
Tikure Anbesa	3	C	1.38	E	3	C	1.63	F
Ambassador	3	C	1.43	E	3	C	1.63	F
Rich	3	C	1.43	E	3	C	1.63	F
Tell Garage	3	C	1.40	E	3	C	1.6	F
Agona	3	C	1.53	F	3	C	1.68	F
Gotera Shell	3	C	1.35	E	3	C	1.55	F
Kadisco	3	C	1.33	E	3	C	1.50	E
Adey Abeba	3	C	1.10	D	3	C	1.33	E
Saris Abo	3	C	0.73	B	3	C	0.88	C

Table 4.7: Transit stop LOS score and LOS grade for route 3 along Northbound direction.

Northbound direction								
Stop Station	Morning Peak hour period				Afternoon peak hour period			
	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade	Frequency (veh/h)	LOS grade	Passenger Loading ( p/seat)	LOS grade
Saris Abo	3	C	1.28	E	3	C	1.13	D
Adey Abeba	3	C	1.63	F	3	C	1.23	D
Kadisco	3	C	1.78	F	3	C	1.33	E
Gotera Shell	3	C	1.88	F	3	C	1.35	E
Agona	3	C	1.53	F	3	C	1.35	E
Tell Garage	3	C	1.40	E	3	C	1.38	E
Rich	3	C	1.40	E	3	C	1.38	E
Ambassador	3	C	1.15	D	3	C	1.38	E
Tikure Anbessa	3	C	1.18	D	3	C	1.30	E
Tewodros Adebabay	3	C	1.05	D	3	C	1.18	D
Piasa	3	C	0.85	C	3	C	1.05	C

#### 4.4 Results of hours of service

Table 4.8: Hour of service LOS on the study routes

No	Route	Hour of service	
		Value (hours of the day)	LOS
1	From Shiromeda → Mexico	14	C
2	From Mexico → Jemo 2	14	C
3	From Piasa → Saris Abo	14	C

Table 4.8 above shows that the service for all routes is 14 working hours per day, which provides daytime and early evening service. In Addis Ababa and other parts of the country, the working time for most of the offices is 8 hours per day. Therefore, the service provides a long enough service span to serve the work trips made in the city.

Figure 4.7 below illustrates variation of headway with time of day from Mexico to Shiromeda.

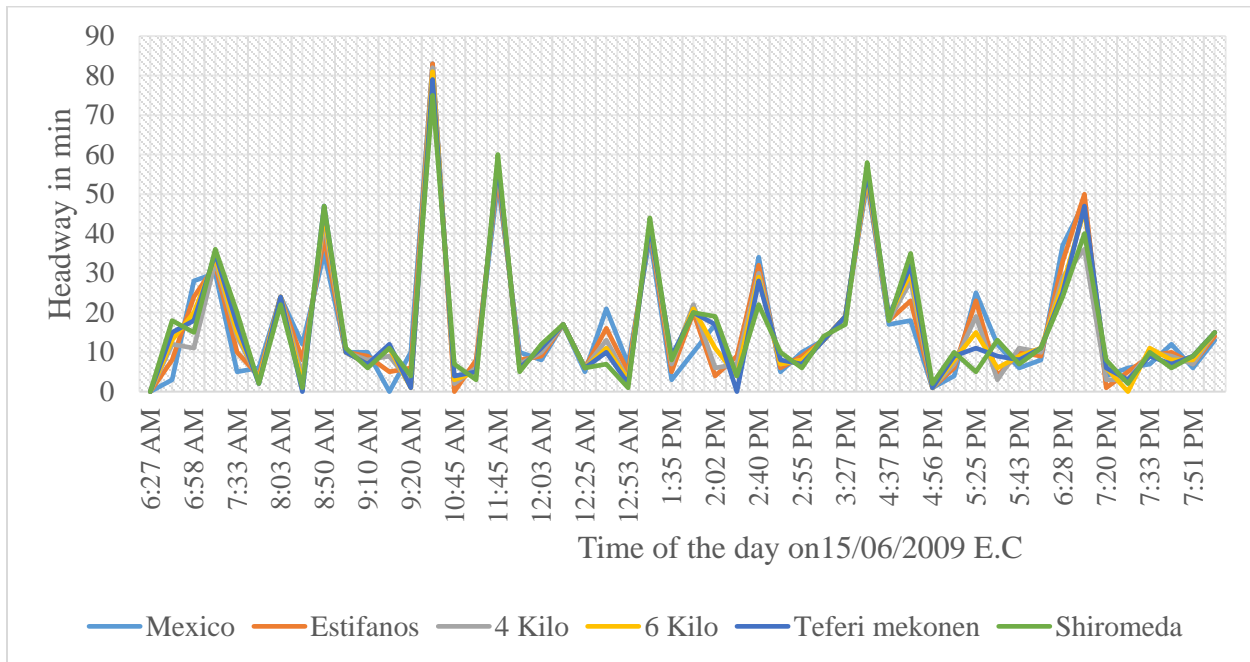


Figure 4.7: Variation of headway with time for the route from Mexico to Shiromeda

Figure 4.7 above shows that headways between transit buses vary throughout the day. The headway varies from 1 to 83 minutes. This shows that two or more transit buses moving along the same route arrive closely together or followed by large gap. It can be seen that around 10:34 a.m., the maximum headway was 83 minutes. Similarly, irregularity of lines in the graph shows large variation of headways along the route. The irregularity of bus arrivals at each stop station is either due to irregularity of headway at starting point of the route or throughout the route. Widely spaced lines in the graph indicates that a given transit vehicle cannot maintain equal headways on each stop stations. For example, at 12:46 a.m., a transit bus has a headway of 21 and 7 minutes at Mexico and Shiromeda stop stations respectively. On the other hand, from 9:20 a.m. to 10:45 a.m., 11:45 a.m., 1:32 p.m. and 4:20 p.m. closed spaced line in the graph indicates that a given transit vehicle moves with nearly equal headways at each stop station along the route. Figures 4.8 and 4.9 below illustrate percentages of headways for Route 2 along Northbound and Southbound directions respectively.

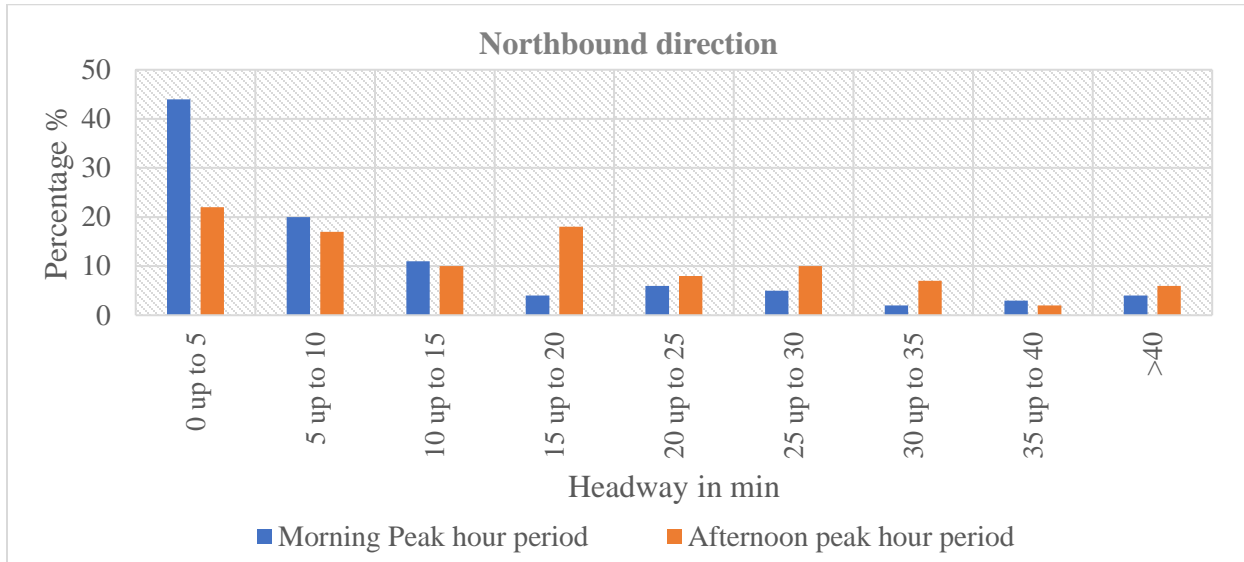


Figure 4.8: Percentage of headway occurrence on route 2 along Northbound direction.

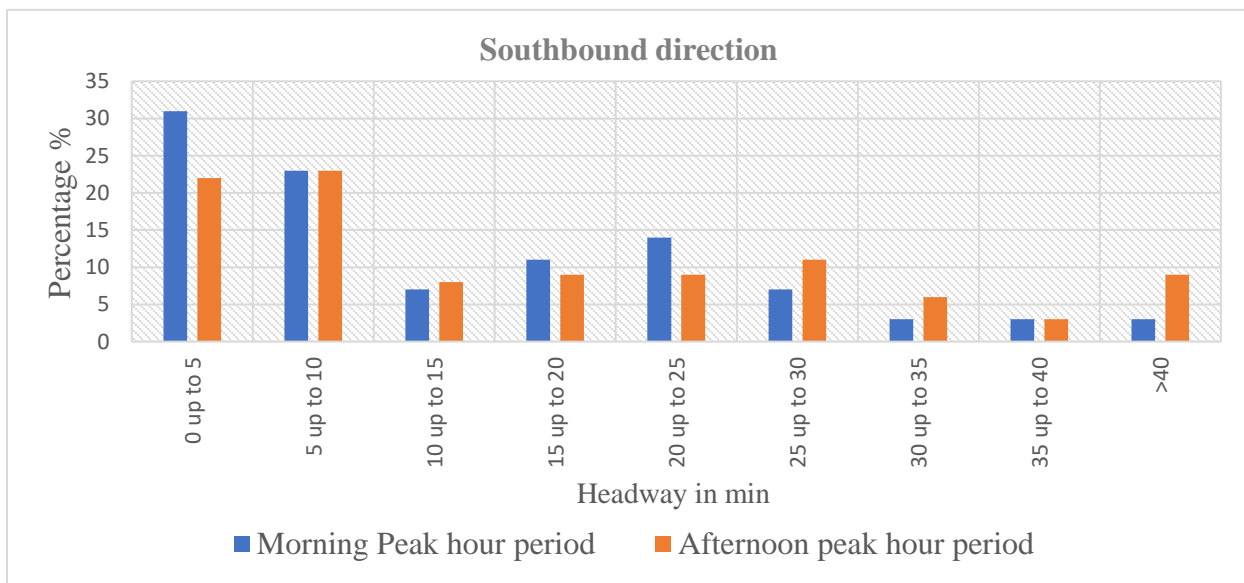


Figure 4.9: Percentage of headways occurred on route 2 along Southbound direction.

In Figure 4.8 and Figure 4.9 above, it is shown that headway up to 10 minutes constitute larger percentages of headways for both directions and peak hour periods. Figure 4.10 below illustrates variations of headways for each stop station during different times of the day on the route from Jemo 2 to Mexico.

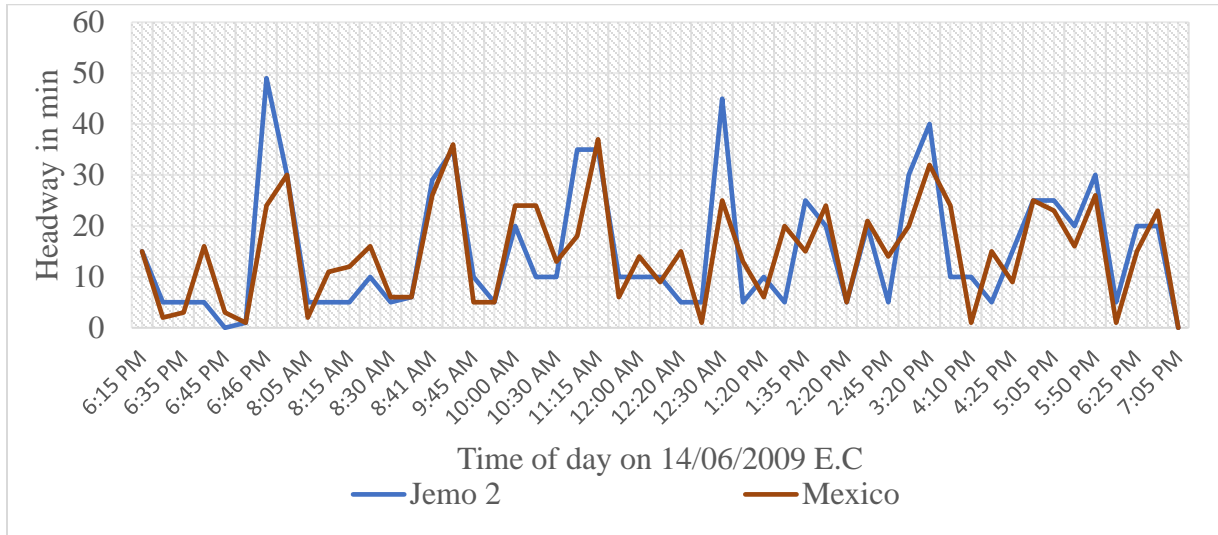


Figure 4.10: Variation of headways with time of day from Jemo 2 to Mexico.

Figure 4.10 above shows the irregularity of headways during different times of the day. These variations start at the first bus stop station and continues throughout the remaining stop stations. The closely spaced line or lines forming a single line in the graph shows that headways of remaining stop stations have nearly similar headway as the first stop station. Whereas, the widely spaced lines in the graph show that headways of the remaining stop stations significantly vary from the first stop station. Figure 4.11 below illustrates variation of headways at each stop station during different times of the day from Saris Abo to Piasa.

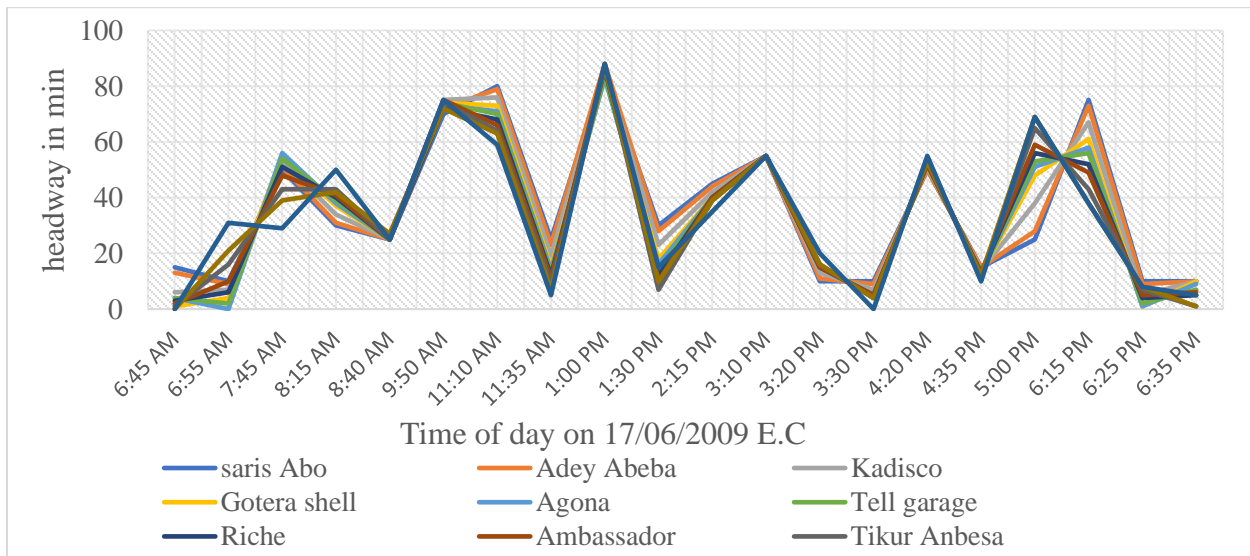


Figure 4.11: Variations of headways with time of day from Saris Abo to Piasa

Figure 4.11 above shows that most of the time for a given transit vehicle, headway at each stop station is nearly similar with headway of first stop station. Compared to the first two routes, variation of headway on this route is very high. Even if the frequency on this route is low, extreme high and low headway values indicate the departure time at the first stop station is not properly controlled.

#### **4.5 Results of reliability**

Among the selected routes, only the route from Mexico to Jemo 2 (Route 2) is operating with a frequency of 6 buses/hr. Therefore, on this route headway adherence is used to evaluate the reliability of transit service.

Table 4.9 below shows the actual arriving time of buses at the Sarbet stop station along southbound direction in respect of headways as recorded on 18/06/2009 E.C. According to the Sheger Mass Transport Enterprise, the buses on this route are scheduled to operate at a fixed 10 min headway. The standard deviation from the collected headway on this day is 10.18 minutes. Therefore, the resulting coefficient of variation (Headway adherence) is 1.02 indicating that most vehicles are bunched.

Table 4.9: Actual arrival time of buses at the Sarbet stop station along Southbound direction

<b>Headway (HW) in minutes</b>									
Time	HW	Time	HW	Time	HW	Time	HW	Time	HW
1:05	9	2:39	5	4:38	14	7:39	35	11:04	15
1:14	4	2:44	1	4:52	13	8:14	25	11:19	7
1:18	5	2:45	3	5:05	7	8:39	7	11:26	16
1:23	2	2:48	13	5:12	11	8:46	35	11:42	6
1:25	2	3:01	2	5:23	26	9:25	4	11:48	10
1:27	4	3:03	3	5:49	3	9:29	10	11:58	6
1:31	3	3:06	18	5:52	21	9:39	2	12:04	10
1:34	18	3:24	27	6:13	1	10:41	22	12:14	6
1:52	20	3:51	23	6:14	28	10:03	25	12:20	20
2:12	17	4:14	21	6:42	46	10:28	18	12:40	
2:29	10	4:35	3	7:28	11	10:46	18		

Using similar method for all stop station and study periods, the average headway adherences were calculated for all stop stations. Table 4.10 below shows that for all stop stations most vehicles are bunched.

Table 4.10: Results of Headway Adherence LOS for the route from Mexico to Jemo 2.

Stop station	Morning Peak hour period		Afternoon Peak hour period	
	Headway Adherence	LOS grade	Headway Adherence	LOS grade
Mexico	1.09	F	1.60	F
Sarbet	1.09	F	1.51	F
Abo-Mazoria	1.09	F	1.33	F
Mekanisa	1.07	F	1.44	F
Germen Adebabay	1.04	F	1.39	F
Michael Adebabay	1.03	F	1.39	F
Jemo 1	1.07	F	1.30	F
Jemo 3	1.09	F	1.30	F
Jemo 2	1.12	F	1.41	F

Table 4.11: Results of Headway Adherence LOS for the route from Jemo 2 to Mexico.

Stop station	Morning Peak hour period		Afternoon Peak hour period	
	Headway Adherence	LOS grade	Headway Adherence	LOS grade
Jemo 2	1.39	F	1.17	F
Jemo 3	1.38	F	1.17	F
Jemo 1	1.34	F	1.30	F
Michael Adebabay	1.34	F	1.31	F
Germen Adebabay	1.36	F	1.23	F
Mekanisa	1.41	F	1.37	F
Abo-Mazoria	1.35	F	1.37	F
Sarbet	1.33	F	1.38	F
Mexico	1.43	F	1.46	F

Tables 4.10 and 4.11 above shows that the results of headway adherence is high due to large value of standard deviation of headway (representing the range of actual headways) compare to average

headway. Similarly, the LOS indicates that there is high variation of headways are experienced by each vehicle on each stop stations.

#### 4.6 Results of Multimodal Transit LOS

The following calculation step involves sample calculation of transit LOS for the route segment from Estifanos to Stadium during morning peak hour period and results of the all segments on the study routes are presented in tabular form in the appendix part of this paper.

##### Step 1:- Determination of the Transit Wait-Ride Score

The transit wait – ride score involves the calculation of headway factor and a perceived travel time factor.

- **Headway factor**

Calculation of headway factor depends on the frequency of bus service on the study routes. It is found that the frequency of bus service is 5 veh/hr. The headway factor is computed using Equation 5.6 of TCQSM as depicted below:

$$f_h = 4.00e^{\frac{-1.434}{(f+0.001)}}$$

$$f_h = 4.00e^{\frac{-1.434}{(5+0.001)}}$$

$$f_h = 3.0$$

This result indicates that the route is estimated to produce 3.0 times the ridership if operated hourly. The results of headway factor for all routes are summarized in Table 4.12 below.

Table 4.12: Results of headway factor for all routes under study

Route	Direction	Morning peak hour		Afternoon peak hour	
		Frequency Veh/hr	Headway value	Frequency Veh/hr	Headway value
Route 1	Southbound	5	3.00	5	3.00
	Northbound	5	3.00	5	3.00
Route 2	Southbound	6	3.15	6	3.15
	Northbound	6	3.15	6	3.15
Route 3	Southbound	3	2.48	3	2.48
	Northbound	3	2.48	3	2.48

- **Perceived travel time rate**

The perceived travel time factor includes components related to passenger loading, transit vehicle speed, reliability and condition of stop amenities. From the field data, a bus having 40-seat and 30 standing capacity carry an average of 62 passengers. Therefore, average passenger load factor for the segment from Estifanos to Stadium is calculated as  $L_f = 62/40 = 0.83$  P/seat. The passenger load-weighting factor is determined using Equation 5.9 of TCQSM.

$$f_{pl} = \begin{cases} 1.00 & L_f \leq 0.80 \\ 1 + \frac{4(L_f-0.8)}{4.2} & 0.8 < L_f \leq 1.00 \\ 1 + \frac{4(L_f-0.8)+(L_f-1.00)(6.5+[5(L_f-1.00)])}{4.2L_f} & L_f > 1.00 \end{cases}$$

The average passenger load factor for the segment was found to be between 0.8 and 1. Therefore, the second choice of equation, 5.9 was used to determine passenger load weighting factor.

$$f_{pl} = 1 + \frac{4(L_f-0.8)}{4.2}$$

$$f_{pl} = 1 + \frac{4(0.83-0.8)}{4.2}$$

$$f_{pl} = 1.03$$

- **Perceived amenity time rate**

The perceived amenity data includes information about the presence of benches and shelter for each stop station in the analysis segment. There are no amenities under the given segment Therefore perceived amenity time rate was calculated using Equation 5.10 of TCQSM as depicted below.

$$T_{at} = \frac{1.3P_{sh} + 0.2P_{be}}{L_{pt}}$$

$$T_{at} = \frac{1.3(0)+0.2(0)}{3.23}$$

$$T_{at} = 0 \text{ min/mi}$$

The results of passenger load weighing factor and perceived amenity time rate for the route from Shiromeda to Mexico are summarized in Table 4.13 below.

Table 4.13: Results of passenger load weighting factor and perceived amenity time rate for route 1 along Southbound direction.

Direction	Segment Id	Morning peak hour period					Afternoon peak hour period				
		$L_f$ P/seat	$f_{pt}$	$P_{sh}$	$P_{be}$	$T_{at}$ min/m i	$L_f$ P/seat	$f_{pt}$	$P_{sh}$	$P_{be}$	$T_{at}$ min/mi
Southbound	SM 1	1.45	2.07	1	1	0.47	1.33	1.85	1	1	0.46
	SM 2	1.78	2.60	1	1	0.47	1.63	2.36	1	1	0.46
	SM 3	1.78	2.60	1	1	0.47	1.63	2.36	1	1	0.46
	SM 4	1.38	1.94	0	0	0.00	1.38	1.94	0	0	0
	SM 5	1.38	1.94	0	0	0.00	1.38	1.94	0	0	0
	SM 6	0.83	1.03	0	0	0.00	1.08	1.36	0	0	0
	SM 7	0.50	1.00	0	0	0.00	0.65	1.00	0	0	0
	SM 8	0.50	1.00	0	0	0.00	0.65	1.00	0	0	0
	MS 8	0.78	1.00	1	1	0.48	1.45	2.07	1	1	0.50

- **Excess waiting time rate**

The excess waiting time rate for late arrival  $T_{ex}$  is the excess wait time  $t_{ex}$  divided by the average passenger trip length  $L_{pt}$ . When departure is not perfectly reliable, the average waiting time is longer than half the average headway and is related to the spread in headway distribution. Therefore, average wait time was computed using the following formula as provided by Equation 5.4 of TCQSM.

$$t_w = 0.5h_o(1 + C_{vh}^2)$$

$$t_w = 0.5 * 16.93 * (1 + (0.70)^2)$$

$$t_w = 12.70 \text{ min}$$

The observed average headway on this segment is 16.93 minute with a standard deviation of 11.86 minutes. Therefore, resulting coefficient of variation of headway becomes 0.70. Similarly, results of average headway, standard deviation and coefficient of variation of headway for the remaining segments are shown in Table 4.14 below.

Table 4.14: Results of average wait time for route 1 during morning peak hour period

Segment ID	SM 1	SM 2	SM 3	SM 4	SM 5	SM 6	SM 7	SM 8
Average headway (min)	16.50	16.59	16.59	16.71	16.71	16.93	17.22	17.66
Standard deviation	10.46	10.72	10.72	11.25	11.25	11.86	12.37	14.55
Coefficient of variation of headway	0.64	0.65	0.65	0.68	0.68	0.70	0.72	0.83
Average wait time (min)	11.72	11.90	11.90	12.25	12.25	12.70	13.14	15.02

Average passenger trip length can be determined by dividing total passenger miles by total number of boarding passengers. For each day, the number of passengers boarding and their trip destination varies. For this reason, the average passenger trip length varies for each day. The total number of trip for each day varies depending on the traffic condition and availability of buses on the route. Table 4.15, 4.16 and 4.17 below presents the average passenger trip length for route 1, 2 and 3 respectively.

Table 4.15: Average passenger trip length for route 1

<b>Average passenger trip length ( km)</b>				
Date	Northbound direction		Southbound direction	
	Morning peak hour period	Afternoon peak hour period	Morning peak hour period	Afternoon peak hour period
Tuesday	5.10	4.50	4.49	4.69
Wednesday	5.10	5.20	4.80	5.1
Thursday	5.20	4.90	5.80	6.1
Friday	5.10	4.60	5.10	4.9
<b>Average</b>	<b>5.12</b>	<b>4.80</b>	<b>5.05</b>	<b>5.20</b>

Table 4.16: Average passenger trip length for route 2

<b>Average passenger trip length ( km)</b>				
Date	Northbound direction		Southbound direction	
	Morning peak hour period	Afternoon peak hour period	Morning peak hour period	Afternoon peak hour period
Tuesday	8.20	7.60	6.98	6.98
Wednesday	7.70	7.69	6.83	7.35
Thursday	8.02	7.92	6.00	6.19
Friday	8.40	7.12	7.31	7.07
Saturday	8.14	7.66	7.20	7.58
<b>Average</b>	<b>8.09</b>	<b>7.60</b>	<b>6.86</b>	<b>7.03</b>

Table 4.17: Average passenger trip length for route 3

<b>Average passenger trip length ( km)</b>				
Date	Northbound direction		Southbound direction	
	Morning peak hour period	Afternoon peak hour period	Morning peak hour period	Afternoon peak hour period
Thursday	5.90	6.25	6.93	6.38
Friday	6.40	6.33	7.37	8.02
Saturday	6.34	6.50	8.74	8.08
Monday	6.12	5.44	7.12	6.99
Tuesday	5.52	5.18	7.13	7.18
Wednesday	5.86	5.69	7.06	7.75
<b>Average</b>	<b>6.02</b>	<b>5.90</b>	<b>7.39</b>	<b>7.40</b>

Excess wait time is the difference between average wait times minus schedule wait time resulting to  $t_{ex} = 13.24 - 7.5 = 5.74$  minutes. Similarly, for the remaining days, the excess wait time become 5.74, 5.30, 2.50 and 7.27 minutes and the average excess wait time for the given study period was calculated at 5.06 minutes. Therefore the  $T_{ex} = (5.20 \text{ min}) / (3.14 \text{ mi}) = 1.66 \text{ min/mi}$ .

- **Perceived travel time rate**

A transit vehicle takes 3.96 minutes to travel 0.49 miles. Therefore, the average travel speed of transit vehicle is 7.42 mi/h. then the perceived travel time rate was computed using Equation 5.8 of TCQSM.

$$T_{ptt} = \left( f_{pl} \frac{60}{s} \right) + (2T_{ex}) - T_{at}$$

$$T_{ptt} = \left( 1.03 \frac{60}{7.42} \right) + (2 * 1.66) - 0$$

$$T_{ptt} = 11.64 \text{ min/mi.}$$

- **Perceived travel time factor**

In the absence of other information, the default travel time rate elasticity of -0.40 will be used. Since this segment is not located within the central district of metropolitan areas of 5 million or more, the base travel time rate used will be 4 min/mi. The perceived travel time factor is calculated using Equation 5.7 of TCQSM.

$$f_{tt} = \frac{(E-1)T_{btt} - (E+1)T_{ptt}}{(E-1)T_{ptt} - (E+1)T_{btt}}$$

$$f_{tt} = \frac{(-0.4 - 1) * 4 - (-0.4 + 1) * 11.41}{(-0.4 - 1) * 11.41 - (-0.4 + 1) * 4}$$

$$f_{tt} = 0.67$$

Finally, the results of transit wait – ride score was computed using the following equations as provided in Equation 5.5 of TCQSM.

$$S_{W-r} = f_h f_{tt}$$

$$S_{W-r} = 3 * 0.67$$

$$S_{W-r} = 2.01$$

Similarly, the results of transit wait – ride score from Shiromeda to Mexico during morning peak hour period are summararily presented in the Table 4.18 below.

Table 4.18: Input data and results of transit wait-ride score from Shiromeda to Mexico.

Direction	Segment Id	Morning peak hour period									
		<i>S</i> (mil/h)	<i>E</i>	<i>t<sub>ex</sub></i> min	<i>l<sub>pt</sub></i> mi	<i>T<sub>e</sub></i> min	<i>T<sub>ptt</sub></i> min/mi	<i>T<sub>bt</sub></i>	<i>f<sub>tt</sub></i>	<i>f<sub>h</sub></i>	<i>S<sub>w-1</sub></i>
Southbound	SM 1	14.9	-0.40	4.22	3.14	1.34	10.56	4.0	0.69	3.00	2.09
	SM 2	7.5	-0.40	4.40	3.14	1.40	23.16	4.0	0.56	3.00	1.68
	SM 3	4.6	-0.40	4.40	3.14	1.40	36.53	4.0	0.51	3.00	1.54
	SM 4	3.6	-0.40	4.75	3.14	1.51	35.27	4.0	0.52	3.00	1.55
	SM 5	23.1	-0.40	4.75	3.14	1.51	8.07	4.0	0.76	3.00	2.29
	SM 6	7.4	-0.40	5.20	3.14	1.66	11.64	4.0	0.67	3.00	2.01
	SM 7	2.9	-0.40	5.64	3.14	1.80	24.22	4.0	0.55	3.00	1.67
	SM 8	3.7	-0.40	7.52	3.14	2.39	20.99	4.0	0.57	3.00	1.72

Table 4.18 above shows that the transit wait - ride score increase with increase in frequency and increased in perceived travel time factor. The perceived travel time factor can also increase by increasing transit speed, decreasing passenger loading and decreasing excess wait time.

### Step 2: - Determination of Pedestrian Environmental Score

- **Motorized vehicle volume adjustment factor**

The input data for this calculation is the outside lane motorized vehicle demand flow rate at the given segment. For the given segment, the outside lane motorized vehicle demand flow rate is 1,195 veh/h. The motorized vehicle volume adjustment factor is calculated using Equation 5.13 of TCQSM.

$$f_v = 0.0091 \frac{V_m}{4} \quad \text{Equation 5.13}$$

$$f_v = 0.0091 \frac{1195}{4}$$

$$f_v = 2.72$$

- **Motorized vehicle speed adjustment factor**

The input data for this calculation is the motorized vehicle running speed. In this research to consider delay due to intersection on the segment and speed difference throughout the segment, it is assumed that the average speed of transit vehicle are used as motorized vehicle running speed.

Therefore, motorized vehicle speed adjustment factor is calculated using Equation 5.14 of TCQSM.

$$f_s = 4\left(\frac{S_R}{100}\right)^2 \quad \text{Equation 5.14}$$

$$f_s = 4\left(\frac{7.4}{100}\right)^2$$

$$f_s = 0.022$$

- **Road cross-Section Adjustment factor**

The road cross-section adjustment factor is computed using equation 5.12 of TCQSM.

$$f_w = -1.2276 \ln(W_v + 0.5W_1 + 50P_{pk} + W_{buf}f_b + W_{AA}f_{sw}) \quad \text{Equation 5.12}$$

The percentage of utilized parking for the given segment is zero under the existing condition, Therefore, the total width  $W_t$  is calculated as the sum of the width of the outside lane ( 9.84 ft ), bicycle lane ( 0 ft ) and the adjusted width of paved outside shoulder or parking lane ( 0 ft ).

$$W_t = W_{ol} + W_{bl} + W_{os}^*$$

$$W_t = 9.84 + 0 + 0$$

$$W_t = 9.84 \text{ ft}$$

Because the proportion of occupied on –street parking is less than 0.25 then the effective width of combined bicycle lane and shoulder  $W_1 = 0$  ft.

The available side walk width for the segment  $W_A = 34.45$  ft. the adjusted available sidewalk width is determined as  $W_{AA} = \min (W_A, 10)$ . Therefore,  $W_{AA} = \min (34.4, 10) = 10$  ft. the sidewalk width coefficient  $f_{sw}$  is computed as

$$f_{sw} = 6.0 - 0.3W_{AA}$$

$$f_{sw} = 6.0 - 0.3 \cdot 10$$

$$f_{sw} = 3 \text{ ft}$$

The sidewalk is curb-tight, therefore the buffer width  $W_{Buf}$  is 0 ft. Next, the factor related to the buffering effect of barrier or street trees is considered. There are continuous barrier along the segment; therefore, the buffer area coefficient is  $f_b = 5.37$

After determining the widths of the various cross sections, the road cross-section adjustment factor for the given segments were calculated as follows:

$$f_w = -1.2276 \ln(W_v + 0.5W_1 + 50P_{pk} + W_{buf}f_b + W_{aA}f_{sw})$$

$$f_w = -1.2276 \ln(9.84 + 0.5 * 0 + 50 * 0 + 0 * 5.37 + 10 * 3)$$

$$f_w = -4.52$$

Finally, the pedestrian environmental score can be calculated using Equation 5.11 of TCQSM as follows:

$$I_p = 6.0468 + f_w + f_v + f_s$$

$$I_p = 6.0468 + (-4.52) + 2.72 + 0.022$$

$$I_p = 4.26$$

Similarly, the results of road cross –section adjustment factor from Shiromeda to Mexico are summarized in Table 4.19 shown below.

Table 4.19: Input data and results of road cross –section adjustment factor for route 1 along Southbound direction.

Direction	Segment Id	Morning peak hour period								
		$P_{pk}$	$W_v$ ft	$W_1$ ft	$W_{buf}$ ft	$F_b$	$W_A$ ft	$W_{aA}$	$f_{sw}$	$f_w$
Southbound	SM 1	0.03	11.48	0	0	5.37	11.5	10.0	3.00	-4.61
	SM 2	0.02	11.48	0	0	5.37	13.1	10.0	3.00	-4.61
	SM 3	0.07	11.48	0	0	5.37	11.5	10.0	3.00	-4.67
	SM 4	0.03	11.48	0	0	5.37	9.8	9.8	3.05	-4.62
	SM 5	0.00	11.48	0	0	5.37	14.8	10.0	3.00	-4.57
	SM 6	0.00	11.48	0	0	5.37	34.4	10.0	3.00	-4.57
	SM 7	0.05	9.84	0	0	5.37	11.5	10.0	3.00	-4.60
	SM 8	0.05	9.84	0	0	5.37	9.8	9.8	3.05	-4.60

### Step 3: Determine the transit LOS score

The transit LOS score is computed using equation 5.15 of TCQSM

$$I_t = 6.0 - 1.50S_{w-r} + 0.15I_p \quad \text{Equation 5.15}$$

Similarly, the results of Transit LOS for the route from Shiromeda to Mexico are summarized in the table 4.20 shown below.

Table 4.20: Input data and results of transit LOS for route from Shiromeda to Mexico.

Direction	Segment Id	Morning peak hour period						
		$V_m$	$f_v$	$S_R$	$f_s$	$I_P$	$S_{w-r}$	$I_t$
Southbound	SM 1	517	1.18	15	0.09	2.70	2.09	3.28
	SM 2	428	0.97	7	0.02	2.43	1.68	3.84
	SM 3	610	1.39	5	0.01	2.77	1.54	4.10
	SM 4	723	1.64	4	0.01	3.08	1.55	4.13
	SM 5	1062	2.42	23	0.21	4.10	2.29	3.18
	SM 6	1195	2.72	7	0.02	4.21	2.01	3.60
	SM 7	892	2.03	3	0.00	3.48	1.67	4.02
	SM 8	380	0.86	4	0.01	2.31	1.72	3.77

The transit LOS can be increased by increasing transit wait- ride score and decreasing the pedestrian environmental score. From the results of analysis, it is found that high number of outside lane motorized traffic volume around Estifanos and Stadium intersection and absence of sidewalk on the segment from signal to piasa increases the pedestrian environmental score and thus decrease the transit Los.

#### **Step 4: Determine Transit LOS**

The results of existing LOS analysis for the given transit service during the study period indicates poor quality of service. From the analysis, it is shown that LOS varies from route to route; from period to period and from direction to direction. Results of existing and improved transit LOS score and the corresponding LOS grade for all routs in both direction are shown in the Tables 4.21, 4.22, 4.23, 4.24, 4.25 and 4.26 below.

Table 4.21: Existing and improved transit LOS for segment from Shiromeda to Mexico.

Southbound									
No.	Segment ID	Morning peak hour period				Afternoon peak hour period			
		Existing		Improved		Existing		Improved	
		I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS
1	SM 1	3.28	C	2.94	C	3.35	C	2.91	C
2	SM 2	3.84	D	3.10	C	3.72	D	3.06	C
3	SM 3	4.10	D	3.16	C	4.00	D	3.07	C
4	SM 4	4.13	D	3.05	C	3.85	D	3.01	C
5	SM 5	3.18	C	2.94	C	3.61	D	3.26	C
6	SM 6	3.60	D	2.82	C	3.77	D	3.03	C
7	SM 7	4.02	D	2.72	B	3.34	C	2.59	B
8	SM 8	3.77	D	2.72	B	3.63	D	2.60	B

Table 4.22: Existing and improved transit LOS for segment from Mexico to Shiromeda.

Northbound									
No.	Segment ID	Morning peak hour period				Afternoon peak hour period			
		Existing		Improved		Existing		Improved	
		I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS
1	MS 1	3.79	D	2.73	B	3.99	D	2.67	B
2	MS 2	3.50	D	2.81	C	4.22	D	2.79	C
3	MS 3	3.95	D	2.74	B	4.24	D	2.83	C
4	MS 4	3.57	D	2.82	C	3.92	D	2.92	C
5	MS 5	3.58	D	2.80	C	4.05	D	2.90	C
6	MS 6	4.02	D	2.73	B	3.70	D	2.92	C
7	MS 7	3.51	D	2.72	B	3.82	D	2.95	C
8	MS 8	2.95	C	2.54	B	3.53	D	2.48	B
9	MS 9	3.00	C	2.53	B	3.65	D	2.36	B

Table 4.21 above shows that along Southbound direction, poor quality of service happened on the segment from Arat Kilo to Estifanos. On this segment, the causes of poor quality of service are high passenger loading and low transit speed. Similarly, along Northbound direction, poor quality of service happened on the segment from Estifanos to Sidist Kilo. On these routes, in addition to traffic congestion the presence of 6 intersections and 2 roundabouts slow the transit travel speed.

Therefore, slight improvement in transit travel speed will increase the quality of service. On this route, the average travel speed of transit vehicle is 9.25 mph. Therefore, if the transit vehicle allows to travel with a minimum speed of 16 mph then the frequency increases to 8 veh/hr with 7min headway. Similarly, the passenger loading decreases by 37.5%. However, by assuming all passengers are sitting (i.e p/seat = 1.00). Therefore, the change in the above variables improve the existing transit LOS. Table 4.23 belw presents the existing and improved transit LOS for the route segment from Mexico to Jemo 2.

Table 4.23: Existing and improved transit LOS for segment from Mexico to Jemo 2.

Southbound									
No.	Segment ID	Morning peak hour period				Afternoon peak hour period			
		Existing		Improved		Existing		Improved	
		I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS
1	MJ 1	2.19	B	2.09	B	3.60	D	2.83	C
2	MJ 2	2.36	B	2.24	B	3.52	D	2.62	B
3	MJ 3	2.13	B	2.02	B	3.67	D	2.70	B
4	MJ 4	2.46	B	2.20	B	3.49	C	2.73	B
5	MJ 5	3.03	C	2.32	B	3.57	D	2.73	B
6	MJ 6	1.84	A	1.84	A	3.83	D	2.62	B
7	MJ 7	2.60	B	2.16	B	3.25	C	2.73	B
8	MJ 8	2.30	B	2.22	B	3.12	C	2.68	B

Table 4.24: Existing and improved transit LOS for segment from Jemo 2 to Mexico.

No.	Segment ID	Northbound							
		Morning peak hour period				Afternoon peak hour period			
		Existing		Improved		Existing		Improved	
		I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS
1	JM 1	2.85	C	2.39	B	2.2	B	1.94	A
2	JM 2	3.44	C	2.36	B	2.43	B	2.19	B
3	JM 3	4.04	D	2.29	B	2.46	B	2.20	B
4	JM 4	3.55	D	2.45	B	2.54	B	2.11	B
5	JM 5	3.92	D	2.43	B	2.79	C	2.18	B
6	JM 6	3.56	D	2.33	B	2.82	C	2.16	B
7	JM 7	3.62	D	2.30	B	3.12	C	2.39	B
8	JM 8	3.69	D	2.45	B	3.10	C	2.53	B

Table 4.23 and 4.24 above show that the existing transit LOS for Route 2 in both directions of travel is good. On this Route, the transit service provides frequent service with a frequency of 6 veh/hr and a headway of 10 min. There is a variation of passenger demand and travel speed during morning and afternoon peak hour periods. For example, along Southbound direction the average speed of transit vehicle was 17 and 8.27 mph during morning and afternoon peak hour periods respectively. Poor LOS happened in the segment from Germen Adebabay to Michael Adebabay due to traffic congestion and presence of signalized intersection. This decreases the travel speed of transit vehicle to 8 mph (12.8 kmh). On the other hand, during afternoon peak hour period the LOS on all segment was poor due to the reduction of speed because of traffic congestion and high passenger loading.

Along Northbound direction, the average speed of transit vehicle is 8 and 12.12 mph (12.8 to 19.4 kmh) during morning and afternoon peak hour periods respectively. Therefore, during morning peak hour period high passenger loading and low travel speed are the causes of poor quality of service. On the other hand, moderate travel speed and low passenger loading improves the transit LOS. On both periods and directions, the transit vehicle have average travel speed of 11.25 mph (18 kmh). Therefore, increasing the travel speed to a minimum of 16 mph (25.6 kmh) can improve the transit LOS. The slight improvement in transit travel speed also increased the headway to 7

minutes and by assuming maximum passenger loading is 1 p/seat. Therefore, the transit LOS has improved as depicted in the Table 4.23 and Table 4.24 above. Table 4.25 below shows the existing and improved transit level of service on Piasa - Saris Abo route. Similarly, Table 4.26 shows the existing and improved transit LOS on Saris Abo to Piasa route segment.

Table 4.25: Existing and improved transit LOS from Piasa to Saris Abo segment.

Southbound									
No.	Segment ID	Morning peak hour period				Afternoon peak hour period			
		Existing		Improved		Existing		Improved	
		I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS
1	PS 1	4.20	D	2.85	C	4.55	E	2.85	C
2	PS 2	3.82	D	2.67	B	4.19	D	2.88	C
3	PS 3	4.31	E	2.85	C	4.42	E	2.85	C
4	PS 4	4.35	E	2.85	C	4.61	E	2.86	C
5	PS 5	4.12	D	2.83	C	4.42	E	2.88	C
6	PS 6	4.01	D	2.74	B	4.37	E	2.74	B
7	PS 7	4.18	D	2.72	B	4.31	E	2.73	B
8	PS 8	3.94	D	2.77	C	4.41	E	2.77	C
9	PS 9	3.93	D	2.81	C	4.17	D	2.70	B
10	PS 10	3.7	D	2.67	B	4.17	D	2.76	C
11	PS 11	3.49	C	2.63	B	4.3	E	2.83	C
12	PS 12	3.65	D	2.63	B	4.28	E	2.76	C

Table 4.26: Existing and improved transit LOS for segment from Saris Abo to Piasa.

Northbound									
No.	Segment ID	Morning peak hour period				Afternoon peak hour period			
		Existing		Improved		Existing		Improved	
		I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS	I <sub>t</sub>	LOS
1	SP 1	4.12	D	2.88	C	4.08	D	2.84	C
2	SP 2	4.08	D	2.89	C	4.30	E	2.87	C
3	SP 3	4.13	D	2.89	C	4.14	D	2.89	C
4	SP 4	4.16	D	2.93	C	4.10	D	2.89	C
5	SP 5	4.18	D	2.95	C	4.01	D	2.71	B
6	SP 6	4.02	D	2.85	C	4.43	E	2.93	C
7	SP 7	4.59	E	2.97	C	4.32	E	2.95	C
8	SP 8	4.44	E	2.94	C	4.18	D	2.87	C
9	SP 9	4.44	E	3.06	C	4.49	E	3.07	C
10	SP 10	4.05	D	2.96	C	3.88	D	2.77	C
11	SP 11	4.27	E	3.17	C	4.32	E	3.25	C
12	SP 12	3.98	D	2.75	B	4.18	D	2.98	C

Tables 4.25 and 4.26 above show the results of existing and improved transit LOS scores and the corresponding LOS grades on the routes from Piasa to Saris Abo and Saris Abo to Piasa respectively. Compared to the above two routes, the existing LOS is very poor which is characterized by higher headway, higher passenger loading, lower frequency and higher excess waiting time. Therefore as improvement, the above variables should be given special emphasis. For most of the segments the LOS on the routes are D and E. These existing routes have an average travel speed of 11.5 mph (18.4 kmh); a headway of 20-30 minutes and an average excess waiting time of 20 minutes.. Therefore, the improved LOS are presented in Tables 4.25 and 4.26 above which were obtained by doubling the frequency to 6 veh/hr; reducing the maximum excess waiting time by half; improving the transit travel speed to 16 mph (25.6 kmh) and reducing the maximum passenger loading to 1 p/seat. Finally, the transit agencies should continuously evaluate the quality of service on each segment and stop station. The analyses and the results help them to identify the causes of problem and identify areas in need of improvement by considering all concerned bodies.

## **CHAPTER FIVE**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **5.1 Conclusions**

The research dealt with the evaluation of the quality of service in the case of Sheger Mass Transport Enterprise in the City of Addis Ababa. Based on the analysis and generated results of the study, the following conclusions have been drawn:

- The results regarding frequency at stop station shows that Route 1 (Mexico - Shiromeda) and Route 2 (Mexico - Jemo 2) operate with a frequency of 5 and 6 veh/hr respectively; whereas, Route 3 (Piasa - Saris Abo) operates with a frequency of 3 veh/hr. All routes are operating 12 – 14 hours of service per day, providing daytime and early evening services.
- On all routes, it was found that passenger loadings gradually increase from starting stop station to the middle stop station and then gradually decreases to the end of the last stop station. During the morning peak hour, passenger loadings are high towards the central parts of the city; whereas passenger loadings are low towards the periphery and residential areas..
- The study showed that for all routes, the variations of headways were due to variation of headways at the initial stop stations and impacts the variation of headways along the route segment. Variation of headways at first stop stations resulted due to lack of professional field supervision. Furthermore, delays at stop stations, delays at intersections, on-street parking, traffic accidents and condition of traffic are some of the reasons for headway variation along the route segment. Compared to Routes 1 and 2 variation of headways, Route 3 has very high variation of headways and the adherence LOS is F indicating that most of vehicles are bunched.
- Existing transit LOS indicates that the transit LOS for Route 1 and Route 3 are D and E on most segments; whereas, for Route 2, the LOS becomes B and D on most segments, depending on the period and direction of travel.
- Transit LOS can be improved by increasing the transit wait - ride score (increasing frequency, increasing speed and decreasing passenger loading) and by decreasing pedestrian environmental score (appropriate travel lane and sidewalk and by decreasing outside lane motorized traffic volume.

- Generally, the study showed that slight improvement in transit travel speed, frequency and passenger loading will improve the existing transit LOS.

## **5.2 Recommendations**

Based on the results of the study, in order to improve the quality of service on public bus transportation services and solve the existing transportation problems in the city, the following recommendation have been forwarded for considerations.

- In the cities like Addis Ababa, where the size of population and vehicle numbers are significantly increasing, the increasing transportation demand and transportation problems can be solved by improving and encouraging the mass transit system; by encouraging non-motorized transportation; by providing and maintaining appropriate infrastructure and by applying appropriate traffic management systems. I think non-motorized transportation operations in Addis Ababa is not feasible because of topographical challenges.
- Reliability of public service can be enhanced by maintaining equal headways and by applying proper scheduling and field supervision.
- In case of traffic accidents and bus breakage, the damaged vehicle should be removed from the road as fast as possible.
- During morning and afternoon peak hour periods, lane reallocation system should be established to reduce traffic congestion and improve travel time.
- To reduce traffic congestion due to on-street parking and solve parking difficulties, off-street parking should be provided in areas where larger proportion of street parking is required such as supermarkets, sport stadium and large organizations.
- To make the service more reliable and convenient, the decision makers should implement right-of-way and transit priority measures such as dedicated right-of-way; high occupancy vehicle lanes; express bus routes; queue jump lane and priority signalization.
- Transportation service providers should continuously analyze the quality of their services to identify areas for improvement.
- The transit agencies should continuously evaluate the quality of their service provisions on each route and at each bus stop station.

- The existing transportation infrastructures such as: travel lane; sidewalk; terminal; depots; stop stations; shelters and benches should be improved.
- In order to create more livable and attractive cities, decision makers should establish sustainable urban transportation system. In this regard, the Nacto Urban Street Design Guide helps to plan and design sustainable urban transportation system.
- The special arrangement of the Addis Ababa City should be changed by constructing high rise apartments in central areas and some institutions near the residential areas
- Finally, each transportation planner and service provider should use modern intelligent transportation system during planning, operation and analysis of the transportation service.

## **CHAPTER SIX**

### **PROPOSED FUTURE RESEARCH AREAS**

The research points out the following areas of study for further research:

- The HCM and TCQSM were utilized in the thresholds for LOS analysis. This manual was developed using the traffic condition and travel behavior in the United States of America. Therefore, to reflect the traffic condition and travel behavior of Addis Ababa, the LOS thresholds, equation and procedures should be calibrated to local conditions.
- Evaluation of quality of service for other types of bus transit operators; a study on the Addis Ababa LRT and pedestrians should be conducted by specifically developing a Standard LOS framework.
- This study evaluated the quality of service on public transportation only for limited service quality indicators. Therefore, it is also important to evaluate quality of service for other indicators such as: on time performance; customer satisfaction; service coverage and transit /Auto travel time.

## REFERENCES

- Abreha, D. Abate (2007). Analysing Public Transport Performance using Efficiency Measures and Spatial Analysis; the case of Addis Ababa, Ethiopia.
- Addis Ababa City Administration Transport Authority (AACATA) (2017). Waiting Time to get Public Transportation service at Public Transport Terminals and Survey to Identify related problems, Addis Ababa, Ethiopia.
- Addis Ababa City Roads Authority (AACRA) (2016), Addis Ababa Draft Road Network – AutoCAD Drawing on June 2016, Addis Ababa, Ethiopia.
- Beirão, G. & Sarsfield Cabral, J.A. (2007). Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy*, 14 (6), 478-489.
- Botswana Roads Department (2004), Traffic Data Collection and Analysis ISBN 99912 - 0 - 417 - 2, Ministry of Works and Transport, Gaborone, Botswana.
- Dorina Pojani 1,\* and Dominic Stead 2,\*(2015) “Sustainable Urban Transport in the Developing World: Beyond Megacities” *Sustainability* **2015**, 7, page 7784-7805; doi: 10.3390/su7067784.
- Dowling, R., Reinke, D., Flannery, A., Ryus, P., Vandehay, M., Petritsch, T.,...Bonneson, J.(2008a). Multimodal level of service analysis for urban streets (NCHRP Report 616, pp. 1-55). Washington, DC: TRB.
- Dr. Jean-Paul Rodrigue, Dept. of Global Studies & Geography , Hofstra University, New York, USA. Retrieved from:[https:// people.hofstra.edu/geotrans/eng/ch6en/conc6en/ch6c4en](https://people.hofstra.edu/geotrans/eng/ch6en/conc6en/ch6c4en). cited in Dennis Jhave C. Edano. (2014). Urban transport problem November 21, 2014
- Eboli, L., Mazzulla, G. (2008) “An SP Experiment for Measuring Service Quality in Public Transport”, *Transportation Planning and Technology* 31 (5), pp. 509-523.
- Eboli, L., Mazzulla, G. (2009) A New Customer Satisfaction Index for Evaluating Transit Service Quality. *Journal of Public Transportation*, Vol. 12, No. 3, 2009.
- Eboli, L., Mazzulla, G. (2011) “A methodology for evaluating transit service quality based on subjective and objective measures from the passenger’s point of view”, *Transport Policy* 18 (1), pp. 172-181.

- Eboli, L. & Mazzulla, G. (2012) “Performance indicators for an objective measure of public transport service quality”, *European Transport* \ Issue 51, Paper n° 3, ISSN 1825-3997.
- Edvarsson, B. (1998). Causes of customer dissatisfaction - Studies of public transport by critical incident method. *Managing Service Quality*, 8 (3), 189-197.
- Eshete, M. (2015). Public Transportation System: The case of Addis Ababa.
- Friman, M. & Gärling, T. (2001). Frequency of negative critical incidents and satisfaction with public transport services. II. *Journal of Retailing and Consumer Services*, 8 (2), 105-114.
- Gang-Len Chang and Hani S. Mahmassani, (1988) “Travel Time Prediction and Departure Time Adjustment Behavior Dynamics in a Congested Traffic System,” *Transportation Research Part B: Methodological* 22, no. 3 (1988): 217–232.
- Gris Orange Consultant (2012). Improving bus system modest investment to increase transit ridership. TP 15183E ISBN: 978-1-100-20402-4 Catalogue No.: T42-8/2012E-PDF
- Hill N, Brierley G, MacDougall R. (2003) *How to Measure Customer Satisfaction*. Gower Publishing, Hampshire.
- History of Addis Ababa. (n.d.). In Wikipedia. Retrieved August 21, 2017 from [https://upload.wikimedia.org/wikipedia/commons/1/14/Addis\\_Abeba\\_montage\\_1](https://upload.wikimedia.org/wikipedia/commons/1/14/Addis_Abeba_montage_1).
- Juan de Oña and Rocio de Oña ( in press) Quality of service in public transport based on customer satisfaction surveys: A review and assessment of methodological approaches. *Transportation Science*, DOI:10.1287/trsc.2014.0544
- Kittelson & Associates, Inc.; KFH Group, Inc.; Parsons Brinckerhoff Quade & Douglass, Inc.; and K. Hunter-Zaworski. TCRP Report 100: Transit Capacity and Quality of Service Manual, 2nd Edition. Transportation Research Board. Washington, D.C., 2003 .
- Kittelson & Associates, Inc., KFH Group, Inc., Parsons Brinckerhoff Quade & Douglass, Inc., and K. Hunter-Zaworski. TCRP Report 165: Transit Capacity and Quality of Service Manual, 3<sup>rd</sup> ed. Transportation Research Board. Washington, D.C., 2013.
- Landis, B., et al. “Modeling the Roadside Walking Environment: Pedestrian LOS,” *Transportation Research Record* 1773, Transportation Research Board, Washington, DC (2001).

- Meead Saberi and Ali Zockaie. (2013). Definition and Properties of Alternative Bus Service Reliability Measures at the Stop Level. *Journal of Public Transportation*, Vol. 16, No. 1, 2013
- Mekonnen. M. (2010). Assessment of Customer Satisfaction in Transportation Service Delivery: The Case of Three Terminals of Anbassa City Bus Service Enterprise.
- Meron. K (2007). Public transportation system and its impact on urban mobility: The case of Addis Ababa. M.Sc. thesis.
- Meshesha, Telahun (2014) Demands for Urban Public Transportation in Addis Ababa *Journal of Intelligent Transportation and Urban Planning*
- Mihelis, A., E. Grigoroudis, Y. Siskos, Y. Politis and Y. Malandrakis, 2001. Customer satisfaction measurement in the private bank sector.
- Monzon A, Hernandez S, Cascajo R, (2013). Quality of Bus Services Performance: Benefits of Real Time Passenger Information Systems: Transport Research Centre (TRANSyT), Universidad Politécnica de Madrid.
- National Association of City Transportation Officials (NACTO) (2013), *Urban Street Design Guide*. Washington, DC: Island Press, 2013.
- Parasuraman A, Zeithaml VA, Berry LL. (1988) SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing*, 64(1), 12-40.
- P. K. Bhuyan & Minakshi Sheshadri Nayak (2013): A Review on Level of Service Analysis of Urban Streets, *Transport Reviews: A Transnational Transdisciplinary Journal*, 33:2, 219-238.
- Ranawana and Hewage.(2015) “Factors Affecting Service Quality in Public Bus Transportation in Sri Lanka” *Proceedings of 8th International Research Conference, KDU*,
- Shanghai Manual (2010), Chapter 4 - Sustainable Urban Transport – a Guide for Sustainable Urban Development in the 21st Century, Shanghai, China (P.2)
- Sheger Bus banner (2016). Sheger Mass Transport Enterprise Exhibition from May 26 up to May 28, Addis Ababa, Ethiopia.
- Stephen Arhin, Errol C. Noel, (2013) Evaluation of Bus Transit Reliability in the District of Columbia, Form DOT F 1700.7 (8-72)

- Transport Mode “n.d” Urban public transport modes: SARB chair of transportation Engineering. University of Peritoria. SVC31005, PP. 6-11
- Transportation Research Board – TRB (2000), Highway Capacity Manual (HCM), National Research Council, Washington D.C., U.S.A.
- Tilahun Meshesha Fenta (2014) Demands for Urban Public Transportation in Addis Ababa Journal of Intelligent Transportation and Urban Planning, Vol, 2 Iss. 3, PP. 81 – 88, July 2014.
- UK Department for Transport (2003). Understanding customer needs. United Kingdom:
- UN-Habitat (2013). Planning and Design of Sustainable Urban mobility. Global report on human settlement.
- Urban Infrastructure. (2015). Urban Infrastructure in Sub-Saharan Africa – Harnessing Land Values, Housing and Transport. Literature review on public transport Report 4. Pp.8-11.
- Verma Meghna; Verma Ashish; P. Ajith; Sindhe Sneha, (2013). Urban Bus Transport Service Quality and Sustainable Development: Understanding the Gaps, Jul. 2014, Vol. 2 Iss. 3, PP. 81-88
- Vuchic, V., (2005). Urban transit: Operations, Planning and Economics. John Wiley & Sons, New York.
- Y. Xin, L. Fu, and F. Saccomanno (2005). “Assessing Transit Level of Service along Travel Corridors Using TCQSM – A Case Study.” Presented at the Transportation Research Board Annual Meeting, Washington, DC (2005).
- Yetnayet Ayalneh (2012). Evaluating Transport Network Structure: Case Study in Addis Ababa, University of Twente, Netherlands.



*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex- B:1 Outside lane motorized traffic volume for the Route 1</b>																
<b>DAY ONE</b>																
Segment ID	Morning Peak hour period							Segment ID	Morning Peak hour period							
	Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total		Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total	
SM 1	5	9	385	20	21	8	507	SM 1	3	4	127	7	5	3	165	
SM 2	3	8	305	18	16	7	407	SM 2	2	5	147	8	7	4	195	
SM 3	5	10	491	30	24	8	641	SM 3	3	4	186	11	9	3	242	
SM 4	4	16	539	35	30	5	708	SM 4	3	7	251	15	14	2	326	
SM 5	3	27	808	68	29	16	1079	SM 5	4	27	745	47	33	15	981	
SM 6	0	54	913	76	40	13	1231	SM 6	1	41	819	54	41	16	1098	
SM 7	2	38	699	54	31	11	937	SM 7	1	12	211	16	10	4	286	
SM 8	2	19	272	18	14	4	365	SM 8	3	14	198	13	11	3	268	
MS 1	2	24	390	25	19	5	515	MS 1	4	29	474	31	23	6	627	
MS 2	1	32	529	38	29	5	709	MS 2	2	41	707	45	38	7	934	
MS 3	1	45	705	46	33	9	929	MS 3	3	47	993	61	44	12	1285	
MS 4	7	19	265	18	15	4	361	MS 4	7	18	265	18	13	4	356	
MS 5	5	14	187	9	10	3	247	MS 5	5	21	273	14	15	5	365	
MS 6	4	8	430	24	22	5	553	MS 6	3	7	305	17	16	4	395	
MS 7	5	5	204	11	10	4	267	MS 7	7	8	254	14	13	5	335	
MS 8	3	5	226	13	11	5	298	MS 8	4	5	204	12	11	5	274	
MS 9	3	7	95	3	5	2	124	MS 9	8	13	148	5	8	4	198	
<b>Day Two</b>																
Segment ID	Morning Peak hour period							Segment ID	Morning Peak hour period							
	Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total		Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total	
SM 1	5	9	405	20	21	8	527	SM 1	1	3	115	6	7	3	155	
SM 2	3	8	335	19	19	8	449	SM 2	2	4	155	10	9	4	212	
SM 3	5	9	450	25	21	7	579	SM 3	2	4	182	11	9	3	238	
SM 4	4	17	562	36	31	5	736	SM 4	2	8	222	14	13	3	296	
SM 5	3	27	796	45	38	16	1043	SM 5	3	27	782	44	36	15	1019	
SM 6	1	49	878	55	43	13	1159	SM 6	1	41	770	49	37	11	1014	
SM 7	2	34	627	45	33	10	847	SM 7	1	12	222	17	12	4	304	
SM 8	3	22	288	19	17	5	395	SM 8	2	14	181	12	11	4	252	
MS 1	2	24	400	25	19	5	525	MS 1	3	29	486	30	24	6	639	
MS 2	1	30	490	35	26	5	655	MS 2	2	41	688	48	36	7	916	
MS 3	1	44	692	45	32	9	911	MS 3	1	55	946	59	43	12	1235	
MS 4	8	22	294	19	17	4	399	MS 4	7	21	264	18	16	4	364	
MS 5	5	14	173	9	10	3	233	MS 5	8	25	297	16	18	5	403	
MS 6	4	9	457	25	24	5	587	MS 6	4	6	282	16	14	4	365	
MS 7	8	10	403	21	19	8	523	MS 7	5	7	264	15	13	6	349	
MS 8	4	5	242	13	13	6	322	MS 8	3	7	222	14	12	6	302	
MS 9	5	7	85	4	5	2	116	MS 9	8	12	138	7	9	4	194	

## Annex- B:2 Outside lane motorized traffic volume for the Route 2

### DAY ONE

Segment ID	Morning Peak hour period							Segment ID	Morning Peak hour period						
	Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total		Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total
MJ 1	4	8	84	7	6	2	124	MJ 1	7	18	187	14	13	5	273
MJ 2	5	14	255	21	16	4	357	MJ 2	4	12	247	19	15	4	341
MJ 3	6	15	206	15	12	5	290	MJ 3	7	18	241	17	15	6	341
MJ 4	3	9	121	7	10	9	192	MJ 4	6	15	230	12	19	15	355
MJ 5	5	12	119	9	9	6	185	MJ 5	6	15	148	9	11	7	223
MJ 6	5	16	226	18	14	8	330	MJ 6	5	17	235	18	15	9	345
MJ 7	4	21	188	15	10	7	275	MJ 7	3	23	218	16	12	8	316
MJ 8	5	9	111	9	9	7	178	MJ 8	6	12	144	11	12	9	230
JM 1	2	14	235	15	12	6	320	JM 1	2	8	140	8	7	4	190
JM 2	0	15	176	14	12	5	257	JM 2	4	15	188	13	13	6	273
JM 3	2	11	172	13	10	5	244	JM 3	3	14	220	16	13	6	310
JM 4	3	25	294	19	15	7	404	JM 4	2	10	117	7	7	3	163
JM 5	5	17	254	20	14	5	354	JM 5	3	9	144	10	8	3	198
JM 6	6	22	292	17	15	5	391	JM 6	4	12	154	9	8	3	208
JM 7	4	18	321	21	17	3	424	JM 7	3	11	177	11	9	2	234
JM 8	7	19	318	22	18	4	430	JM 8	5	15	245	16	15	4	335
Day Two															
Segment ID	Morning Peak hour period							Segment ID	Morning Peak hour period						
	Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total		Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total
MJ 1	4	7	74	7	7	2	116	MJ 1	9	17	183	17	18	5	287
MJ 2	5	16	276	21	16	4	379	MJ 2	5	15	259	19	15	4	355
MJ 3	5	13	186	13	11	5	262	MJ 3	6	15	220	15	13	6	309
MJ 4	3	9	130	7	8	9	196	MJ 4	5	16	231	12	14	16	347
MJ 5	5	15	110	9	9	6	177	MJ 5	7	19	146	13	12	8	237
MJ 6	5	17	243	18	15	8	350	MJ 6	5	18	254	19	15	9	367
MJ 7	3	20	184	14	10	7	269	MJ 7	3	24	117	17	13	9	223
MJ 8	6	9	122	9	10	7	192	MJ 8	6	9	133	10	11	8	210
JM 1	2	13	215	13	12	6	296	JM 1	2	9	131	9	8	4	186
JM 2	1	15	180	14	13	5	263	JM 2	2	15	189	16	15	6	284
JM 3	2	9	173	11	10	5	240	JM 3	2	11	202	12	12	6	280
JM 4	3	28	327	19	17	8	446	JM 4	1	8	111	7	6	3	153
JM 5	4	16	234	18	13	5	326	JM 5	3	9	140	10	8	3	194
JM 6	5	21	273	16	15	5	369	JM 6	3	13	162	9	10	4	224
JM 7	4	17	319	18	17	3	416	JM 7	2	9	172	10	10	2	228
JM 8	7	20	346	23	19	5	466	JM 8	4	14	234	15	14	4	319

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

**Annex- B: 3 Outside lane motorized traffic volume for the Route 3**

DAY ONE																
Segment ID	Morning Peak hour period							Segment ID	Morning Peak hour period							
	Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total		Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total	
PS 1	3	15	293	19	16	4	391	PS 1	3	15	280	18	16	4	376	
PS 2	3	19	362	23	16	5	473	PS 2	4	19	363	22	17	5	475	
PS 3	5	23	497	37	26	7	670	PS 3	3	17	361	26	20	6	490	
PS 4	4	29	406	32	21	5	553	PS 4	4	29	405	31	21	5	550	
PS 5	6	21	406	23	19	4	523	PS 5	5	20	371	19	18	4	477	
PS6	3	13	162	11	9	2	220	PS6	2	6	79	6	5	2	113	
PS 7	5	12	161	13	10	3	228	PS 7	3	7	92	8	6	2	133	
PS 8	4	15	178	11	12	3	247	PS 8	3	8	101	7	7	3	146	
PS 9	5	13	195	13	10	2	260	PS 9	4	12	148	10	8	2	201	
PS 10	6	9	186	12	9	2	244	PS 10	5	9	143	10	7	2	192	
PS 11	5	12	153	10	9	3	212	PS 11	7	17	203	13	12	4	281	
PS 12	7	15	161	12	12	2	230	PS 12	8	18	197	14	15	3	282	
SP 1	4	9	138	11	10	2	196	SP 1	3	7	100	8	8	2	146	
SP 2	5	11	186	11	9	1	240	SP 2	3	8	134	7	7	1	173	
SP 3	5	13	168	9	11	2	227	SP 3	3	10	122	7	9	3	173	
SP 4	3	16	201	14	13	3	279	SP 4	3	13	147	10	10	4	211	
SP 5	5	18	203	13	14	3	283	SP 5	5	16	164	11	12	4	237	
SP 6	6	21	230	13	13	4	312	SP 6	6	20	197	10	12	5	273	
SP 7	7	22	236	14	12	4	318	SP 7	7	15	146	8	8	3	200	
SP 8	6	19	329	19	19	5	440	SP 8	3	11	167	9	10	4	228	
SP 9	5	18	321	21	18	6	436	SP 9	5	19	338	21	19	7	459	
SP 10	8	21	357	19	19	5	470	SP 10	7	20	327	16	17	5	428	
SP 11	3	16	220	18	17	3	316	SP 11	5	16	221	17	18	4	321	
SP 12	6	13	154	13	9	2	216	SP 12	8	17	202	15	12	3	281	
DAY TWO																
Segment ID	Morning Peak hour period							Segment ID	Morning Peak hour period							
	Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total		Bicycle	M/Cycle	Car	Small Truck	Medium Truck	Heavy Truck	Total	
PS 1	3	14	288	17	15	4	379	PS 1	3	15	304	18	16	4	400	
PS 2	3	22	391	22	17	6	507	PS 2	3	22	379	22	17	6	495	
PS 3	5	14	313	17	14	4	402	PS 3	4	18	399	28	20	5	530	
PS 4	4	31	427	29	21	5	569	PS 4	3	27	372	26	18	5	498	
PS 5	5	22	398	20	18	4	507	PS 5	5	22	378	20	18	4	487	
PS6	3	13	168	11	10	2	228	PS6	2	6	83	6	5	2	117	
PS 7	5	13	162	13	11	3	232	PS 7	3	7	92	7	6	2	131	
PS 8	4	15	175	10	10	3	237	PS 8	3	8	112	6	7	2	152	
PS 9	3	9	135	9	8	2	184	PS 9	4	10	146	11	9	3	205	
PS 10	5	9	170	11	9	2	226	PS 10	4	7	136	9	8	2	184	
PS 11	5	14	153	11	10	4	220	PS 11	5	16	175	13	12	5	255	
PS 12	6	14	148	12	12	2	216	PS 12	7	17	204	15	14	3	288	
SP 1	4	8	144	13	13	3	216	SP 1	2	5	91	7	8	2	134	
SP 2	4	10	183	11	9	1	236	SP 2	3	9	1142	9	8	2	1191	
SP 3	5	15	190	10	11	3	255	SP 3	3	10	121	7	7	3	167	
SP 4	3	15	184	13	12	3	257	SP 4	2	11	145	11	10	3	207	
SP 5	5	17	207	12	11	3	277	SP 5	4	13	156	10	9	3	215	
SP 6	5	20	201	11	12	4	276	SP 6	5	20	199	11	12	4	274	
SP 7	7	24	238	14	13	4	324	SP 7	4	16	160	10	9	3	220	
SP 8	6	19	313	19	18	5	422	SP 8	3	11	170	11	10	3	232	
SP 9	5	19	326	21	19	6	444	SP 9	4	18	302	20	18	6	415	
SP 10	7	21	336	17	18	5	442	SP 10	6	19	312	16	17	5	412	
SP 11	3	16	243	18	17	4	342	SP 11	3	16	243	19	17	5	347	
SP 12	6	12	150	12	10	2	212	SP 12	6	15	195	15	13	3	275	

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:1 Input and results of existing transit LOS for Route from Shiromeda to Mexico</b>								
<b>Multimodal Transit LOS Calculation</b>								
<b>Morning peak hour period</b>								
<b>Segment ID</b>								
<b>Inputs</b>	SM 1	SM 2	SM 3	SM 4	SM 5	SM 6	SM 7	SM 8
<b>TRANSIT OPERATIONS INFORMATION</b>								
Number of local buses on street segment per hour (bus/h)	5	5	5	5	5	5	5	5
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	4.22	4.40	4.40	4.75	4.75	5.20	5.64	7.52
$L_f$ Average passenger load factor (p/seat)	1.45	1.78	1.78	1.38	1.38	0.83	0.50	0.50
$S$ Average transit travel speed (mi/h)	15	7	5	4	23	7	3	4
$l_{pt}$ Average passenger trip length (mi)	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>								
$p_{sh}$ Percent stops in segment with a shelter	100%	100%	100%	0%	0%	0%	0%	0%
$p_{be}$ Percent stops in segment with a bench	100%	100%	100%	0%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>								
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	11.5	13.12	11.48	9.84	14.76	34.44	11.48	9.84
$W_{bu}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No
$p_{pk}$ Proportion of on-street parking occupied	3%	3%	7%	3%	0%	0%	5%	5%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	11.5	11.48	11.48	11.48	11.48	11.48	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	517	428	610	723	1062	1195	892	380
Average vehicle running speed, including intersection delay								
$S_R$ (mi/h)	15	7	5	4	23	7	2.909	4
<b>Calculations</b>								
$f$ Transit frequency (bus/h)	5	5	5	5	5	5	5	5
$f_h$ Headway factor	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
$f_{pl}$ Passenger load weighting factor	2.07	2.60	2.60	1.94	1.94	1.02	1.00	1.00
$T_{at}$ Perceived amenity time rate (min/mi)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	1.3	1.4	1.4	1.5	1.5	1.7	1.8	2.4
$T_{ptt}$ Perceived travel time rate (min/mi)	10.6	23.2	36.5	35.3	8.1	11.7	24.2	21.0
$T_{bt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.69	0.56	0.51	0.52	0.76	0.67	0.55	0.57
$s_{w-r}$ Transit wait-ride score	2.09	1.68	1.54	1.55	2.29	2.02	1.67	1.72
$f_s$ Motorized vehicle speed adjustment factor	0.09	0.02	0.01	0.01	0.21	0.02	0.00	0.01
$f_v$ Motorized vehicle volume adjustment factor	1.18	0.97	1.39	1.64	2.42	2.72	2.03	0.86
$W_{aa}$ Adjusted available sidewalk width (ft)	10.0	10.0	10.0	9.8	10.0	10.0	10.0	9.8
$f_{sw}$ Sidewalk width coefficient	3.00	3.00	3.00	3.05	3.00	3.00	3.00	3.05
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Total width of outside lane, bike lane, and parking lane/shoulder								
$W_t$ (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8
$W_v$ Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8
$W_1$ Effective width of combined bike lane and shoulder (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-4.62	-4.62	-4.67	-4.62	-4.57	-4.57	-4.60	-4.60
$I_p$ Pedestrian environment score	2.70	2.43	2.77	3.08	4.10	4.21	3.48	2.32
Pedestrian LOS	B	B	C	C	D	D	C	B
$I_t$ Transit LOS score	3.28	3.84	4.10	4.13	3.18	3.60	4.02	3.77
<b>Output</b>								
<b>Transit LOS</b>	<b>C</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>C</b>	<b>D</b>	<b>D</b>	<b>D</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:2 Input and results of improved transit LOS for Route from Shiromeda to Mexico</b>												
<b>Multimodal Transit LOS Calculation</b>					<b>Morning peak hour period</b>							
					<b>Segment ID</b>							
<b>Inputs</b>					<b>SM 1</b>	<b>SM 2</b>	<b>SM 3</b>	<b>SM 4</b>	<b>SM 5</b>	<b>SM 6</b>	<b>SM 7</b>	<b>SM 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>												
	Number of local buses on street segment per hour	8	8	8	8	8	8	8	8			
	Number of express buses stopping in segment per hour	0	0	0	0	0	0	0	0			
$t_{ex}$	Average excess wait time (min)	5.72	5.90	5.90	6.25	6.25	6.70	7.14	9.02			
$L_r$	Average passenger load factor (p/seat)	0.91	1.11	1.11	0.86	0.86	0.52	0.31	0.31			
$S$	Average transit travel speed (mi/h)	16	16	16	16	23	16	16	16			
$l_{pt}$	Average passenger trip length (mi)	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14			
	Is the segment in the CBD of a metro area of 5 million	No	No	No	No	No	No	No	No			
<b>TRANSIT AMENITY DATA</b>												
$p_{sh}$	Percent stops in segment with a shelter	100%	100%	100%	0%	0%	0%	0%	0%			
$p_{bc}$	Percent stops in segment with a bench	100%	100%	100%	0%	0%	0%	0%	0%			
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	13.12	11.48	9.84	14.76	34.44	11.48	9.84			
$W_{buf}$	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
	Does a continuous barrier exist between the street and Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes			
	Are parking spaces striped?	No	No	No	No	No	No	No	No			
$p_{pk}$	Proportion of on-street parking occupied	3%	3%	7%	3%	0%	0%	5%	5%			
$W_{bl}$	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
$W_{os}$	Shoulder/parking lane width (ft)	9.8	0.0	0.0	0.0	0.0	0.0	9.8	9.8			
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)	11.48	11.48	11.48	11.48	11.48	11.48	9.84	9.84			
$v_m$	Outside lane demand flow rate at midsegment (veh/h)	517	428	610	723	1062	1195	892	380			
	Average vehicle running speed, including intersection											
$S_R$	delay (mi/h)	15	7	5	4	23	7	2.909	4			
<b>Calculations</b>												
$f$	Transit frequency (bus/h)	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00			
$f_h$	Headway factor	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34			
$f_{pl}$	Passenger load weighting factor	2.1	2.6	2.6	1.9	1.9	1.0	1.0	1.0			
$T_{at}$	Perceived amenity time rate (min/mi)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0			
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)	1.8	1.9	1.9	2.0	2.0	2.1	2.3	2.9			
$T_{ptt}$	Perceived travel time rate (min/mi)	10.9	13.0	13.0	11.3	9.0	8.1	8.3	9.5			
$T_{btt}$	Base travel time rate (min/mi)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00			
$f_{tt}$	Perceived travel time factor	0.69	0.65	0.65	0.68	0.73	0.76	0.75	0.72			
$s_{w-r}$	Transit wait-ride score	2.30	2.17	2.17	2.27	2.45	2.54	2.52	2.41			
$f_s$	Motorized vehicle speed adjustment factor	0.09	0.02	0.01	0.01	0.21	0.02	0.00	0.01			
$f_v$	Motorized vehicle volume adjustment factor	1.2	1.0	1.4	1.6	2.4	2.7	2.0	0.9			
$W_{aA}$	Adjusted available sidewalk width (ft)	10.00	10.00	10.00	9.84	10.00	10.00	10.00	9.84			
$f_{sw}$	Sidewalk width coefficient	3.00	3.00	3.00	3.05	3.00	3.00	3.00	3.05			
$f_b$	Buffer area coefficient	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4			
	Total width of outside lane, bike lane, and parking											
$W_t$	lane/shoulder (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8			
$W_v$	Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8			
$W_l$	Effective width of combined bike lane and shoulder (ft)	9.84	0.00	0.00	0.00	0.00	0.00	9.84	9.84			
$f_w$	Cross-section adjustment factor	-4.75	-4.62	-4.67	-4.62	-4.57	-4.57	-4.73	-4.73			
$I_p$	Pedestrian environment score	2.56	2.43	2.77	3.08	4.10	4.21	3.35	2.18			
	Pedestrian LOS	B	B	C	C	D	D	C	B			
$I_t$	Transit LOS score	3	3.104	3.156	3.05	2.941	2.815	2.717	2.717			
<b>Output</b>												
	<b>Transit LOS</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>B</b>	<b>B</b>			

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:3 Input and results of existing transit LOS for Route from Shiromeda to Mexico</b>									
<b>Multimodal Transit LOS Calculation</b>					<b>Afternoon peak hour period</b>				
<b>Segment ID</b>									
<b>Inputs</b>	SM 1	SM 2	SM 3	SM 4	SM 5	SM 6	SM 7	SM 8	
<b>TRANSIT OPERATIONS INFORMATION</b>									
Number of local buses on street segment per hour (bus/h)	5	5	5	5	5	5	5	5	5
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0
t <sub>ex</sub> Average excess wait time (min)	8.74	8.12	8.12	8.18	8.18	7.95	8.41	8.65	
L <sub>r</sub> Average passenger load factor (p/seat)	1.33	1.63	1.63	1.38	1.38	1.08	0.65	0.65	
S Average transit travel speed (mi/h)	14	9	4	6	16	8	8	5	
l <sub>pt</sub> Average passenger trip length (mi)	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	
<b>TRANSIT AMENITY DATA</b>									
p <sub>sh</sub> Percent stops in segment with a shelter	100%	100%	100%	0%	0%	0%	0%	0%	
p <sub>be</sub> Percent stops in segment with a bench	100%	100%	100%	0%	0%	0%	0%	0%	
<b>PEDESTRIAN ENVIRONMENT DATA</b>									
W <sub>A</sub> Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	13.12	11.48	9.84	14.76	26.24	11.48	9.84	
W <sub>buf</sub> Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Are parking spaces striped?	No	No	No	No	No	No	No	No	
p <sub>pk</sub> Proportion of on-street parking occupied	2%	0%	0%	0%	0%	4%	22%	19%	
W <sub>bl</sub> Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
W <sub>os</sub> Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
W <sub>ol</sub> Outside travel lane (closest to sidewalk) width (ft)	11.48	11.48	11.48	11.48	11.48	11.48	9.84	9.84	
v <sub>m</sub> Outside lane demand flow rate at midsegment (veh/h)	160	205	240	310	1000	1056	295	260	
Average vehicle running speed, including intersection delay									
S <sub>R</sub> (mi/h)	14	9	4	6	16	8	8.0157	5	
<b>Calculations</b>									
f Transit frequency (bus/h)	5	5	5	5	5	5	5	5	
f <sub>h</sub> Headway factor	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
f <sub>pt</sub> Passenger load weighting factor	1.85	2.36	2.36	1.94	1.94	1.36	1.00	1.00	
T <sub>at</sub> Perceived amenity time rate (min/mi)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	
T <sub>ex</sub> Excess wait time rate due to late arrivals (min/mi)	2.7	2.5	2.5	2.5	2.5	2.5	2.6	2.7	
T <sub>ptt</sub> Perceived travel time rate (min/mi)	12.9	21.0	37.3	25.1	12.5	15.2	12.7	18.6	
T <sub>bt</sub> Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	
f <sub>tt</sub> Perceived travel time factor	0.65	0.57	0.51	0.55	0.66	0.62	0.66	0.59	
s <sub>w-r</sub> Transit wait-ride score	1.96	1.72	1.54	1.65	1.98	1.87	1.97	1.77	
f <sub>s</sub> Motorized vehicle speed adjustment factor	0.08	0.03	0.01	0.01	0.10	0.03	0.03	0.01	
f <sub>v</sub> Motorized vehicle volume adjustment factor	0.36	0.47	0.55	0.71	2.28	2.40	0.67	0.59	
W <sub>aa</sub> Adjusted available sidewalk width (ft)	10.0	10.0	10.0	9.8	10.0	10.0	10.0	9.8	
f <sub>sw</sub> Sidewalk width coefficient	3.00	3.00	3.00	3.05	3.00	3.00	3.00	3.05	
f <sub>b</sub> Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	
Total width of outside lane, bike lane, and parking lane/shoulder									
W <sub>i</sub> (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8	
W <sub>v</sub> Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8	
W <sub>l</sub> Effective width of combined bike lane and shoulder (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
f <sub>w</sub> Cross-section adjustment factor	-4.60	-4.57	-4.57	-4.57	-4.57	-4.63	-4.82	-4.79	
I <sub>p</sub> Pedestrian environment score	1.89	1.97	2.03	2.19	3.85	3.84	1.92	1.86	
Pedestrian LOS	A	A	B	B	D	D	A	A	
I <sub>t</sub> Transit LOS score	3.35	3.72	4.00	3.85	3.61	3.77	3.34	3.63	
<b>Output</b>									
Transit LOS	<b>C</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>C</b>	<b>D</b>	

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:4 Input and results of improved transit LOS for Route from Shiromeda to Mexico</b>								
<b>Multimodal Transit LOS Calculation</b>				<b>Afternoon peak hour period</b>				
				<b>Segment ID</b>				
<b>Inputs</b>	<b>SM 1</b>	<b>SM 2</b>	<b>SM 3</b>	<b>SM 4</b>	<b>SM 5</b>	<b>SM 6</b>	<b>SM 7</b>	<b>SM 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>								
Number of local buses on street segment per hour (bus/h)	8	8	8	8	8	8	8	8
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	8.74	8.12	8.12	8.18	8.18	7.95	8.41	8.65
$L_f$ Average passenger load factor (p/seat)	0.83	1.02	1.02	0.86	0.86	0.67	0.41	0.41
$S$ Average transit travel speed (mi/h)	16	16	16	16	16	16	16	16
$l_{pt}$ Average passenger trip length (mi)	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>								
$P_{sh}$ Percent stops in segment with a shelter	100%	100%	100%	0%	0%	0%	0%	0%
$P_{be}$ Percent stops in segment with a bench	100%	100%	100%	0%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>								
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	13.12	11.48	9.84	14.76	26.24	11.48	9.84
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No
$P_{pk}$ Proportion of on-street parking occupied	2%	0%	0%	0%	0%	4%	22%	19%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	9.8	0.0	0.0	0.0	0.0	0.0	9.8	9.8
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	11.48	11.48	11.48	11.48	11.48	11.48	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	160	205	240	310	1000	1056	295	260
$S_R$ Average vehicle running speed, including intersection delay (mi/h)	14	9	4	6	16	8	8	5
<b>Calculations</b>								
$f$ Transit frequency (bus/h)	8	8	8	8	8	8	8	8
$f_h$ Headway factor	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34
$f_{pl}$ Passenger load weighting factor	1.85	2.36	2.36	1.94	1.94	1.36	1.00	1.00
$T_{at}$ Perceived amenity time rate (min/mi)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	2.7	2.5	2.5	2.5	2.5	2.5	2.6	2.7
$T_{ptt}$ Perceived travel time rate (min/mi)	11.9	13.4	13.4	12.3	12.3	10.0	9.0	9.1
$T_{bit}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.67	0.64	0.64	0.66	0.66	0.71	0.73	0.73
$S_{w-r}$ Transit wait-ride score	2.24	2.15	2.15	2.21	2.21	2.36	2.46	2.44
$f_s$ Motorized vehicle speed adjustment factor	0.08	0.03	0.01	0.01	0.10	0.03	0.03	0.01
$f_v$ Motorized vehicle volume adjustment factor	0.36	0.47	0.55	0.71	2.28	2.40	0.67	0.59
$W_{aA}$ Adjusted available sidewalk width (ft)	10.0	10.0	10.0	9.8	10.0	10.0	10.0	9.8
$f_{sw}$ Sidewalk width coefficient	3.00	3.00	3.00	3.05	3.00	3.00	3.00	3.05
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
$W_t$ Total width of outside lane, bike lane, and parking lane/shoulder (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8
$W_v$ Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	11.5	9.8	9.8
$W_l$ Effective width of combined bike lane and shoulder (ft)	9.8	0.0	0.0	0.0	0.0	0.0	9.8	9.8
$f_w$ Cross-section adjustment factor	-4.74	-4.57	-4.57	-4.57	-4.57	-4.63	-4.94	-4.90
$I_p$ Pedestrian environment score	1.75	1.97	2.03	2.19	3.85	3.84	1.81	1.74
Pedestrian LOS	A	A	B	B	D	D	A	A
$I_t$ Transit LOS score	2.91	3.06	3.07	3.01	3.26	3.03	2.59	2.60
<b>Output</b>								
<b>Transit LOS</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>B</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:5 Input and results of existing transit LOS for Route from Mexico to Shiromeda</b>									
<b>Multimodal Transit LOS Calculation</b>					<b>Morning peak hour period</b>				
<b>Segment ID</b>									
<b>Inputs</b>	<b>MS 1</b>	<b>MS 2</b>	<b>MS 3</b>	<b>MS 4</b>	<b>MS 5</b>	<b>MS 6</b>	<b>MS 7</b>	<b>MS 8</b>	<b>MS 9</b>
<b>TRANSIT OPERATIONS INFORMATION</b>									
Number of local buses on street segment per hour (bus/h)	5	5	5	5	5	5	5	5	5
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	8.63	8.63	7.76	7.76	8.27	8.27	8.53	8.78	8.79
$L_f$ Average passenger load factor (p/seat)	1.30	1.30	1.30	1.73	1.73	1.53	1.53	0.78	0.70
$S$ Average transit travel speed (mi/h)	7	15	7	14	13	5	13	18	14
$l_{pt}$ Average passenger trip length (mi)	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>									
$p_{sh}$ Percent stops in segment with a shelter	0%	0%	100%	0%	0%	100%	0%	100%	100%
$p_{be}$ Percent stops in segment with a bench	0%	0%	100%	0%	0%	100%	100%	100%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>									
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	9.84	9.84	26.24	31.16	14.76	9.84	11.48	13.12	11.48
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No	No
$p_{pk}$ Proportion of on-street parking occupied	6%	8%	0%	0%	0%	5%	3%	2%	3%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	9.84	9.84	11.48	11.48	11.48	11.48	11.48	11.48	11.48
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	520	682	920	380	240	570	260	310	120
$S_R$ Average vehicle running speed, including intersection delay (mi/h)	7	15	7	14	13	5	13.4216	18	14
<b>Calculations</b>									
$f$ Transit frequency (bus/h)	5	5	5	5	5	5	5	5	5
$f_h$ Headway factor	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
$f_{pl}$ Passenger load weighting factor	1.81	1.81	1.81	2.52	2.52	2.20	2.20	1.00	1.00
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.5	0.0	0.0	0.5	0.1	0.5	0.5
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	2.7	2.7	2.4	2.4	2.6	2.6	2.7	2.8	2.8
$T_{ptt}$ Perceived travel time rate (min/mi)	20.3	12.5	20.7	15.4	16.7	30.5	15.1	8.3	9.4
$T_{bit}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{it}$ Perceived travel time factor	0.58	0.66	0.57	0.62	0.61	0.53	0.62	0.75	0.72
$s_{w-r}$ Transit wait-ride score	1.73	1.97	1.72	1.86	1.82	1.59	1.87	2.26	2.17
$f_s$ Motorized vehicle speed adjustment factor	0.02	0.09	0.02	0.08	0.07	0.01	0.07	0.13	0.07
$f_v$ Motorized vehicle volume adjustment factor	1.18	1.55	2.09	0.86	0.55	1.30	0.59	0.71	0.27
$W_{aA}$ Adjusted available sidewalk width (ft)	9.8	9.8	10.0	10.0	10.0	9.8	10.0	10.0	10.0
$f_{sw}$ Sidewalk width coefficient	3.05	3.05	3.00	3.00	3.00	3.05	3.00	3.00	3.00
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
$W_t$ Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	9.8	11.5	11.5	11.5	11.5	11.5	11.5	11.5
$W_v$ Effective total width as a function of traffic volume (ft)	12.7	9.8	11.5	11.5	11.5	11.5	11.5	11.5	15.7
$W_1$ Effective width of combined bike lane and shoulder (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-4.69	-4.64	-4.57	-4.57	-4.57	-4.64	-4.62	-4.60	-4.73
$I_p$ Pedestrian environment score	2.56	3.05	3.58	2.42	2.09	2.71	2.09	2.28	1.66
Pedestrian LOS	B	C	D	B	B	B	B	B	A
$I_t$ Transit LOS score	3.79	3.50	3.95	3.57	3.58	4.02	3.51	2.95	3.00
<b>Output</b>									
<b>Transit LOS</b>	<b>D</b>	<b>C</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>C</b>	<b>C</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:6 Input and results of improved transit LOS for Route from Mexico to Shiromeda</b>										
<b>Multimodal Transit LOS Calculation</b>				<b>Morning peak hour period</b>						
				<b>Segment ID</b>						
<b>Inputs</b>		<b>MS 1</b>	<b>MS 2</b>	<b>MS 3</b>	<b>MS 4</b>	<b>MS 5</b>	<b>MS 6</b>	<b>MS 7</b>	<b>MS 8</b>	<b>MS 9</b>
<b>TRANSIT OPERATIONS INFORMATION</b>										
	Number of local buses on street segment per hour (bus/h)	8	8	8	8	8	8	8	8	8
	Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0
t <sub>ex</sub>	Average excess wait time (min)	8.63	8.63	7.76	7.76	8.27	8.27	8.53	8.78	8.79
L <sub>r</sub>	Average passenger load factor (p/seat)	0.81	0.81	0.81	1.08	1.08	0.95	0.95	0.48	0.44
S	Average transit travel speed (mi/h)	16	16	16	16	16	16	16	18	16
I <sub>pt</sub>	Average passenger trip length (mi)	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
	Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>										
P <sub>sh</sub>	Percent stops in segment with a shelter	0%	0%	100%	0%	0%	100%	0%	100%	100%
P <sub>be</sub>	Percent stops in segment with a bench	0%	0%	100%	0%	0%	100%	100%	100%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>										
W <sub>A</sub>	Sidewalk width (ft) (Enter 0 if no sidewalk)	9.84	9.84	26.24	31.16	14.76	9.84	11.48	13.12	11.48
W <sub>buf</sub>	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?	No	No	No	No	No	No	No	No	No
P <sub>pk</sub>	Proportion of on-street parking occupied	6%	8%	0%	0%	0%	5%	3%	2%	3%
W <sub>bl</sub>	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W <sub>os</sub>	Shoulder/parking lane width (ft)	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	9.8
W <sub>ol</sub>	Outside travel lane (closest to sidewalk) width (ft)	9.84	9.84	11.48	11.48	11.48	11.48	11.48	11.48	11.48
v <sub>m</sub>	Outside lane demand flow rate at midsegment (veh/h)	520	682	920	380	240	570	260	310	120
S <sub>R</sub>	Average vehicle running speed, including intersection delay (mi/h)	7	15	7	14	13	5	13.422	18	14
<b>Calculations</b>										
f	Transit frequency (bus/h)	8	8	8	8	8	8	8	8	8
f <sub>h</sub>	Headway factor	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34
f <sub>pl</sub>	Passenger load weighting factor	1.01	1.01	1.01	1.36	1.36	1.15	1.15	1.00	1.00
T <sub>at</sub>	Perceived amenity time rate (min/mi)	0.0	0.0	0.5	0.0	0.0	0.5	0.1	0.5	0.5
T <sub>ex</sub>	Excess wait time rate due to late arrivals (min/mi)	2.7	2.7	2.4	2.4	2.6	2.6	2.7	2.8	2.8
T <sub>ptt</sub>	Perceived travel time rate (min/mi)	9.2	9.2	8.2	10.0	10.3	9.0	9.6	8.3	8.8
T <sub>btt</sub>	Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
f <sub>tt</sub>	Perceived travel time factor	0.73	0.73	0.76	0.71	0.70	0.73	0.72	0.75	0.74
S <sub>w-r</sub>	Transit wait-ride score	2.43	2.43	2.53	2.37	2.34	2.45	2.40	2.52	2.47
f <sub>s</sub>	Motorized vehicle speed adjustment factor	0.02	0.09	0.02	0.08	0.07	0.01	0.07	0.13	0.07
f <sub>v</sub>	Motorized vehicle volume adjustment factor	1.18	1.55	2.09	0.86	0.55	1.30	0.59	0.71	0.27
W <sub>aA</sub>	Adjusted available sidewalk width (ft)	9.8	9.8	10.0	10.0	10.0	9.8	10.0	10.0	10.0
f <sub>sw</sub>	Sidewalk width coefficient	3.05	3.05	3.00	3.00	3.00	3.05	3.00	3.00	3.00
f <sub>b</sub>	Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
	Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	9.8	11.5	11.5	11.5	11.5	11.5	11.5	11.5
W <sub>t</sub>	Effective total width as a function of traffic volume (ft)	9.8	9.8	11.5	11.5	11.5	11.5	11.5	11.5	15.7
W <sub>l</sub>	Effective width of combined bike lane and shoulder (ft)	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	9.8
f <sub>w</sub>	Cross-section adjustment factor	-4.75	-4.64	-4.57	-4.57	-4.57	-4.64	-4.62	-4.74	-4.85
I <sub>p</sub>	Pedestrian environment score	2.50	3.05	3.58	2.42	2.09	2.71	2.09	2.15	1.54
	Pedestrian LOS	B	C	D	B	B	B	B	B	A
I <sub>t</sub>	Transit LOS score	2.73	2.81	2.74	2.82	2.80	2.73	2.72	2.54	2.53
<b>Output</b>										
	<b>Transit LOS</b>	<b>B</b>	<b>C</b>	<b>B</b>	<b>C</b>	<b>C</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:7 Input and results of existing transit LOS for Route from Mexico to Shiromeda</b>									
<b>Multimodal Transit LOS Calculation</b>					<b>Afternoon peak hour period</b>				
<b>Segment ID</b>									
<b>Inputs</b>	<b>MS 1</b>	<b>MS 2</b>	<b>MS 3</b>	<b>MS 4</b>	<b>MS 5</b>	<b>MS 6</b>	<b>MS 7</b>	<b>MS 8</b>	<b>MS 9</b>
<b>TRANSIT OPERATIONS INFORMATION</b>									
Number of local buses on street segment per hour (bus/h)	5	5	5	5	5	5	5	5	5
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	7.48	7.48	7.44	7.44	6.95	6.95	7.10	7.14	6.74
$L_f$ Average passenger load factor (p/seat)	1.35	1.35	1.35	2.03	2.03	2.18	2.18	1.45	1.35
$S$ Average transit travel speed (mi/h)	5	4	5	8	5	13	10	11	7
$I_{pt}$ Average passenger trip length (mi)	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>									
$p_{sh}$ Percent stops in segment with a shelter	0%	0%	100%	0%	0%	100%	0%	100%	100%
$p_{bc}$ Percent stops in segment with a bench	0%	0%	100%	0%	0%	100%	100%	100%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>									
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	9.84	9.84	26.24	31.16	14.76	9.84	11.48	13.12	11.48
$W_{bul}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No	No
$p_{pk}$ Proportion of on-street parking occupied	4%	5%	0%	0%	0%	3%	4%	3%	2%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	9.84	9.84	11.48	11.48	11.48	11.48	11.48	11.48	11.48
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	634	925	1260	360	384	380	342	288	196
$S_R$ Average vehicle running speed, including intersection delay (mi/h)	5	4	5	8	5	13	10.0806	11	7
<b>Calculations</b>									
$f$ Transit frequency (bus/h)	5	5	5	5	5	5	5	5	5
$f_h$ Headway factor	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
$f_{pl}$ Passenger load weighting factor	1.90	1.90	1.90	2.98	2.98	3.19	3.19	2.07	1.90
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.5	0.0	0.0	0.5	0.1	0.5	0.5
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.1
$T_{ptt}$ Perceived travel time rate (min/mi)	26.7	37.0	28.6	28.1	37.1	18.7	23.3	15.4	19.1
$T_{btt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.54	0.51	0.54	0.54	0.51	0.59	0.56	0.62	0.59
$s_{w-r}$ Transit wait-ride score	1.63	1.54	1.61	1.62	1.54	1.77	1.68	1.86	1.76
$f_s$ Motorized vehicle speed adjustment factor	0.01	0.00	0.01	0.02	0.01	0.07	0.04	0.05	0.02
$f_v$ Motorized vehicle volume adjustment factor	1.44	2.10	2.87	0.82	0.87	0.86	0.78	0.66	0.45
$W_{aA}$ Adjusted available sidewalk width (ft)	9.8	9.8	10.0	10.0	10.0	9.8	10.0	10.0	10.0
$f_{sw}$ Sidewalk width coefficient	3.05	3.05	3.00	3.00	3.00	3.05	3.00	3.00	3.00
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
$W_t$ Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	9.8	11.5	11.5	11.5	11.5	11.5	11.5	11.5
$W_v$ Effective total width as a function of traffic volume (ft)	9.8	9.8	11.5	11.5	11.5	11.5	11.5	11.5	11.5
$W_1$ Effective width of combined bike lane and shoulder (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-4.58	-4.60	-4.57	-4.57	-4.57	-4.62	-4.63	-4.62	-4.60
$I_p$ Pedestrian environment score	2.92	3.56	4.35	2.32	2.36	2.36	2.23	2.13	1.91
Pedestrian LOS	C	D	E	B	B	B	B	B	A
$I_t$ Transit LOS score	3.99	4.22	4.24	3.92	4.05	3.70	3.82	3.53	3.65
<b>Output</b>									
<i>Transit LOS</i>	<i>D</i>	<i>D</i>	<i>D</i>	<i>D</i>	<i>D</i>	<i>D</i>	<i>D</i>	<i>D</i>	<i>D</i>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:8 Input and results of improved transit LOS for Route from Mexico to shiromeda</b>										
<b>Multimodal Transit LOS Calculation</b>					<b>Afternoon peak hour period</b>					
					<b>Segment ID</b>					
<b>Inputs</b>		<b>MS 1</b>	<b>MS 2</b>	<b>MS 3</b>	<b>MS 4</b>	<b>MS 5</b>	<b>MS 6</b>	<b>MS 7</b>	<b>MS 8</b>	<b>MS 9</b>
<b>TRANSIT OPERATIONS INFORMATION</b>										
	Number of local buses on street segment per hour (bus/h)	8	8	8	8	8	8	8	8	8
	Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0
$t_{ex}$	Average excess wait time (min)	7.48	7.48	7.44	7.44	6.95	6.95	7.10	7.14	6.74
$L_f$	Average passenger load factor (p/seat)	0.84	0.84	0.84	1.27	1.27	1.36	1.36	0.91	0.84
$S$	Average transit travel speed (mi/h)	16	16	16	16	16	16	16	16	16
$l_{pt}$	Average passenger trip length (mi)	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23
	Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>										
$p_{sh}$	Percent stops in segment with a shelter	0%	0%	100%	0%	0%	100%	0%	100%	100%
$p_{be}$	Percent stops in segment with a bench	0%	0%	100%	0%	0%	100%	100%	100%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>										
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)	9.84	9.84	26.24	31.16	14.76	9.84	11.48	13.12	11.48
$W_{buf}$	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?	No	No	No	No	No	No	No	No	No
$p_{pk}$	Proportion of on-street parking occupied	4%	5%	0%	0%	0%	3%	4%	3%	2%
$W_{bl}$	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$	Shoulder/parking lane width (ft)	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	9.8
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)	9.84	9.84	11.48	11.48	11.48	11.48	11.48	11.48	11.48
$v_m$	Outside lane demand flow rate at midsegment (veh/h)	634	925	1260	360	384	380	342	288	196
$S_R$	Average vehicle running speed, including intersection delay (mi/h)	5	4	5	8	5	13	10	11	7
<b>Calculations</b>										
$f$	Transit frequency (bus/h)	8	8	8	8	8	8	8	8	8
$f_h$	Headway factor	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34
$f_{pl}$	Passenger load weighting factor	1.04	1.04	1.04	1.74	1.74	1.91	1.91	1.10	1.04
$T_{at}$	Perceived amenity time rate (min/mi)	0.0	0.0	0.5	0.0	0.0	0.5	0.1	0.5	0.5
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.1
$T_{ptt}$	Perceived travel time rate (min/mi)	8.5	8.5	8.0	11.1	10.8	11.0	11.5	8.1	7.6
$T_{btt}$	Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$	Perceived travel time factor	0.75	0.75	0.76	0.68	0.69	0.69	0.68	0.76	0.78
$S_{w-r}$	Transit wait-ride score	2.50	2.50	2.55	2.28	2.30	2.29	2.26	2.55	2.60
$f_s$	Motorized vehicle speed adjustment factor	0.01	0.00	0.01	0.02	0.01	0.07	0.04	0.05	0.02
$f_v$	Motorized vehicle volume adjustment factor	1.44	2.10	2.87	0.82	0.87	0.86	0.78	0.66	0.45
$W_{atA}$	Adjusted available sidewalk width (ft)	9.8	9.8	10.0	10.0	10.0	9.8	10.0	10.0	10.0
$f_{sw}$	Sidewalk width coefficient	3.05	3.05	3.00	3.00	3.00	3.05	3.00	3.00	3.00
$f_b$	Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
$W_t$	Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	9.8	11.5	11.5	11.5	11.5	11.5	11.5	11.5
$W_v$	Effective total width as a function of traffic volume (ft)	9.8	9.8	11.5	11.5	11.5	11.5	11.5	11.5	11.5
$W_l$	Effective width of combined bike lane and shoulder (ft)	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	9.8
$f_w$	Cross-section adjustment factor	-4.72	-4.60	-4.57	-4.57	-4.57	-4.62	-4.63	-4.75	-4.74
$I_p$	Pedestrian environment score	2.78	3.56	4.35	2.32	2.36	2.36	2.23	2.00	1.78
	Pedestrian LOS	C	D	E	B	B	B	B	A	A
$I_t$	Transit LOS score	2.67	2.79	2.83	2.92	2.90	2.92	2.95	2.48	2.36
<b>Output</b>										
	<b>Transit LOS</b>	<b>B</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>B</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

Annex - C:9 Input and results of existing transit LOS for Route from Jemo 2 to Mexico								
Multimodal Transit LOS Calculation				Afternoon peak hour period				
Segment ID								
Inputs	JM 1	JM 2	JM 3	JM 4	JM 5	JM 6	JM 7	JM 8
<b>TRANSIT OPERATIONS INFORMATION</b>								
Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6	6
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	5.53	7.08	6.53	6.21	7.47	7.24	7.15	8.08
$L_f$ Average passenger load factor (p/seat)	0.52	0.69	0.89	0.73	0.73	0.75	0.76	0.59
$S$ Average transit travel speed (mi/h)	18	17	16	13	10	9	6	7
$l_{pt}$ Average passenger trip length (mi)	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>								
$P_{sh}$ Percent stops in segment with a shelter	0%	0%	100%	0%	0%	0%	0%	0%
$P_{be}$ Percent stops in segment with a bench	0%	0%	100%	0%	0%	0%	0%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>								
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	13.12	13.12	14.76	6.56	13.12	13.12	13.12	11.48
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	Yes	No	No	No	No
$P_{pk}$ Proportion of on-street parking occupied	3%	7%	2%	3%	27%	32%	27%	13%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	9.84	9.84	9.84	11.48	11.48	11.48	11.48	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	188	278	295	158	196	216	230	327
Average vehicle running speed, including intersection delay								
$S_R$ (mi/h)	18	17	16	13	10	9	6	7
<b>Calculations</b>								
$f$ Transit frequency (bus/h)	6	6	6	6	6	6	6	6
$f_h$ Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pl}$ Passenger load weighting factor	1.00	1.00	1.08	1.00	1.00	1.00	1.00	1.00
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	1.2	1.5	1.4	1.3	1.6	1.5	1.5	1.7
$T_{ptt}$ Perceived travel time rate (min/mi)	5.7	6.5	6.6	7.2	9.2	9.5	12.5	11.5
$T_{btt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.87	0.83	0.82	0.79	0.73	0.72	0.66	0.68
$S_{w-r}$ Transit wait-ride score	2.74	2.60	2.59	2.50	2.29	2.27	2.08	2.13
$f_s$ Motorized vehicle speed adjustment factor	0.13	0.12	0.10	0.07	0.04	0.03	0.02	0.02
$f_v$ Motorized vehicle volume adjustment factor	0.43	0.63	0.67	0.36	0.45	0.49	0.52	0.74
$W_{aA}$ Adjusted available sidewalk width (ft)	10.0	10.0	10.0	6.6	10.0	10.0	10.0	10.0
$f_{sw}$ Sidewalk width coefficient	3.00	3.00	3.00	4.03	3.00	3.00	3.00	3.00
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Total width of outside lane, bike lane, and parking lane/shoulder (ft)								
$W_t$	9.8	9.8	9.8	11.5	11.5	11.5	11.5	9.8
$W_v$ Effective total width as a function of traffic volume (ft)	9.8	9.8	9.8	13.9	11.5	11.5	11.5	9.8
$W_l$ Effective width of combined bike lane and shoulder (ft)	0.0	0.0	0.0	0.0	10.0	10.0	10.0	8.0
$f_w$ Cross-section adjustment factor	-4.57	-4.62	-4.56	-4.58	-5.03	-5.08	-5.02	-4.81
$I_p$ Pedestrian environment score	2.04	2.18	2.26	1.90	1.50	1.50	1.57	2.00
Pedestrian LOS	B	B	B	A	A	A	A	B
$I_t$ Transit LOS score	2.20	2.43	2.46	2.53	2.79	2.82	3.12	3.10
<b>Output</b>								
Transit LOS	B	B	B	B	C	C	C	C

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:10 Input and results of improved transit LOS for Route from Jemo 2 to Mexico</b>									
<b>Multimodal Transit LOS Calculation</b>				<b>Afternoon peak hour period</b>					
				<b>Segment ID</b>					
<b>Inputs</b>		<b>JM 1</b>	<b>JM 2</b>	<b>JM 3</b>	<b>JM 4</b>	<b>JM 5</b>	<b>JM 6</b>	<b>JM 7</b>	<b>JM 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>									
	Number of local buses on street segment per hour (bus/h)	8	8	8	8	8	8	6	6
	Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0
$t_{ex}$	Average excess wait time (min)	5.53	7.08	6.53	6.21	7.47	7.24	7.15	8.08
$L_f$	Average passenger load factor (p/seat)	0.52	0.69	0.89	0.73	0.73	0.75	0.76	0.59
$S$	Average transit travel speed (mi/h)	18	17	16	16	16	16	16	16
$l_{pt}$	Average passenger trip length (mi)	4.72	4.72	4.72	4.72	4.72	4.72	4.72	4.72
	Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>									
$p_{sh}$	Percent stops in segment with a shelter	0%	0%	100%	0%	0%	0%	0%	0%
$p_{be}$	Percent stops in segment with a bench	0%	0%	100%	0%	0%	0%	0%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>									
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)	13.12	13.12	14.76	6.56	13.12	13.12	13.12	11.48
$W_{buf}$	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?	No	No	No	Yes	No	No	No	No
$p_{pk}$	Proportion of on-street parking occupied	3%	7%	2%	3%	27%	32%	27%	13%
$W_{bl}$	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$	Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)	9.84	9.84	9.84	11.48	11.48	11.48	11.48	9.84
$v_m$	Outside lane demand flow rate at midsegment (veh/h)	188	278	295	158	196	216	230	327
	Average vehicle running speed, including intersection delay								
$S_R$	(mi/h)	18	17	16	13	10	9	6	7
<b>Calculations</b>									
$f$	Transit frequency (bus/h)	8	8	8	8	8	8	6	6
$f_h$	Headway factor	3.34	3.34	3.34	3.34	3.34	3.34	3.15	3.15
$f_{pl}$	Passenger load weighting factor	1.00	1.00	1.08	1.00	1.00	1.00	1.00	1.00
$T_{at}$	Perceived amenity time rate (min/mi)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)	1.2	1.5	1.4	1.3	1.6	1.5	1.5	1.7
$T_{ptt}$	Perceived travel time rate (min/mi)	5.7	6.5	6.5	6.4	6.9	6.8	6.8	7.1
$T_{btt}$	Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$	Perceived travel time factor	0.87	0.83	0.83	0.83	0.81	0.81	0.81	0.80
$S_{w-r}$	Transit wait-ride score	2.91	2.76	2.76	2.78	2.70	2.71	2.56	2.51
$f_b$	Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
$W_t$	lane/shoulder (ft)	9.8	9.8	9.8	11.5	11.5	11.5	11.5	9.8
$W_v$	Effective total width as a function of traffic volume (ft)	9.8	9.8	9.8	13.9	11.5	11.5	11.5	9.8
$W_1$	Effective width of combined bike lane and shoulder (ft)	0.0	0.0	0.0	0.0	10.0	10.0	10.0	8.0
$f_w$	Cross-section adjustment factor	-4.57	-4.62	-4.56	-4.58	-5.03	-5.08	-5.02	-4.81
$I_p$	Pedestrian environment score	2.04	2.18	2.26	1.90	1.50	1.50	1.57	2.00
	Pedestrian LOS	B	B	B	A	A	A	A	B
$I_t$	Transit LOS score	1.94	2.19	2.20	2.11	2.18	2.16	2.39	2.53
<b>Output</b>									
	<b>Transit LOS</b>	<b>A</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:11 Input and results of existing transit LOS for Route from Jemo 2 to Mexico</b>									
<b>Multimodal Transit LOS Calculation</b>				<b>Morning peak hour period</b>					
				<b>Segment ID</b>					
<b>Inputs</b>		<b>JM 1</b>	<b>JM 2</b>	<b>JM 3</b>	<b>JM 4</b>	<b>JM 5</b>	<b>JM 6</b>	<b>JM 7</b>	<b>JM 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>									
	Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6	6
	Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0
$t_{ex}$	Average excess wait time (min)	7.35	7.21	7.25	7.48	8.18	7.26	6.81	7.94
$L_r$	Average passenger load factor (p/seat)	1.17	1.53	1.97	1.72	1.74	1.78	1.69	1.38
$S$	Average transit travel speed (mi/h)	16	10	3	11	4	9	7	6
$l_{pt}$	Average passenger trip length (mi)	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03
	Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>									
$p_{sh}$	Percent stops in segment with a shelter	0%	0%	100%	0%	0%	0%	0%	0%
$p_{be}$	Percent stops in segment with a bench	0%	0%	100%	0%	0%	0%	0%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>									
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)	13.12	13.12	14.76	6.56	13.12	13.12	13.12	9.84
$W_{buf}$	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?	No	No	No	Yes	No	No	No	No
$p_{pk}$	Proportion of on-street parking occupied	0%	0%	0%	0%	10%	29%	35%	3%
$W_{bl}$	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$	Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)	9.84	9.84	9.84	11.48	11.48	11.48	11.48	9.84
$v_m$	Outside lane demand flow rate at midsegment (veh/h)	308	260	242	425	340	380	420	448
$S_R$	Average vehicle running speed, including intersection delay (mi/h)	16	10	3	11	4	9	7.49993	6
<b>Calculations</b>									
$f$	Transit frequency (bus/h)	6	6	6	6	6	6	6	6
$f_h$	Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pl}$	Passenger load weighting factor	1.56	2.20	2.89	2.51	2.54	2.61	2.47	1.95
$T_{at}$	Perceived amenity time rate (min/mi)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)	1.5	1.4	1.4	1.5	1.6	1.4	1.4	1.6
$T_{ptt}$	Perceived travel time rate (min/mi)	8.7	16.2	61.6	17.3	39.6	20.4	22.4	22.1
$T_{btt}$	Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$	Perceived travel time factor	0.74	0.61	0.48	0.60	0.51	0.58	0.56	0.57
$s_{w-r}$	Transit wait-ride score	2.33	1.92	1.51	1.89	1.60	1.82	1.78	1.78
$f_s$	Motorized vehicle speed adjustment factor	0.10	0.04	0.00	0.04	0.01	0.03	0.02	0.02
$f_v$	Motorized vehicle volume adjustment factor	0.70	0.59	0.55	0.97	0.77	0.86	0.96	1.02
$W_{aA}$	Adjusted available sidewalk width (ft)	10.0	10.0	10.0	6.6	10.0	10.0	10.0	9.8
$f_{sw}$	Sidewalk width coefficient	3.00	3.00	3.00	4.03	3.00	3.00	3.00	3.05
$f_b$	Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
$W_t$	Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	9.8	9.8	11.5	11.5	11.5	11.5	9.8
$W_v$	Effective total width as a function of traffic volume (ft)	9.8	9.8	9.8	11.5	11.5	11.5	11.5	9.8
$W_1$	Effective width of combined bike lane and shoulder (ft)	0.0	0.0	0.0	0.0	0.0	10.0	10.0	8.0
$f_w$	Cross-section adjustment factor	-4.52	-4.52	-4.52	-4.46	-4.72	-5.05	-5.11	-4.68
$I_p$	Pedestrian environment score	2.33	2.15	2.08	2.59	2.11	1.90	1.92	2.40
	Pedestrian LOS	B	B	B	B	B	A	A	B
$I_t$	Transit LOS score	2.85	3.44	4.04	3.55	3.92	3.56	3.62	3.69
<b>Output</b>									
	<b>Transit LOS</b>	<b>C</b>	<b>C</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:12 Input and results of improved transit LOS for Route from Jemo 2 to Mexico</b>										
<b>Multimodal Transit LOS Calculation</b>			<b>Morning peak hour period</b>							
			<b>Segment ID</b>							
<b>Inputs</b>			<b>JM 1</b>	<b>JM 2</b>	<b>JM 3</b>	<b>JM 4</b>	<b>JM 5</b>	<b>JM 6</b>	<b>JM 7</b>	<b>JM 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>										
	Number of local buses on street segment per hour (bus/h)		8	8	8	8	8	8	8	8
	Number of express buses stopping in segment per hour (bus/h)		0	0	0	0	0	0	0	0
$t_{ex}$	Average excess wait time (min)		7.35	7.21	7.25	7.48	8.18	7.26	6.81	7.94
$L_f$	Average passenger load factor (p/seat)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
$S$	Average transit travel speed (mi/h)		16	16	16	16	16	16	16	16
$l_{pt}$	Average passenger trip length (mi)		5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03
	Is the segment in the CBD of a metro area of 5 million or more?		No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>										
$p_{sh}$	Percent stops in segment with a shelter		0%	0%	100%	0%	0%	0%	0%	0%
$p_{be}$	Percent stops in segment with a bench		0%	0%	100%	0%	0%	0%	0%	100%
<b>PEDESTRIAN ENVIRONMENT DATA</b>										
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)		13.12	13.12	14.76	6.56	13.12	13.12	13.12	9.84
$W_{buf}$	Buffer width from sidewalk to street (ft)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Is the street divided?		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?		No	No	No	Yes	No	No	No	No
$p_{pk}$	Proportion of on-street parking occupied		0%	0%	0%	0%	10%	29%	35%	3%
$W_{bl}$	Bicycle lane width (ft)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$	Shoulder/parking lane width (ft)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)		9.84	9.84	9.84	11.48	11.48	11.48	11.48	9.84
$v_m$	Outside lane demand flow rate at midsegment (veh/h)		308	260	242	425	340	380	420	448
$S_R$	Average vehicle running speed, including intersection delay (mi/h)		16	10	3	11	4	9	7.5	6
<b>Calculations</b>										
$f$	Transit frequency (bus/h)		8	8	8	8	8	8	8	8
$f_h$	Headway factor		3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34
$f_{pl}$	Passenger load weighting factor		1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
$T_{at}$	Perceived amenity time rate (min/mi)		0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)		1.5	1.4	1.4	1.5	1.6	1.4	1.4	1.6
$T_{ptt}$	Perceived travel time rate (min/mi)		7.4	7.3	7.1	7.4	7.7	7.3	7.2	7.6
$T_{btt}$	Base travel time rate (min/mi)		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$	Perceived travel time factor		0.79	0.79	0.80	0.79	0.77	0.79	0.80	0.78
$s_{w-r}$	Transit wait-ride score		2.64	2.64	2.68	2.63	2.59	2.64	2.66	2.61
$f_s$	Motorized vehicle speed adjustment factor		0.10	0.04	0.00	0.04	0.01	0.03	0.02	0.02
$f_v$	Motorized vehicle volume adjustment factor		0.70	0.59	0.55	0.97	0.77	0.86	0.96	1.02
$W_{aA}$	Adjusted available sidewalk width (ft)		10.0	10.0	10.0	6.6	10.0	10.0	10.0	9.8
$f_{sw}$	Sidewalk width coefficient		3.00	3.00	3.00	4.03	3.00	3.00	3.00	3.05
$f_b$	Buffer area coefficient		5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
	Total width of outside lane, bike lane, and parking lane/shoulder (ft)		9.8	9.8	9.8	11.5	11.5	11.5	11.5	9.8
$W_v$	Effective total width as a function of traffic volume (ft)		9.8	9.8	9.8	11.5	11.5	11.5	11.5	9.8
$W_l$	Effective width of combined bike lane and shoulder (ft)		0.0	0.0	0.0	0.0	0.0	10.0	10.0	8.0
$f_w$	Cross-section adjustment factor		-4.52	-4.52	-4.52	-4.46	-4.72	-5.05	-5.11	-4.68
$I_p$	Pedestrian environment score		2.33	2.15	2.08	2.59	2.11	1.90	1.92	2.40
	Pedestrian LOS		B	B	B	B	B	A	A	B
$I_t$	Transit LOS score		2.39	2.36	2.29	2.45	2.43	2.33	2.30	2.45
<b>Output</b>										
	<b>Transit LOS</b>		<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:13 Input and results of existing transit LOS for Route from Mexico to Jemo 2</b>											
<b>Multimodal Transit LOS Calculation</b>				<b>Afternoon peak hour period</b>							
				<b>Segment ID</b>							
<b>Inputs</b>				<b>MJ 1</b>	<b>MJ 2</b>	<b>MJ 3</b>	<b>MJ 4</b>	<b>MJ 5</b>	<b>MJ 6</b>	<b>MJ 7</b>	<b>MJ 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>											
	Number of local buses on street segment per hour (bus/h)			6	6	6	6	6	6	6	6
	Number of express buses stopping in segment per hour (bus/h)			0	0	0	0	0	0	0	0
$t_{ex}$	Average excess wait time (min)			9.81	7.18	8.39	8.07	8.08	7.10	7.74	7.76
$L_f$	Average passenger load factor (p/seat)			1.54	1.67	1.64	1.71	1.52	1.52	1.13	0.97
$S$	Average transit travel speed (mi/h)			8	9	7	11	8	5	10	9
$l_{pt}$	Average passenger trip length (mi)			4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37
	Is the segment in the CBD of a metro area of 5 million or more?			No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>											
$p_{sh}$	Percent stops in segment with a shelter			0%	0%	0%	0%	0%	100%	0%	0%
$p_{be}$	Percent stops in segment with a bench			100%	0%	0%	0%	0%	100%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>											
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)			9.84	13.12	13.12	13.12	6.56	13.12	13.12	13.12
$W_{buf}$	Buffer width from sidewalk to street (ft)			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?			No	No	No	No	Yes	No	No	No
	Is the street divided?			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?			No	No	No	Yes	No	No	No	No
$p_{pk}$	Proportion of on-street parking occupied			3%	29%	26%	12%	1%	4%	2%	2%
$W_{bl}$	Bicycle lane width (ft)			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$	Shoulder/parking lane width (ft)			8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)			9.84	11.48	11.48	11.48	11.48	9.84	9.84	9.84
$v_m$	Outside lane demand flow rate at midsegment (veh/h)			280	348	325	350	230	356	320	220
	Average vehicle running speed, including intersection delay (mi/h)			8	9	7	11	8	5	9.568	9
<b>Calculations</b>											
$f$	Transit frequency (bus/h)			6	6	6	6	6	6	6	6
$f_h$	Headway factor			3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pl}$	Passenger load weighting factor			2.23	2.43	2.40	2.50	2.20	2.19	1.48	1.16
$T_{at}$	Perceived amenity time rate (min/mi)			0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)			2.2	1.6	1.9	1.8	1.8	1.6	1.8	1.8
$T_{ptt}$	Perceived travel time rate (min/mi)			21.1	19.6	25.1	17.5	19.6	29.7	12.8	11.6
$T_{btt}$	Base travel time rate (min/mi)			4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$	Perceived travel time factor			0.57	0.58	0.55	0.60	0.58	0.53	0.65	0.67
$s_{w-r}$	Transit wait-ride score			1.80	1.83	1.73	1.89	1.83	1.68	2.06	2.12
$f_s$	Motorized vehicle speed adjustment factor			0.03	0.03	0.02	0.05	0.03	0.01	0.04	0.03
$f_v$	Motorized vehicle volume adjustment factor			0.64	0.79	0.74	0.80	0.52	0.81	0.73	0.50
$W_{aA}$	Adjusted available sidewalk width (ft)			9.8	10.0	10.0	10.0	6.6	10.0	10.0	10.0
$f_{sw}$	Sidewalk width coefficient			3.05	3.00	3.00	3.00	4.03	3.00	3.00	3.00
$f_b$	Buffer area coefficient			1.00	1.00	1.00	1.00	5.37	1.00	1.00	1.00
$W_t$	Total width of outside lane, bike lane, and parking lane/shoulder (ft)			9.8	11.5	11.5	11.5	11.5	9.8	9.8	9.8
$W_v$	Effective total width as a function of traffic volume (ft)			9.8	11.5	11.5	11.5	11.5	9.8	9.8	9.8
$W_1$	Effective width of combined bike lane and shoulder (ft)			8.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0
$f_w$	Cross-section adjustment factor			-4.68	-5.05	-5.02	-4.74	-4.49	-4.58	-4.55	-4.55
$I_p$	Pedestrian environment score			2.03	1.82	1.79	2.15	2.11	2.29	2.26	2.03
	Pedestrian LOS			B	A	A	B	B	B	B	B
$I_t$	Transit LOS score			3.60	3.52	3.67	3.49	3.57	3.83	3.25	3.12
<b>Output</b>											
	<b>Transit LOS</b>			<b>D</b>	<b>D</b>	<b>D</b>	<b>C</b>	<b>D</b>	<b>D</b>	<b>C</b>	<b>C</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:14 Input and results of improved transit LOS for Route from Mexico to Jemo 2</b>								
<b>Multimodal Transit LOS Calculation</b>				<b>Afternoon peak hour period</b>				
				<b>Segment ID</b>				
<b>Inputs</b>	<b>MJ 1</b>	<b>MJ 2</b>	<b>MJ 3</b>	<b>MJ 4</b>	<b>MJ 5</b>	<b>MJ 6</b>	<b>MJ 7</b>	<b>MJ 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>								
Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6	6
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	9.81	7.18	8.39	8.07	8.08	7.10	7.74	7.76
$L_p$ Average passenger load factor (p/seat)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97
$S$ Average transit travel speed (mi/h)	16	16	16	16	16	16	16	16
$l_{pt}$ Average passenger trip length (mi)	4.37	4.37	4.37	4.37	4.37	4.37	4.37	4.37
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>								
$p_{sh}$ Percent stops in segment with a shelter	0%	0%	0%	0%	0%	100%	0%	0%
$p_{bc}$ Percent stops in segment with a bench	100%	0%	0%	0%	0%	100%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>								
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	9.84	13.12	13.12	13.12	6.56	13.12	13.12	13.12
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	No	No	No	No	Yes	No	No	No
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	Yes	No	No	No	No
$p_{pk}$ Proportion of on-street parking occupied	3%	29%	26%	12%	1%	4%	2%	2%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ss}$ Shoulder/parking lane width (ft)	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	9.84	11.48	11.48	11.48	11.48	9.84	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	280	348	325	350	230	356	320	220
$S_e$ Average vehicle running speed, including intersection delay (mi/h)	8	9	7	11	8	5	9.5681	9
<b>Calculations</b>								
$f$ Transit frequency (bus/h)	6	6	6	6	6	6	6	6
$f_h$ Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pt}$ Passenger load weighting factor	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.16
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
$T_{en}$ Excess wait time rate due to late arrivals (min/mi)	2.2	1.6	1.9	1.8	1.8	1.6	1.8	1.8
$T_{ptt}$ Perceived travel time rate (min/mi)	8.9	7.8	8.3	8.2	8.2	7.4	8.0	7.9
$T_{btt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tr}$ Perceived travel time factor	0.74	0.77	0.75	0.76	0.76	0.79	0.76	0.77
$S_{wr}$ Transit wait-ride score	2.32	2.44	2.38	2.39	2.39	2.48	2.41	2.42
$f_v$ Motorized vehicle speed adjustment factor	0.03	0.03	0.02	0.05	0.03	0.01	0.04	0.03
$f_v$ Motorized vehicle volume adjustment factor	0.64	0.79	0.74	0.80	0.52	0.81	0.73	0.50
$W_{sa}$ Adjusted available sidewalk width (ft)	9.8	10.0	10.0	10.0	6.6	10.0	10.0	10.0
$f_{sw}$ Sidewalk width coefficient	3.05	3.00	3.00	3.00	4.03	3.00	3.00	3.00
$f_b$ Buffer area coefficient	1.00	1.00	1.00	1.00	5.37	1.00	1.00	1.00
Total width of outside lane, bike lane, and parking lane/shoulder								
$W_t$ (ft)	9.8	11.5	11.5	11.5	11.5	9.8	9.8	9.8
$W_e$ Effective total width as a function of traffic volume (ft)	9.8	11.5	11.5	11.5	11.5	9.8	9.8	9.8
$W_l$ Effective width of combined bike lane and shoulder (ft)	8.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-4.68	-5.05	-5.02	-4.74	-4.49	-4.58	-4.55	-4.55
$I_p$ Pedestrian environment score	2.03	1.82	1.79	2.15	2.11	2.29	2.26	2.03
Pedestrian LOS	B	A	A	B	B	B	B	B
$I_t$ Transit LOS score	2.83	2.62	2.70	2.73	2.73	2.62	2.73	2.68
<b>Output</b>								
<i>Transit LOS</i>	<i>C</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C: 15 Input and results of existing transit LOS for Route from Mexico to Jemo 2</b>									
<b>Multimodal Transit LOS Calculation</b>				<b>Morning peak hour period</b>					
				<b>Segment ID</b>					
<b>Inputs</b>		<b>MJ 1</b>	<b>MJ 2</b>	<b>MJ 3</b>	<b>MJ 4</b>	<b>MJ 5</b>	<b>MJ 6</b>	<b>MJ 7</b>	<b>MJ 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>									
	Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6	6
	Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0
$t_{ex}$	Average excess wait time (min)	4.32	4.43	4.19	3.86	3.77	4.11	3.88	4.37
$L_f$	Average passenger load factor (p/seat)	1.04	1.07	1.06	1.15	0.98	0.85	0.60	0.45
$S$	Average transit travel speed (mi/h)	20	19	22	18	8	21	11	15
$l_{pt}$	Average passenger trip length (mi)	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27
	Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>									
$p_{sh}$	Percent stops in segment with a shelter	0%	0%	0%	0%	0%	100%	0%	0%
$p_{be}$	Percent stops in segment with a bench	100%	0%	0%	0%	0%	100%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>									
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	13.12	13.12	13.12	6.56	13.12	13.12	13.12
$W_{buf}$	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?	No	No	No	No	Yes	No	No	No
	Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?	No	No	No	Yes	No	No	No	No
$p_{pk}$	Proportion of on-street parking occupied	2%	31%	27%	7%	0%	18%	11%	3%
$W_{bl}$	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$	Shoulder/parking lane width (ft)	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)	9.84	11.48	11.48	11.48	11.48	9.84	9.84	9.84
$v_m$	Outside lane demand flow rate at midsegment (veh/h)	120	368	276	194	181	340	272	185
$S_R$	Average vehicle running speed, including intersection delay (mi/h)	20	19	22	18	8	21	10.584	15
<b>Calculations</b>									
$f$	Transit frequency (bus/h)	6	6	6	6	6	6	6	6
$f_h$	Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pl}$	Passenger load weighting factor	1.29	1.34	1.33	1.52	1.17	1.05	1.00	1.00
$T_{at}$	Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)	1.0	1.0	1.0	0.9	0.9	1.0	0.9	1.0
$T_{ptt}$	Perceived travel time rate (min/mi)	5.8	6.4	5.6	6.8	10.6	4.5	7.5	6.1
$T_{bit}$	Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{it}$	Perceived travel time factor	0.86	0.83	0.88	0.81	0.69	0.95	0.78	0.85
$s_{w-r}$	Transit wait-ride score	2.72	2.62	2.76	2.55	2.18	3.00	2.47	2.66
$f_s$	Motorized vehicle speed adjustment factor	0.17	0.14	0.19	0.13	0.03	0.18	0.04	0.09
$f_v$	Motorized vehicle volume adjustment factor	0.27	0.84	0.63	0.44	0.41	0.77	0.62	0.42
$W_{atA}$	Adjusted available sidewalk width (ft)	10.0	10.0	10.0	10.0	6.6	10.0	10.0	10.0
$f_{sw}$	Sidewalk width coefficient	3.00	3.00	3.00	3.00	4.03	3.00	3.00	3.00
$f_b$	Buffer area coefficient	1.00	1.00	1.00	1.00	5.37	1.00	1.00	1.00
$W_t$	Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	11.5	11.5	11.5	11.5	9.8	9.8	9.8
$W_v$	Effective total width as a function of traffic volume (ft)	13.8	11.5	11.5	11.5	11.5	9.8	9.8	9.8
$W_l$	Effective width of combined bike lane and shoulder (ft)	8.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0
$f_w$	Cross-section adjustment factor	-4.77	-5.07	-5.03	-4.67	-4.46	-4.77	-4.68	-4.57
$I_p$	Pedestrian environment score	1.71	1.96	1.84	1.95	2.02	2.23	2.03	1.99
	Pedestrian LOS	A	A	A	A	B	B	B	A
$I_t$	Transit LOS score	2.17	2.36	2.13	2.46	3.03	1.84	2.60	2.30
<b>Output</b>									
	<b>Transit LOS</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>C</b>	<b>A</b>	<b>B</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:16 Input and results of improved transit LOS for Route from Mexico to Jemo 2</b>								
<b>Multimodal Transit LOS Calculation</b>				<b>Morning peak hour period</b>				
				<b>Segment ID</b>				
<b>Inputs</b>	<b>MJ 1</b>	<b>MJ 2</b>	<b>MJ 3</b>	<b>MJ 4</b>	<b>MJ 5</b>	<b>MJ 6</b>	<b>MJ 7</b>	<b>MJ 8</b>
<b>TRANSIT OPERATIONS INFORMATION</b>								
t <sub>ex</sub>	Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6
	Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0
L <sub>f</sub>	Average excess wait time (min)	4.32	4.43	4.19	3.86	3.77	4.11	3.88
S	Average passenger load factor (p/seat)	1.00	1.00	1.00	1.00	0.98	0.85	0.60
I <sub>pt</sub>	Average transit travel speed (mi/h)	20	19	22	18	16	21	16
	Average passenger trip length (mi)	4.27	4.27	4.27	4.27	4.27	4.27	4.27
	Is the segment in the CBD of a metro area of 5 million or	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>								
p <sub>sh</sub>	Percent stops in segment with a shelter	0%	0%	0%	0%	0%	100%	0%
p <sub>be</sub>	Percent stops in segment with a bench	100%	0%	0%	0%	0%	100%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>								
W <sub>A</sub>	Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	13.12	13.12	13.12	6.56	13.12	13.12
W <sub>buf</sub>	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?	No	No	No	No	Yes	No	No
	Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?	No	No	No	Yes	No	No	No
p <sub>pk</sub>	Proportion of on-street parking occupied	2%	31%	27%	7%	0%	18%	11%
W <sub>bl</sub>	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W <sub>os</sub>	Shoulder/parking lane width (ft)	8.0	0.0	0.0	0.0	0.0	0.0	0.0
W <sub>ol</sub>	Outside travel lane (closest to sidewalk) width (ft)	9.84	11.48	11.48	11.48	11.48	9.84	9.84
v <sub>m</sub>	Outside lane demand flow rate at midsegment (veh/h)	120	368	276	194	181	340	272
S <sub>R</sub>	Average vehicle running speed, including intersection delay (mi/h)	20	19	22	18	8	21	11
								15
<b>Calculations</b>								
f	Transit frequency (bus/h)	6	6	6	6	6	6	6
f <sub>h</sub>	Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15
f <sub>pl</sub>	Passenger load weighting factor	1.19	1.19	1.19	1.19	1.17	1.05	1.00
T <sub>at</sub>	Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.0	0.0	0.4	0.0
T <sub>ex</sub>	Excess wait time rate due to late arrivals (min/mi)	1.0	1.0	1.0	0.9	0.9	1.0	0.9
T <sub>ptt</sub>	Perceived travel time rate (min/mi)	5.5	5.9	5.2	5.7	6.1	4.5	5.6
T <sub>btt</sub>	Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
f <sub>tt</sub>	Perceived travel time factor	0.88	0.86	0.90	0.87	0.84	0.95	0.88
s <sub>w-r</sub>	Transit wait-ride score	2.78	2.70	2.84	2.73	2.66	3.00	2.76
f <sub>s</sub>	Motorized vehicle speed adjustment factor	0.17	0.14	0.19	0.13	0.03	0.18	0.04
f <sub>v</sub>	Motorized vehicle volume adjustment factor	0.27	0.84	0.63	0.44	0.41	0.77	0.62
W <sub>aa</sub>	Adjusted available sidewalk width (ft)	10.0	10.0	10.0	10.0	6.6	10.0	10.0
f <sub>sw</sub>	Sidewalk width coefficient	3.00	3.00	3.00	3.00	4.03	3.00	3.00
f <sub>b</sub>	Buffer area coefficient	1.00	1.00	1.00	1.00	5.37	1.00	1.00
W <sub>t</sub>	Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	11.5	11.5	11.5	11.5	9.8	9.8
W <sub>v</sub>	Effective total width as a function of traffic volume (ft)	13.8	11.5	11.5	11.5	11.5	9.8	9.8
W <sub>1</sub>	Effective width of combined bike lane and shoulder (ft)	8.0	10.0	10.0	0.0	0.0	0.0	0.0
f <sub>w</sub>	Cross-section adjustment factor	-4.77	-5.07	-5.03	-4.67	-4.46	-4.77	-4.68
I <sub>p</sub>	Pedestrian environment score	1.71	1.96	1.84	1.95	2.02	2.23	2.03
	Pedestrian LOS	A	A	A	A	B	B	B
I <sub>t</sub>	Transit LOS score	2.09	2.24	2.02	2.20	2.32	1.84	2.16
								2.22
<b>Output</b>								
	<b>Transit LOS</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>B</b>	<b>A</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:17 Input and results of existing transit LOS for Route from Saris Abo to Piasa</b>												
<b>Multimodal Transit LOS Calculation</b>												
<b>Morning peak hour period</b>												
<b>Segment ID</b>												
<b>Inputs</b>	<b>SP 1</b>	<b>SP 2</b>	<b>SP 3</b>	<b>SP 4</b>	<b>SP 5</b>	<b>SP 6</b>	<b>Sp 7</b>	<b>SP 8</b>	<b>SP 9</b>	<b>SP 10</b>	<b>SP 11</b>	<b>SP 12</b>
<b>TRANSIT OPERATIONS INFORMATION</b>												
Number of local buses on street segment per hour (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	16.13	16.57	17.80	18.54	18.09	17.78	17.78	17.87	15.55	14.60	14.47	14.91
$L_r$ Average passenger load factor (p/seat)	1.28	1.63	1.78	1.88	1.53	1.40	1.40	1.15	1.18	1.05	0.85	0.85
$S$ Average transit travel speed (mi/h)	9	14	13	17	12	20	6	7	9	14	9	22
$l_{pt}$ Average passenger trip length (mi)	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>												
$P_{sh}$ Percent stops in segment with a shelter	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
$P_{be}$ Percent stops in segment with a bench	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	11.48	11.48	11.48	11.48	11.48	13.12	9.84	4.26	13.12	0	6.56
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	Yes	No	No	No	No	No	No	No	No
$P_{pk}$ Proportion of on-street parking occupied	21%	28%	27%	3%	8%	14%	2%	11%	0%	26%	0%	5%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	9.94	9.84	9.84	9.84	9.84	9.84	9.84	11.48	11.48	11.48	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	206	238	241	268	280	294	321	431	440	456	329	214
Average vehicle running speed, including intersection delay	9	14	13	17	12	20	6	7	9	14	9	22
$S_R$ (mi/h)	9	14	13	17	12	20	6	7	9	14	9	22
<b>Calculations</b>												
$f$ Transit frequency (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
$f_h$ Headway factor	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
$f_{pl}$ Passenger load weighting factor	1.76	2.36	2.60	2.75	2.20	1.99	1.99	1.52	1.57	1.30	1.05	1.05
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	4.3	4.4	4.8	5.0	4.8	4.8	4.8	4.8	4.2	3.9	3.9	4.0
$T_{pt}$ Perceived travel time rate (min/mi)	20.4	19.3	21.2	19.5	20.8	15.5	29.4	22.5	19.2	13.3	14.7	10.8
$T_{bt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.58	0.58	0.57	0.58	0.57	0.62	0.53	0.56	0.58	0.65	0.63	0.69
$s_{w-r}$ Transit wait-ride score	1.43	1.45	1.42	1.44	1.42	1.53	1.32	1.40	1.45	1.60	1.56	1.71
$f_s$ Motorized vehicle speed adjustment factor	0.03	0.07	0.07	0.12	0.06	0.16	0.01	0.02	0.03	0.08	0.03	0.20
$f_v$ Motorized vehicle volume adjustment factor	0.47	0.54	0.55	0.61	0.64	0.67	0.73	0.98	1.00	1.04	0.75	0.49
$W_{aA}$ Adjusted available sidewalk width (ft)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.8	4.3	10.0	0.0	6.6
$f_{sw}$ Sidewalk width coefficient	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.05	4.72	3.00	6.00	4.03
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.9	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_v$ Effective total width as a function of traffic volume (ft)	9.9	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_l$ Effective width of combined bike lane and shoulder (ft)	0.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-4.82	-5.00	-4.99	-4.57	-4.64	-4.72	-4.56	-4.72	-4.24	-5.01	-2.81	-4.50
$I_p$ Pedestrian environment score	1.73	1.66	1.68	2.21	2.10	2.15	2.24	2.32	2.84	2.16	4.02	2.24
Pedestrian LOS	A	A	A	B	B	B	B	B	C	B	D	B
$I_t$ Transit LOS score	4.12	4.08	4.13	4.16	4.18	4.02	4.35	4.25	4.25	3.92	4.27	3.77
<b>Output</b>												
<b>Transit LOS</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>E</b>	<b>E</b>	<b>E</b>	<b>D</b>	<b>E</b>	<b>D</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:18 Input and results of improved transit LOS for Route from Saris Abo to Piasa</b>												
<b>Multimodal Transit LOS Calculation</b>												
<b>Morning peak hour period</b>												
<b>Segment ID</b>												
<b>Inputs</b>	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6	SP 7	SP 8	SP 9	SP 10	SP 11	SP 12
<b>TRANSIT OPERATIONS INFORMATION</b>												
Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6	6	6	6	6	6
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
$L_r$ Average passenger load factor (p/seat)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.85
$S$ Average transit travel speed (mi/h)	16	16	16	17	16	20	16	16	16	16	16	22
$l_{pt}$ Average passenger trip length (mi)	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>												
$P_{sh}$ Percent stops in segment with a shelter	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
$P_{bc}$ Percent stops in segment with a bench	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	11.48	11.48	11.48	11.48	11.5	13.12	9.84	4.26	13.1	0	6.56
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	Yes	No	No	No	No	No	No	No	No
$P_{pk}$ Proportion of on-street parking occupied	21%	28%	27%	3%	8%	14%	2%	11%	0%	26%	0%	5%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	9.8	9.8	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	9.94	9.84	9.84	9.84	9.84	9.84	9.84	11.48	11.5	11.5	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	206	238	241	268	280	294	321	431	440	456	329	214
$S_R$ Average vehicle running speed, including intersection delay (mi/h)	9	14	13	17	12	20	6	7	9	14	9	22
<b>Calculations</b>												
$f$ Transit frequency (bus/h)	6	6	6	6	6	6	6	6	6	6	6	6
$f_h$ Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pl}$ Passenger load weighting factor	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.05	1.05
$T_a$ Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
$T_{pt}$ Perceived travel time rate (min/mi)	9.8	9.8	9.8	9.5	9.8	8.9	9.8	9.4	9.8	9.8	9.3	8.1
$T_{bt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{it}$ Perceived travel time factor	0.71	0.71	0.71	0.72	0.71	0.74	0.71	0.72	0.71	0.71	0.73	0.76
$s_{w-r}$ Transit wait-ride score	2.24	2.24	2.24	2.27	2.24	2.32	2.24	2.27	2.24	2.24	2.29	2.39
$f_s$ Motorized vehicle speed adjustment factor	0.03	0.07	0.07	0.12	0.06	0.16	0.01	0.02	0.03	0.08	0.03	0.20
$f_v$ Motorized vehicle volume adjustment factor	0.47	0.54	0.55	0.61	0.64	0.67	0.73	0.98	1.00	1.04	0.75	0.49
$W_{aA}$ Adjusted available sidewalk width (ft)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.8	4.3	10.0	0.0	6.6
$f_{s-w}$ Sidewalk width coefficient	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.05	4.72	3.00	6.00	4.03
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.9	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_v$ Effective total width as a function of traffic volume (ft)	9.9	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_i$ Effective width of combined bike lane and shoulder (ft)	9.8	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-4.93	-5.00	-4.99	-4.57	-4.64	-4.72	-4.56	-4.72	-4.24	-5.01	-2.81	-4.50
$I_p$ Pedestrian environment score	1.62	1.66	1.68	2.21	2.10	2.15	2.24	2.32	2.84	2.16	4.02	2.24
Pedestrian LOS	A	A	A	B	B	B	B	B	C	B	D	B
$I_t$ Transit LOS score	2.88	2.89	2.89	2.93	2.95	2.85	2.97	2.94	3.06	2.96	3.17	2.75
<b>Output</b>												
<b>Transit LOS</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:19 Input and results of existing transit LOS for Route from Saris Abo to Piasa</b>												
<b>Multimodal Transit LOS Calculation</b>												
<b>Afternoon peak hour period</b>												
<b>Segment ID</b>												
<b>Inputs</b>	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6	Sp 7	SP 8	SP 9	SP 10	SP 11	SP 12
<b>TRANSIT OPERATIONS INFORMATION</b>												
Number of local buses on street segment per hour (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	25.63	23.81	22.52	21.55	20.41	19.66	18.50	18.68	17.04	15.94	15.21	14.82
$L_f$ Average passenger load factor (p/seat)	1.13	1.23	1.33	1.35	1.35	1.38	1.38	1.38	1.30	1.18	1.05	1.05
$S$ Average transit travel speed (mi/h)	11	5	12	19	29	3	6	9	4	25	10	7
$l_{pt}$ Average passenger trip length (mi)	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>												
$p_{sh}$ Percent stops in segment with a shelter	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
$p_{bc}$ Percent stops in segment with a bench	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	11.48	11.48	11.48	11.48	11.48	13.12	9.84	4.264	13.12	0	6.56
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No	No	No	No	No
$p_{pk}$ Proportion of on-street parking occupied	33%	25%	20%	0%	11%	19%	2%	19%	0%	31%	0%	4%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	13	9.84	9.84	9.84	9.84	9.84	9.84	11.48	11.48	11.48	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	140	182	170	209	226	274	210	230	437	420	334	278
Average vehicle running speed, including intersection delay												
$S_R$ (mi/h)	11	5	12	19	29	3	5.837	9	4	25	10	7
<b>Calculations</b>												
$f$ Transit frequency (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
$f_h$ Headway factor	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
$f_{pl}$ Passenger load weighting factor	1.46	1.66	1.85	1.90	1.90	1.94	1.95	1.94	1.81	1.57	1.30	1.30
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	7.0	6.5	6.1	5.9	5.6	5.4	5.0	5.1	4.6	4.3	4.1	4.0
$T_{ptt}$ Perceived travel time rate (min/mi)	21.8	35.0	21.5	17.8	15.1	44.7	30.1	22.9	34.6	12.5	15.7	19.9
$T_{bt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.57	0.52	0.57	0.60	0.62	0.50	0.53	0.56	0.52	0.66	0.62	0.58
$s_{w-r}$ Transit wait-ride score	1.41	1.28	1.41	1.48	1.55	1.24	1.32	1.39	1.29	1.63	1.53	1.44
$f_s$ Motorized vehicle speed adjustment factor	0.05	0.01	0.06	0.14	0.33	0.00	0.01	0.03	0.01	0.24	0.04	0.02
$f_v$ Motorized vehicle volume adjustment factor	0.32	0.41	0.39	0.48	0.51	0.62	0.48	0.52	0.99	0.96	0.76	0.63
$W_{aA}$ Adjusted available sidewalk width (ft)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.8	4.3	10.0	0.0	6.6
$f_{sw}$ Sidewalk width coefficient	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.05	4.72	3.00	6.00	4.03
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
$W_t$ lane/shoulder (ft)	13.0	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_v$ Effective total width as a function of traffic volume (ft)	13.0	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_l$ Effective width of combined bike lane and shoulder (ft)	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-5.11	-4.97	-4.79	-4.52	-4.68	-4.78	-4.55	-4.83	-4.24	-5.07	-2.81	-4.48
$I_p$ Pedestrian environment score	1.31	1.50	1.70	2.14	2.21	1.89	1.99	1.78	2.81	2.18	4.04	2.22
Pedestrian LOS	A	A	A	B	B	A	A	A	C	B	D	B
$I_t$ Transit LOS score	4.08	4.30	4.14	4.10	4.01	4.43	4.32	4.18	4.49	3.88	4.32	4.18
<b>Output</b>												
<b>Transit LOS</b>	<b>D</b>	<b>E</b>	<b>D</b>	<b>D</b>	<b>D</b>	<b>E</b>	<b>E</b>	<b>D</b>	<b>E</b>	<b>D</b>	<b>E</b>	<b>D</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:20 Input and results of improved transit LOS for Route from Saris Abo to Piasa</b>												
<b>Multimodal Transit LOS Calculation</b>												
<b>Afternoon peak hour period</b>												
<b>Segment ID</b>												
Inputs	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6	SP 7	SP 8	SP 9	SP 10	SP 11	SP 12
<b>TRANSIT OPERATIONS INFORMATION</b>												
Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6	6	6	6	6	6
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
$L_r$ Average passenger load factor (p/seat)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
$S$ Average transit travel speed (mi/h)	16	16	16	19	29	16	16	16	16	25	16	16
$l_{pt}$ Average passenger trip length (mi)	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>												
$p_{sh}$ Percent stops in segment with a shelter	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
$p_{be}$ Percent stops in segment with a bench	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	11.48	11.48	11.48	11.48	11.48	13.12	9.84	4.264	13.12	0	6.56
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No	No	No	No	No
$p_{pk}$ Proportion of on-street parking occupied	33%	25%	20%	0%	11%	19%	2%	19%	0%	31%	0%	4%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	9.8	9.8	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	13	9.84	9.84	9.84	9.84	9.84	9.84	11.48	11.48	11.48	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	140	182	170	209	226	274	210	230	437	420	334	278
$S_R$ Average vehicle running speed, including intersection delay (mi/h)	11	5	12	19	29	3	5.837	9	4	25	10	7
<b>Calculations</b>												
$f$ Transit frequency (bus/h)	6	6	6	6	6	6	6	6	6	6	6	6
$f_h$ Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pl}$ Passenger load weighting factor	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
$T_{ptt}$ Perceived travel time rate (min/mi)	9.9	9.9	9.9	9.3	7.9	9.9	9.9	9.5	9.9	8.3	9.9	9.9
$T_{btt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.71	0.71	0.71	0.73	0.77	0.71	0.71	0.72	0.71	0.75	0.71	0.71
$s_{wr}$ Transit wait-ride score	2.23	2.23	2.23	2.29	2.42	2.23	2.23	2.27	2.23	2.37	2.23	2.23
$f_s$ Motorized vehicle speed adjustment factor	0.05	0.01	0.06	0.14	0.33	0.00	0.01	0.03	0.01	0.24	0.04	0.02
$f_v$ Motorized vehicle volume adjustment factor	0.32	0.41	0.39	0.48	0.51	0.62	0.48	0.52	0.99	0.96	0.76	0.63
$W_{sa}$ Adjusted available sidewalk width (ft)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.8	4.3	10.0	0.0	6.6
$f_{sw}$ Sidewalk width coefficient	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.05	4.72	3.00	6.00	4.03
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Total width of outside lane, bike lane, and parking lane/shoulder (ft)	9.8	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_e$ Effective total width as a function of traffic volume (ft)	12.7	9.8	9.8	9.8	9.8	9.8	9.8	11.5	11.5	11.5	9.8	9.8
$W_1$ Effective width of combined bike lane and shoulder (ft)	10.0	10.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-5.11	-4.97	-4.91	-4.52	-4.68	-4.78	-4.55	-4.83	-4.24	-5.07	-2.81	-4.48
$I_p$ Pedestrian environment score	1.31	1.50	1.58	2.14	2.21	1.89	1.99	1.78	2.81	2.18	4.04	2.22
Pedestrian LOS	A	A	A	B	B	A	A	A	C	B	D	B
$I_t$ Transit LOS score	2.84	2.87	2.89	2.89	2.71	2.93	2.95	2.87	3.07	2.77	3.25	2.98
<b>Output</b>												
Transit LOS	C	C	C	C	B	C	C	C	C	C	C	C

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:21 Input and results of existing transit LOS for Route from Piasa to Saris Abo</b>												
<b>Multimodal Transit LOS Calculation</b>												
<b>Morning peak hour period</b>												
<b>Segment ID</b>												
Inputs	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12
<b>TRANSIT OPERATIONS INFORMATION</b>												
Number of local buses on street segment per hour (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0	0	0	0
$t_{ex}$ Average excess wait time (min)	15.05	16.50	11.55	9.53	9.23	9.15	9.09	9.28	9.77	10.91	9.85	9.35
$L_f$ Average passenger load factor (p/seat)	1.08	1.08	1.43	1.38	1.43	1.43	1.40	1.53	1.35	1.33	1.10	0.73
$S$ Average transit travel speed (mi/h)	6	24	6	6	10	10	6	13	12	20	21	10
$l_{pt}$ Average passenger trip length (mi)	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>												
$p_{sh}$ Percent stops in segment with a shelter	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
$p_{bc}$ Percent stops in segment with a bench	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
$W_A$ Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	19.68	6.56	9.84	9.84	13.12	11.48	11.48	11.5	11.48	11.48	11.48
$W_{buf}$ Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	Yes	No	No	No	No	No	No	No	No
$p_{pk}$ Proportion of on-street parking occupied	8%	13%	31%	0%	15%	11%	20%	9%	6%	11%	18%	17%
$W_{bl}$ Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$ Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{ol}$ Outside travel lane (closest to sidewalk) width (ft)	11.48	11.48	11.48	11.48	11.48	9.84	9.84	9.84	9.84	9.84	9.84	9.84
$v_m$ Outside lane demand flow rate at midsegment (veh/h)	385	490	536	560	515	224	230	242	248	235	216	223
$S_R$ (mi/h)	6	24	6	6	10	10	6.351	13	12	20	21	10
<b>Calculations</b>												
$f$ Transit frequency (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
$f_h$ Headway factor	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
$f_{pl}$ Passenger load weighting factor	1.36	1.37	2.03	1.94	2.03	2.04	1.99	2.20	1.90	1.85	1.41	1.00
$T_{at}$ Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$T_{ex}$ Excess wait time rate due to late arrivals (min/mi)	3.3	3.6	2.5	2.1	2.0	2.0	2.0	2.0	2.1	2.4	2.1	2.0
$T_{pt}$ Perceived travel time rate (min/mi)	20.6	10.6	26.0	24.0	16.8	16.2	22.7	14.2	13.7	10.3	8.3	10.1
$T_{bt}$ Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$ Perceived travel time factor	0.58	0.69	0.55	0.56	0.60	0.61	0.56	0.63	0.64	0.70	0.75	0.71
$s_{w-r}$ Transit wait-ride score	1.43	1.72	1.36	1.38	1.50	1.52	1.39	1.57	1.59	1.74	1.87	1.75
$f_s$ Motorized vehicle speed adjustment factor	0.01	0.23	0.01	0.01	0.04	0.04	0.02	0.07	0.06	0.16	0.18	0.04
$f_v$ Motorized vehicle volume adjustment factor	0.88	1.11	1.22	1.27	1.17	0.51	0.52	0.55	0.56	0.53	0.49	0.51
$W_{aA}$ Adjusted available sidewalk width (ft)	10.0	10.0	6.6	9.8	9.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0
$f_{sw}$ Sidewalk width coefficient	3.00	3.00	4.03	3.05	3.05	3.00	3.00	3.00	3.00	3.00	3.00	3.00
$f_b$ Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Total width of outside lane, bike lane, and parking lane/shoulder (ft)	11.5	11.5	11.5	11.5	11.5	9.8	9.8	9.8	9.8	9.8	9.8	9.8
$W_v$ Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	9.8	9.8	9.8	9.8	9.8	9.8	9.8
$W_1$ Effective width of combined bike lane and shoulder (ft)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$f_w$ Cross-section adjustment factor	-4.68	-4.75	-4.99	-4.57	-4.78	-4.68	-4.80	-4.66	-4.61	-4.68	-4.77	-4.76
$I_p$ Pedestrian environment score	2.25	2.65	2.29	2.76	2.48	1.92	1.79	2.01	2.06	2.06	1.95	1.83
Pedestrian LOS	B	B	B	C	B	A	A	B	B	B	A	A
$I_t$ Transit LOS score	4.20	3.82	4.31	4.35	4.12	4.01	4.18	3.94	3.93	3.70	3.49	3.65
<b>Output</b>												
Transit LOS	D	D	E	E	D	D	D	D	D	D	C	D

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

<b>Annex - C:22 Input and results of improved transit LOS for Route from Piasa to Saris Abo</b>													
<b>Multimodal Transit LOS Calculation</b>		<b>Morning peak hour period</b>											
		<b>Segment ID</b>											
<b>Inputs</b>		<b>PS 1</b>	<b>PS 2</b>	<b>PS 3</b>	<b>PS 4</b>	<b>PS 5</b>	<b>PS 6</b>	<b>PS 7</b>	<b>PS 8</b>	<b>PS 9</b>	<b>PS 10</b>	<b>PS 11</b>	<b>PS 12</b>
<b>TRANSIT OPERATIONS INFORMATION</b>													
	Number of local buses on street segment per hour (bus/h)	6	6	6	6	6	6	6	6	6	6	6	6
	Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0	0	0	0
$t_{ex}$	Average excess wait time (min)	10.00	10.00	10.00	9.53	9.23	9.15	9.09	9.28	9.77	10.00	9.85	9.35
$L_f$	Average passenger load factor (p/seat)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.73
$S$	Average transit travel speed (mi/h)	16	24	16	16	16	16	16	16	16	20	21	16
$l_{pt}$	Average passenger trip length (mi)	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
	Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>													
$P_{sh}$	Percent stops in segment with a shelter	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
$P_{be}$	Percent stops in segment with a bench	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>													
$W_A$	Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	19.68	6.56	9.84	9.84	13.12	11.48	11.48	11.48	11.48	11.48	11.48
$W_{buf}$	Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Are parking spaces striped?	No	No	No	Yes	No	No	No	No	No	No	No	No
$P_{pk}$	Proportion of on-street parking occupied	8%	13%	31%	0%	15%	11%	20%	9%	6%	11%	18%	17%
$W_{bl}$	Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$W_{os}$	Shoulder/parking lane width (ft)	0.0	0.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0
$W_{ol}$	Outside travel lane (closest to sidewalk) width (ft)	11.48	11.48	11.48	11.5	11.48	9.84	9.84	9.84	9.84	9.84	9.84	9.84
$v_m$	Outside lane demand flow rate at midsegment (veh/h)	385	490	536	560	515	224	230	242	248	235	216	223
	Average vehicle running speed, including intersection delay (mi/h)	6	24	6	6	10	10	6	13	12	20	21	10
$S_R$		6	24	6	6	10	10	6	13	12	20	21	10
<b>Calculations</b>													
$f$	Transit frequency (bus/h)	6	6	6	6	6	6	6	6	6	6	6	6
$f_h$	Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
$f_{pl}$	Passenger load weighting factor	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.00
$T_{at}$	Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$T_{ex}$	Excess wait time rate due to late arrivals (min/mi)	2.2	2.2	2.2	2.1	2.0	2.0	2.0	2.0	2.1	2.2	2.1	2.0
$T_{ptt}$	Perceived travel time rate (min/mi)	8.8	7.3	8.8	8.3	8.5	8.4	8.4	8.5	8.7	7.9	7.7	7.8
$T_{btt}$	Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
$f_{tt}$	Perceived travel time factor	0.74	0.79	0.74	0.75	0.75	0.75	0.75	0.75	0.74	0.77	0.78	0.77
$S_{w-r}$	Transit wait-ride score	2.33	2.49	2.33	2.38	2.36	2.37	2.36	2.36	2.34	2.42	2.44	2.43
$f_s$	Motorized vehicle speed adjustment factor	0.01	0.23	0.01	0.01	0.04	0.04	0.02	0.07	0.06	0.16	0.18	0.04
$f_v$	Motorized vehicle volume adjustment factor	0.88	1.11	1.22	1.27	1.17	0.51	0.52	0.55	0.56	0.53	0.49	0.51
$W_{aA}$	Adjusted available sidewalk width (ft)	10.0	10.0	6.6	9.8	9.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0
$f_{sw}$	Sidewalk width coefficient	3.00	3.00	4.03	3.05	3.05	3.00	3.00	3.00	3.00	3.00	3.00	3.00
$f_b$	Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
	Total width of outside lane, bike lane, and parking lane/shoulder (ft)	11.5	11.5	11.5	11.5	11.5	9.8	9.8	9.8	9.8	9.8	9.8	9.8
$W_t$	Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	9.8	9.8	9.8	9.8	9.8	9.8	9.8
$W_1$	Effective width of combined bike lane and shoulder (ft)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0
$f_w$	Cross-section adjustment factor	-4.68	-4.75	-4.99	-4.57	-4.78	-4.68	-4.80	-4.66	-4.61	-4.81	-4.77	-4.76
$I_p$	Pedestrian environment score	2.25	2.65	2.29	2.76	2.48	1.92	1.79	2.01	2.06	1.93	1.95	1.83
	Pedestrian LOS	B	B	B	C	B	A	A	B	B	A	A	A
$I_t$	Transit LOS score	2.85	2.67	2.85	2.85	2.83	2.74	2.72	2.77	2.81	2.67	2.63	2.63
<b>Output</b>													
<b>Transit LOS</b>		<b>C</b>	<b>B</b>	<b>C</b>	<b>C</b>	<b>C</b>	<b>B</b>	<b>B</b>	<b>C</b>	<b>C</b>	<b>B</b>	<b>B</b>	<b>B</b>

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

Annex - C:23 Input and results of existing transit LOS for Route from Piasa to Saris Abo												
Multimodal Transit LOS Calculation			Afternoon peak hour period									
			Segment ID									
Inputs	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12
<b>TRANSIT OPERATIONS INFORMATION</b>												
Number of local buses on street segment per hour (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
Number of express buses stopping in segment per hour (bus/h)	0	0	0	0	0	0	0	0	0	0	0	0
t <sub>ex</sub> Average excess wait time (min)	25.46	25.14	26.34	28.84	29.92	30.98	30.98	31.41	31.56	32.16	32.44	44.58
L <sub>r</sub> Average passenger load factor (p/seat)	1.40	1.40	1.55	1.63	1.63	1.63	1.60	1.68	1.55	1.50	1.33	0.88
S Average transit travel speed (mi/h)	2	14	6	3	7	5	6	5	19	15	9	10
l <sub>pt</sub> Average passenger trip length (mi)	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>												
p <sub>sh</sub> Percent stops in segment with a shelter	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
p <sub>be</sub> Percent stops in segment with a bench	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
W <sub>A</sub> Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	19.68	6.56	9.84	9.84	13.12	11.48	11.48	11.48	11.48	11.48	11.48
W <sub>buf</sub> Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No	No	No	No	No
p <sub>pk</sub> Proportion of on-street parking occupied	7%	16%	28%	0%	8%	11%	19%	5%	7%	18%	2%	8%
W <sub>bl</sub> Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W <sub>os</sub> Shoulder/parking lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W <sub>ol</sub> Outside travel lane (closest to sidewalk) width (ft)	11.48	11.48	11.48	11.48	11.48	9.84	9.84	9.84	9.84	9.84	9.84	9.84
v <sub>m</sub> Outside lane demand flow rate at midsegment (veh/h)	392	485	510	524	482	110	132	149	203	188	268	285
Average vehicle running speed, including intersection delay (mi/h)	2	14	6	3	7	5	6.3912	5	19	15	9	10
<b>Calculations</b>												
f Transit frequency (bus/h)	3	3	3	3	3	3	3	3	3	3	3	3
f <sub>h</sub> Headway factor	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
f <sub>pl</sub> Passenger load weighting factor	1.99	1.99	2.24	2.36	2.36	2.37	2.32	2.45	2.24	2.16	1.85	1.07
T <sub>at</sub> Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T <sub>ex</sub> Excess wait time rate due to late arrivals (min/mi)	5.5	5.5	5.7	6.3	6.5	6.7	6.7	6.8	6.9	7.0	7.1	9.7
T <sub>ptt</sub> Perceived travel time rate (min/mi)	59.7	19.3	35.4	61.8	32.8	41.9	35.3	44.0	20.7	22.5	26.6	25.8
T <sub>bt</sub> Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
f <sub>tt</sub> Perceived travel time factor	0.48	0.58	0.52	0.48	0.52	0.50	0.52	0.50	0.57	0.56	0.54	0.55
s <sub>w-r</sub> Transit wait-ride score	1.19	1.45	1.28	1.19	1.30	1.25	1.28	1.24	1.43	1.40	1.35	1.36
f <sub>s</sub> Motorized vehicle speed adjustment factor	0.00	0.08	0.01	0.00	0.02	0.01	0.02	0.01	0.15	0.09	0.03	0.04
f <sub>v</sub> Motorized vehicle volume adjustment factor	0.89	1.10	1.16	1.19	1.10	0.25	0.30	0.34	0.46	0.43	0.61	0.65
W <sub>aa</sub> Adjusted available sidewalk width (ft)	10.0	10.0	6.6	9.8	9.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0
f <sub>sw</sub> Sidewalk width coefficient	3.00	3.00	4.03	3.05	3.05	3.00	3.00	3.00	3.00	3.00	3.00	3.00
f <sub>b</sub> Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
W <sub>t</sub> Total width of outside lane, bike lane, and parking lane/shoulder (ft)	11.5	11.5	11.5	11.5	11.5	9.8	9.8	9.8	9.8	9.8	9.8	9.8
W <sub>e</sub> Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	14.2	13.1	12.3	9.8	9.8	9.8	9.8
W <sub>l</sub> Effective width of combined bike lane and shoulder (ft)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
f <sub>w</sub> Cross-section adjustment factor	-4.67	-4.79	-4.96	-4.57	-4.69	-4.79	-4.87	-4.66	-4.62	-4.77	-4.56	-4.64
I <sub>p</sub> Pedestrian environment score	2.27	2.45	2.26	2.67	2.47	1.51	1.49	1.73	2.04	1.80	2.13	2.10
Pedestrian LOS	B	B	B	B	B	A	A	A	B	A	B	B
I <sub>t</sub> Transit LOS score	4.55	4.19	4.42	4.61	4.42	4.35	4.30	4.40	4.17	4.17	4.30	4.28
<b>Output</b>												
Transit LOS	E	D	E	E	E	E	E	E	D	D	E	E

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

Annex - C:24 Input and results of improved transit LOS for Route from Piasa to Saris Abo												
Multimodal Transit LOS Calculation				Afternoon peak hour period								
				Segment ID								
Inputs	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	PS 8	PS 9	PS 10	PS 11	PS 12
<b>TRANSIT OPERATIONS INFORMATION</b>												
Number of local buses on street segment per hour (bus/h)		6	6	6	6	6	6	6	6	6	6	6
Number of express buses stopping in segment per hour (bus/h)		0	0	0	0	0	0	0	0	0	0	0
t <sub>ex</sub> Average excess wait time (min)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
L <sub>f</sub> Average passenger load factor (p/seat)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88
S Average transit travel speed (mi/h)	16	16	16	16	16	16	16	16	19	16	16	16
l <sub>pt</sub> Average passenger trip length (mi)	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60
Is the segment in the CBD of a metro area of 5 million or more?	No	No	No	No	No	No	No	No	No	No	No	No
<b>TRANSIT AMENITY DATA</b>												
P <sub>sh</sub> Percent stops in segment with a shelter	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
P <sub>be</sub> Percent stops in segment with a bench	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
<b>PEDESTRIAN ENVIRONMENT DATA</b>												
W <sub>A</sub> Sidewalk width (ft) (Enter 0 if no sidewalk)	11.48	19.68	6.56	9.84	9.84	13.1	11.5	11.48	11.48	11.48	11.48	11.5
W <sub>buf</sub> Buffer width from sidewalk to street (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Does a continuous barrier exist between the street and sidewalk?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is the street divided?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are parking spaces striped?	No	No	No	No	No	No	No	No	No	No	No	No
P <sub>pk</sub> Proportion of on-street parking occupied	7%	16%	28%	0%	8%	11%	19%	5%	7%	18%	2%	8%
W <sub>bl</sub> Bicycle lane width (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W <sub>os</sub> Shoulder/parking lane width (ft)	0.0	0.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0
W <sub>ol</sub> Outside travel lane (closest to sidewalk) width (ft)	11.48	11.48	11.48	11.5	11.5	9.84	9.84	9.84	9.84	9.84	9.84	9.84
v <sub>m</sub> Outside lane demand flow rate at midsegment (veh/h)	392	485	510	524	482	110	132	149	203	188	268	285
S <sub>R</sub> Average vehicle running speed, including intersection delay (mi/h)	2	14	6	3	7	5	6	5	19	15	9	10
<b>Calculations</b>												
f Transit frequency (bus/h)	6	6	6	6	6	6	6	6	6	6	6	6
f <sub>h</sub> Headway factor	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
f <sub>pl</sub> Passenger load weighting factor	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.07
T <sub>at</sub> Perceived amenity time rate (min/mi)	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T <sub>ex</sub> Excess wait time rate due to late arrivals (min/mi)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
T <sub>ptt</sub> Perceived travel time rate (min/mi)	8.8	8.8	8.8	8.5	8.8	8.8	8.8	8.8	8.0	8.8	8.8	8.4
T <sub>btt</sub> Base travel time rate (min/mi)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
f <sub>tt</sub> Perceived travel time factor	0.74	0.74	0.74	0.75	0.74	0.74	0.74	0.74	0.76	0.74	0.74	0.75
S <sub>w-r</sub> Transit wait-ride score	2.33	2.33	2.33	2.36	2.33	2.33	2.33	2.33	2.41	2.33	2.33	2.37
f <sub>s</sub> Motorized vehicle speed adjustment factor	0.00	0.08	0.01	0.00	0.02	0.01	0.02	0.01	0.15	0.09	0.03	0.04
f <sub>v</sub> Motorized vehicle volume adjustment factor	0.89	1.10	1.16	1.19	1.10	0.25	0.30	0.34	0.46	0.43	0.61	0.65
W <sub>aA</sub> Adjusted available sidewalk width (ft)	10.0	10.0	6.6	9.8	9.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0
f <sub>sw</sub> Sidewalk width coefficient	3.00	3.00	4.03	3.05	3.05	3.00	3.00	3.00	3.00	3.00	3.00	3.00
f <sub>b</sub> Buffer area coefficient	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37	5.37
W <sub>t</sub> Total width of outside lane, bike lane, and parking lane/shoulder (ft)	11.5	11.5	11.5	11.5	11.5	9.8	9.8	9.8	9.8	9.8	9.8	9.8
W <sub>v</sub> Effective total width as a function of traffic volume (ft)	11.5	11.5	11.5	11.5	11.5	14.2	13.1	12.3	9.8	9.8	9.8	9.8
W <sub>l</sub> Effective width of combined bike lane and shoulder (ft)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.0	0.0
f <sub>w</sub> Cross-section adjustment factor	-4.67	-4.79	-4.96	-4.57	-4.69	-4.79	-4.87	-4.66	-4.62	-4.89	-4.56	-4.64
I <sub>p</sub> Pedestrian environment score	2.27	2.45	2.26	2.67	2.47	1.51	1.49	1.73	2.04	1.68	2.13	2.10
Pedestrian LOS	B	B	B	B	B	A	A	A	B	A	B	B
I <sub>t</sub> Transit LOS score	2.85	2.88	2.85	2.86	2.88	2.74	2.73	2.77	2.70	2.76	2.83	2.76
<b>Output</b>												
Transit LOS	C	C	C	C	C	B	B	C	B	C	C	C

*Evaluating Quality of Service on Public Bus Transportation and Improvement Strategy in  
Addis Ababa :( A Case Study on Sheger Mass Transport Enterprise)*

---