Jimma University

Jimma Institute of Technology

School of Graduate Studies

Faculty of Civil and Environmental Engineering

Highway Engineering Stream

Assessment on the Performance of Bus Station and Identification of the Cause of Traffic Congestion in Harar City Bus Station.

A Final MSc Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Highway Engineering

By:

Ahmed Saali

April, 2019

Jimma, Ethiopia

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DECLARATION

I, the undersigned, declared that the research entitled by "Assessment on the Performance of Bus Station and Identification of the Cause of Traffic Congestion in Harar City Bus Station" is my original work, and has not been presented by any other person for an award of a degree in this university or any other universities except to cite from listed references attached and all sources of materials used for this research have been duly acknowledged.

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As Master Research Advisors, we hereby certify that we have review and evaluated carefully this MSc research prepared under our guidance by me, entitled.

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ABSTRACT

As the increasing number of Vehicles and Passenger users, the traffic Congestions becomes common problem in the developing countries. In Ethiopia, traffic congestion is becoming a new phenomenon on the transportation infrastructures. The bus station is one of the most important transportation infrastructures where a bus stops to pick up and drop off passengers. In Harar city, there is only one bus station which serviced for Local and Long distance bus. Due to different causes, traffic congestion is becoming a more serious problem in the Bus station. The objective of this research is to assess the Performance of bus station and to identify the cause of traffic congestion in Harar City Bus Station. In order to achieve the objective of this research, the necessary data were collected through the field visual inspection, field measurements and traffic data video recording. Typical data required for this were processed and analyzed based on empirical calculation of HCM, GIS, Microsoft Excel and SPSS software. The results of the research displayed that unadjusted and adjusted capacity value of the bus station was 204 and 167 respectively. The cause of traffic congestion in Harar city Bus station is formed by increasing the number of passenger and buses, insufficient capacity in loading area, mixed traffic system, lack of good schedule, unbalance the number of arrival and departure busses and also, the main cause of traffic congestion in bus station is formed by local busses in the morning and long distance busses in the afternoon. So, to minimize traffic congested in the bus station this study was recommended that the Harar City Municipality would have to determine the required number of loading area and Prepare billboard schedule for local and long distance buses and also, the future work would have to be required to prepare manual for Bus Station.

Key words: Bus Dwell Time, Bus Stop, Bus Station Capacity, Congestion, Loading Area, Bus Schedule, Performance.

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ACRONYMS

ASHTOO	American Association of State Highway and Transportation Officials
CBD	Central Business District
D/C	Demand to Capacity ratio
ERA	Ethiopian Road Authority
GIS	Geographical Information System
GPS	Global Position System
HCM	Highway Capacity Manual
JIT	Jimma Institute of Technology
JU	Jimma University
LOS	Level of Service
PHF	Peak Hour Factor
TBR	Transit Bus Rapid
TCQSM	Transit Capacity and Quality Service Manual
V/C	Volume to Capacity ratio

CHAPTER ONE

INTRODUCTION

1.1. Background

Globally, the rate of urbanization is increasing at an alarming rate with 50% of the world population expected to live in urban areas by 2025 and more transformation are expected in developing countries (WorldBank, A Worlds Bank Urban Transport Strategy. Review., 2002.). Despite some economic benefits, the rapid urban growth in the developing countries is out stripping the capacity of most cities to provide adequate services for their citizens (Cohen.B, 2004.).

Public transit services are supported for daily commute in many major cities in the world. A limited stop service serving a selected subset of nodes in a corridor provides another alternative and helps transit operators in reducing overall passenger travel time. Hence, a limited stop service is of reasonable financial and social importance to Bus transit operation and due academic attention needs to be given to developing methodologies for Bus operators to design their operating strategies (Wang, 2018).

Urban economic activities and movements have a direct relationship. An adequate transport system is needed to facilitate a greater choice of the peripheral areas if urban transport provided by the government. Because of most socioeconomic activities concentrated in the center of city, many urban mobility problems are created, such as increasing car usage and trips to the central Business districts. This in turn leads to high demand for parking, urban environmental problem (pollution, noise), and inabilities to handle these problems results in congestion (Cameron J.W.M., 2003).

(Zhang et al, 2014) Different types of Bus stops could have different impacts on the operation of Buses. However, development of human population is having an effect on the increase of facilities and transportation needs. One of the primary problems is the availability of parking area (Herdis, 2017). As the increasing number of vehicles and passenger users, the traffic Congestions become common characteristics in urban road transportation system of cities in developing countries which result in high operating cost, loss of user's productive time, and more fuel consumption among others (WorldBank, A Worlds Bank Urban Transport Strategy. Review., 2002.).

Transit center is one of the most important transportation infrastructures where a Bus stops to pick up and drop off passengers. It may be intended as a terminal or station for a number of routes or as a transfer station where the routes continue. It is larger than a Bus stop where the Bus stop is usually built at the road side for the Bus to stop for a while, but not to wait for passengers (UK, 2017).

Historically, Harar City had a solid advantage of being located on one of the major trade routes which linked to the Northern and Southern regions of the Ethiopian plateau. Nowadays, tourists come to Harar attracted by its historical Jogal rampart and the rapid urbanization process, high vehicular population growth has created significant transport problems in Harar city (WEHIB, 2015). However, the transport system is a serious problem in the city, especially at the Bus station.

The Bus station in Harar city is located in the central Business district and it has connected with route network, which servicing for locals and long distance Bus transport. Nowadays, Congestion is becoming a more serious problem for Busses and passenger demand. It cannot able to manage all the current Bus and passenger demand sufficiently. Lack of the space, good schedule management system, overlapping local and long distance Busses were available at the same station, it could be formed congestion in the station. So, to understand and solve the cause of traffic congestion problem in the study area, assessing the performance of the Bus station and identifying the cause of traffic congestion is a very important area of consideration in order to make the right decision to solve the problems.

1.2. Statement of Problem

The public transportation service has been prioritized for the development of the country, yet the transit centers and the facilities related to it are being neglected and not maintained properly to serve the users well. Lack of sufficient capacity of loading area increases service time for Buses and passengers. High level of passenger activity attracts Business and retail functions, for such activity the Efficient Bus station plays a vital role in the operation, convenient and safe transit system (Translink, 2011).

In Ethiopia, traffic congestion is becoming a new phenomenon. It has an economic cost on the city communities and the economy. The traffic congestion is an outcome of various factors. These are, long travel time to reach a destination that affects Business user's productivity time, increasing fuel consumption are the main impacts of traffic congestion which still prevail (Yared, 2010.).

Harar City is the trade center of Eastern Hararge and Harari region. It has only one Bus station in the city which is servicing for Local and Long distance Bus. The number of passengers and Buses are increasing from time to time at the station. But nowadays, Traffic congestion is the more serious problem in the Bus station. Traffic congestion in the study area were formed by different causes such as insufficient Bus station capacity, increasing passengers and Busses demand, insufficient space, lack of good schedule system, increasing the number of long distance Bus and local Busses at the station etc. However, the existing Harar Bus Station is unable to manage the current high transport services demand with the existing Capacity of the station. So, Assessment on the performance of Bus Station and identifying the cause of Traffic Congestion in the study area is very important area of consideration in this research.

1.3. Research question

1. What are the existing geometric configurations of Bus berth design in the Harar City Bus Station?
2. How a Buses and Passengers are distributed in the study area?
3. What is the maximum estimated Capacity of Harar City Bus Station?
4. What are the causes of traffic congestion in Harar City Bus Station?
5. What are the possible solutions used to minimize traffic congestion in the study area?

1.4. Objective of the Study

1.4.1. General objective

The general objective of this study is to assess Capacity of Bus Station and to identify the cause of Traffic Congestion in Harar City Bus Station.

1.4.2. Specific objectives

1. To identify the existing geometric configuration of Bus berth design in the Harar City Bus Station.
2. To determine the distribution variation of Buses and Passenger at study area.
3. To estimate the maximum capacity of the Harar City Bus Station.
4. To identify causes of traffic congestion in the study area.
5. To indicate possible solutions that used to minimize traffic congestion in the study area.

1.5. Scope of the Study

This study was focused on the existing Bus Station which located in Harar City. The study was address issues related to Capacity of Bus Station and the cause of Traffic Congestion in Harar City Bus Station. The specific focus of it includes: the existing geometric configuration of Bus berth design in the Bus Station, distribution variation of Buses and Passenger, the Level of Service (LOS) of the bus stops in Bus Station and the causes of traffic congestion in the Harar City Bus Station.

1.6. Significance of the Study

It will allow the researcher to assess the Bus station capacity and the cause of congestion on transportation and traffic system by building academic knowledge and provide a base for design improvement.

It will also benefit to Jimma Institute of Technology (JIT) in attaining its objective as a center of academic excellence and hurry the national development through provision of problem solving research output of policy and decision makers.

The Harar city administrator and municipality will be use the finding of this research work as a base for other Bus station planning and design.

Engineers and related researcher would be engineers will be use the result of this research as a reference for any planning and designing of Bus station.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

In this literature review, the researcher was assessed relevant literatures on the operational factors to the estimation capacity of Bus station, Classifications of Bus Stations, the relationship between demand and capacity, and also discusses in detail on the cause of congestion at the Bus station is discussed.

2.2. Bus Station

Transit stops, stations, and terminals (generically referred to as stations) are the locations where passengers board, alight from, and transfer between transit vehicles. They range in size and complexity from simple street side Bus stops to large intermodal terminals (TCQSM, 2013).

The stops and station are the only points where customers access the transit service. However, scheduling a Bus to observe a stop at the station inflates its journey time due to the delay caused by the stop. The time spent by a Bus at a stop to serve its passengers is commonly known as dwell time. However, in reality the dwell time, is not only component of Bus delay due to stop ((Changshan, 2005).

2.3.Types of Station

Various types of transit stop, stations, and terminals provide service tailored to the specific needs of a transit system or a particular locale. These facilities often have common features and elements, but they may display unique characteristics. The basic types of transit stop, stations, and terminals are presented in this chapter (TCQSM, 2013).

2.3.1. Bus Stops

Most Bus stops are located along streets and consist of a waiting area integrated with the public sidewalk, signage to mark the Bus stop, and, in some cases (depending on passenger volume, available space, and available power), small-scale passenger amenities such as a bench, small shelter, bicycle parking, printed schedule and route information, or real-time Bus-arrival displays. Lighting, either from adjacent street lighting or built into a shelter, is desirable to enhance nighttime security. Bus stops can also be located on- or off-street in conjunction with transit centers, rail transit stations, or intermodal terminals; these are discussed in the "Transit Centers “section that follows (TCQSM, 2013).

2.3.2.Transit Centers

The term transit center is normally applied to facilities where multiple Bus routes converge, offering transfer opportunities between routes and, frequently, layover area for Bus routes that terminate at the center. The term can also apply to intermodal stations that may combine transfers between local Buses with opportunities to transfer to rail and other modes. Both types of facilities are normally located wholly or partially off-street. The best way finding information is essential for passengers to find their way to their transfer connection, and should also consider the needs of persons with disabilities. Amenities beyond those that might be found at an on-street Bus stop can include a larger or more elaborate shelter, climate-controlled waiting areas, ticket sales, concessions, transit system and neighborhood maps, secure bicycle parking, taxi stands, restrooms, and a passenger pick-up/drop-off area (TCQSM, 2013).

2.3.3. Busway and Bus Stations

Busway and Bus rapid transit (BRT) stations are located along roadways or lanes dedicated for Buses and are frequently larger and more elaborate than typical Bus stops, but are often shorter than light rail stations. Like the Busways they serve, these stations may be either off-street or on-street. The length of a Busway or BRT station is generally 40 to 100ft (12 to 30m) but some extend to 400ft (120m) to serve multiple routes and services. Amenities may be limited, consisting of just a paved area and sign, or more elaborate, with shelters, seating, ticket machines, real-time Bus arrival information, radiant heating, security features, and other amenities (TCQSM, 2013).

2.3.4. Light Rail and Streetcar Stations

Light rail stations are typically 180 to 400ft (55 to 120m) long. Various platform configurations are possible, including center, side, or split on opposite sides of an intersection. Stations may be on-street, off-street, along a railroad right-of-way, on a transit mall, or as part of a transit center (TCQSM, 2013).

2.3.5. Intermodal Terminals

The term intermodal terminals refer to a variety of stations and terminals that provide key transfers between transit modes. Combinations may include local Bus, Bus rapid transit, intercity Bus, light rail, heavy rail, commuter rail, intercity passenger rail, ferry (TCQSM, 2013).

2.4. Bus Stations Designing Configurations

A Bus station is here defined as a facility for alighting and boarding of passengers from several Bus lines for interconnection or transfer to other modes of transport. Bus station capacity can be defined as the total number of Buses that can be served by the station per time unit (e.g. Hour) at a given frequency ratio for each Bus line (Al-Mudhaffar, 2016).

The station with Bus stops for regional traffic can be placed together with the Bus stops for local traffic at the travel center. The problem can be to allocate space for layover time for the regional Buses. (kommuner, Trafik f¨or en attraktiv stad:, 2015) points out that Bus lines does not necessarily need to have the stations as end destination and thus no layover time there. If the terminal is just as any stop along the route, there is no need for space for time regulation. When the terminal is the end of the line and time regulation is required, more space is needed and the terminal cannot be placed right outside the entrance.

(Traficvetake, 2013) Emphasis that the travelers and their interchanges should have focus when planning Bus stations and travel centers. Furthermore, the design and placement of the Bus stops within the terminal should enable interchanges to be made with a normal walking pace. This means that the Bus stops, and the Bus stations, need to be located near the main walkways from the train platforms.

2.4.1. Bus Berth Designs

Four types of Bus berths are typically applied: linear, sawtooth, drive-through, and pull-in back-out. Many larger Bus-operating transit agencies have developed design guidance for Bus berths specific to their Bus fleets. Preferably, desired operating patterns should dictate the type of Bus berths used, rather than the berths placing

Constraints on the operation. A Bus terminal may have more than one type of berth to best serve different operating patterns and characteristics (TCQSM, 2013).

A. Linier berth

Linier berth can operate in series and have capacity characteristics similar to on-street Bus stops. Their main advantage is that they require the least curb space-as long as Buses do not need to move in and out of berths independently of each other. If independent Bus movement is required, linear berths can actually require more curb space than other types (e.g., sawtooth), as buffer space is needed between each Bus stopping position to allow Buses to enter and exit each berth.

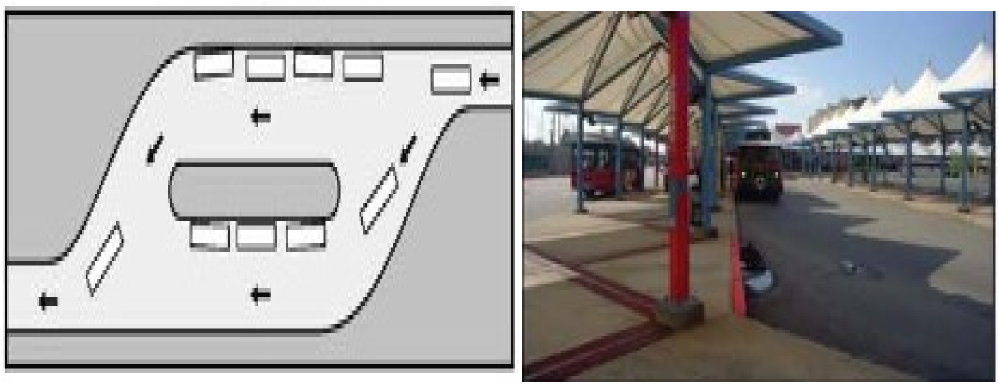

Figure2.1: Linier berth design

B. Sawtooth berth design

Is a popular design, as they permit independent movement into and out of the berth, while retaining the ability to design Bus stops around either a central island platform or along the perimeter of the Bus roadway. Both of these types of stations designs ***minimize the need for pedestrian crossings*** of the Bus roadway. Shallow sawtooth berths laid end to end are increasingly used in transit terminal design.

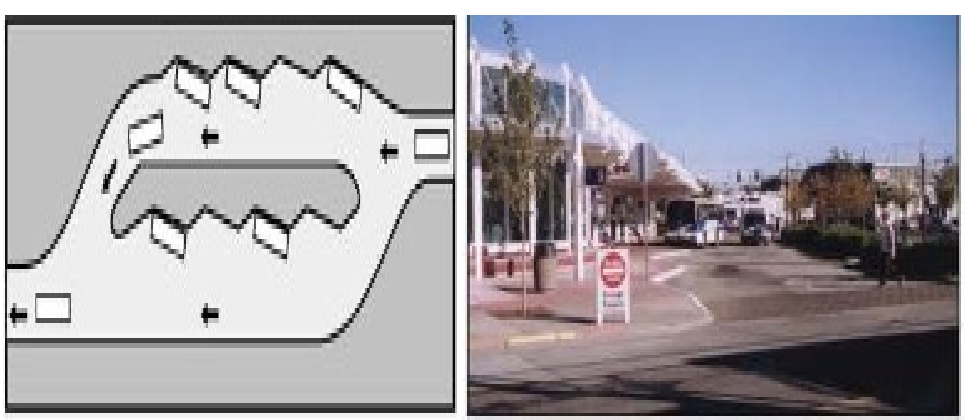

Figure2.2: Sawtooth berth design

C. Drive-through berth

Provide a series of boarding islands placed at a 45° or 90° angle to the flow of Bus traffic through the station. They provide a compact Bus berth layout, but require passengers to cross the Bus roadway to access the islands, which increases potential ***conflicts between Buses and pedestrians.***

Figure 2.3: Drive through berth

D. Pull-in back

Out berths are rarely used in Bus transit stations, except in very constrained sites, due to the hazards of backing a Bus out with ***very limited driver visibility (back-up cameras help mitigate this hazard to some degree***). They are sometimes used in intercity Bus terminals, where Buses occupy berths for long periods of time, and staff may be available to guide Bus drivers out of the berths.

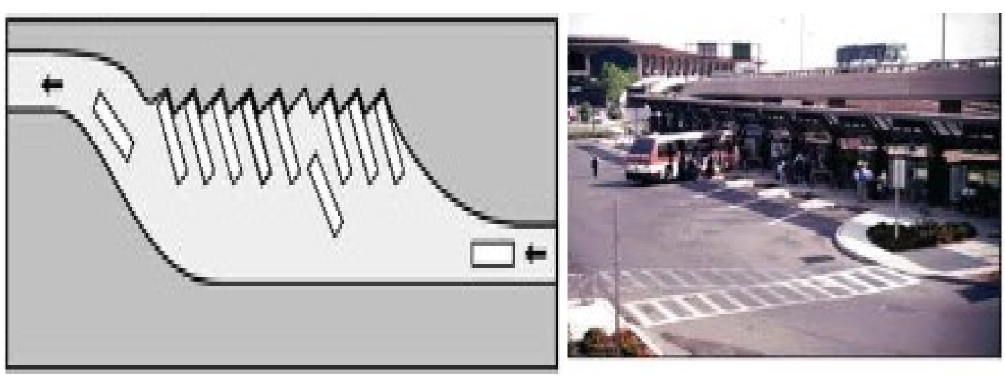

Figure 2. 4: Pull-in back

The National Transportation Safety Board recommends that transit facility designs incorporating sawtooth berths, or other types of berths that may direct errant Buses towards pedestrian-occupied areas, should include provisions for positive separation (such as bollards) between the roadway and pedestrian areas sufficient to stop a Bus operation under normal parking area speed conditions from progressing into the pedestrian area (TCQSM, 2013).

2.4.2. Determining the Required Number of Bus Berths

The number of Bus berths provided at a Bus station depends on a variety of factors, including the size and layout of the site; the number of routes passing through the station and their headways; and the number of routes terminating at the station, their headways, their scheduled layover /recovery time, and the type of Buses and services (e.g., urban, regional, intercity).One method for determining the maximum required Bus berth is as follows (TransLink, 2007).

- Routes running through the station require two berths to pick up and drop off passengers (one for each direction of the route).
- Routes terminating at the station require one berth to pick up passengers and, potentially, additional layover berths, if it is likely that one or more following Buses on a route would arrive prior to the end of a given Bus's recovery time.
- The number of berths needed for a route is determined by the route's recovery time at station divided by the route headway, multiplied by a factor of 1.2 to account for early-arriving Buses, rounded up. For example, a route with 5minute headways and a 10-minute recovery at the station would require (10/5 x 1.2) = 2.4 berths, rounded up to 3 berths. If the calculation indicates that only one berth is required, layover needs can be met in the berth used for passenger pick-up and no separate layover berth is required.
- When layover berths are required, an additional berth shared by all terminating routes should be provided in a convenient for dropping off passengers. More than one berth might be needed, depending on Bus volumes and arrival patterns. Headways and recovery time may vary over the day, so the combination that produces the greatest required number of berths should be used in determining the maximum number of berths needed. Consideration should also be given to sizing the station to accommodate future growth (i.e., anticipated route headways in the long term)."Intelligent" Bus stations have been developed in some European cities (Bussen, 2011.).

2.5. Bus and Passenger Demand Characteristics

2.5.1. Passenger Demand Characteristics

How passenger demand is distributed spatially along a route and how it is distributed over time during the analysis period affects the number of boarding passengers that can be carried. Because of the spatial aspect of passenger demand, person capacity must be stated for a location (typically the maximum load point), not for a route or a street as a whole. Passenger demand fluctuates during the peak hour. The peak-hour factor (PHF) reflects peak demand volumes typically over a 15-min period during the hour. A transit system should provide sufficient capacity to accommodate peak passenger demand. However, since peak demand is not sustained over the entire hour, and since every transit vehicle will not experience the same peak loadings, actual person capacity during the hour will be less than the peak 15-min demand volumes (HCM, 2010).

Passenger load standards typically specify a design load for a transit vehicle, the sum of the seated and standing passengers that is a desirable maximum. Different standards are sometimes established for peak and off-peak periods, reflecting both the need to balance transit agency costs (e.g., increased frequency, longer trains) with passenger comfort during peak periods and differing passenger characteristics at different times of the day. Standards can be expressed as an absolute not to be exceeded, or as an average during a peak 15-, 30-, or 60-min period. Using an average passenger load in a standard provides more flexibility and greater design capacity than using an absolute load, as less capacity has to be held in reserve (and possibly not used) as an allowance for surges in passenger demand (Kittelson, 2013).

The average passenger trip length affects how many passengers can board a transit vehicle as it travels its route. If trips tend to be long with passengers boarding near the start of the route and alighting near the end, vehicles will not board as many passengers as when passengers board and alight at many locations. However, the total number of passengers on board at the maximum load points may be similar for each route. The distribution of the passengers among transit stops affects the dwell time of vehicle at each stop. If passenger boarding's are concentrated at one stop, the vehicle capacity (and person capacity at the maximum load point) is greater when passenger boarding volume (dwell times) is evenly distributed among stops (HCM, 2010).

2.5.2. Peak-Hour Demand Variation

Passenger demand can also vary within the peak period. Some of this variation is attributable to people timing their trips to arrive at a destination (e.g., job, school) as close to the desired starting time as possible; another is due to day-to-day variations in people' s activities that result in them taking different transit vehicles on different days. These variations have implication on the level of onboard crowding, as a service scheduled to accommodate an average demand over the peak hour may experience overcrowded conditions during the peak of the peak

The concept of a peak hour factor (PHF) is used to express this demand variation within the peak hour (or any other analysis hour). The PHF is defined as the demand during the hour divided by four times the demands during the peak 15 min of the hour. Thus a PHF of 1.00 indicates even demand in each 15 min period of the hour, while a PHF of 0.25 would indicate that all the demand occurs in one 15-min period. Typically, transit PHF range from 0.60 to 0.95 (TCQSM, 2013).

2.5.3.Vehicle Characteristics

The number of transit vehicles that can stop simultaneously at a stop or station directly affects the facility capacity. The number of doors available for passenger use and their width influences how many passengers can simultaneously boarding or alighting a transit vehicle, which in turn affects dwell time. However, even when several doors are provided, on board fare collection needs may restrict boarding passengers to using the front door. In addition, the seating arrangement inside the Bus (e.g., seats facing forward vs. seats facing the aisle, number of seats per row) influences the width of the aisle and thus the ease with which passengers can circulate to and from the doors when standees are present (TRB, 2013).

2.5.4. Bus operations on the Bus station platform

The time a Bus occupies the station consists of the following:

- ***Queue time***: The time spent in queue until the Bus reaches the loading area where it will serve passengers.
- ***Dwell time*****:** Including time for passengers to reach the Bus door at its loading area position, time to serve passengers through the Busiest door, and time to open and close the doors.

- ***Clearance time***: is the time which includes any re-entry delay due to waiting in turn for any Buses at loading areas that are blocking the subject Bus to depart, plus any re-entry gap acceptance delay (TRB, 2013).

2.6. General Transit Capacity concepts

Transit capacity is different from highway capacity. It deals with the movement of both people and vehicles; it depends on the size of the transit vehicles and how often they operate; and it reflects the interaction of passenger traffic and vehicle flow. Transit capacity depends on the operating policy of the transit agency, which specifies service frequencies and allowable passenger loadings (HCM, 2010).

Capacity deals with how many people and Buses can move past a given location during a given time period under specified operating conditions; without unreasonable delay, hazard, or restriction; and with reasonable certainty. Public transit service focuses on moving people from one place to another. Consequently, transit capacity is focuses more on the number of people that can be served in a given amount of time (person capacity) than on the number of transit vehicles served by a transit facility (facility or line capacity).

In HCM, demand is the principal measure of the amount of traffic using a given facility. Demand relates to vehicle arriving; volume relates to vehicles departing. If there is no queue, demand is equal to the traffic volume at a given point on the roadway. Throughout this manual, the term volume generally is used for operating condition below the threshold of capacity (HCM, 2010).

2.7. The Estimation of Bus station capacity

According to (SLK, 2013) consideration should be taken to dwell times, clearance times and possible variations of arrival times in a detailed calculation of Bus stop capacity. The capacity of a Bus stop depends on the time for entering as well as leaving the loading area which in turn is influenced by the Bus stop design.

The Bus stop capacity is also reduced if the Bus stop is located next to a pedestrian crossing: Traffic calming measures adjacent to a Bus stop reduce the capacity of the single loading area by around 15% (SKF, 2004) According to the HCM2000 traffic signals have a major effect on the Bus stop capacity. If the green time ratio (g/C) is

0.5 The Bus stop capacity is reduced by 25-37%, depending on the length of the dwell time (TBR, 2000).

HCM2000 concept for terminal capacity is simply based on the sum of the capacity for all loading areas in the terminal. If the Bus loading areas are long and accommodate more than one Bus, the capacity per additional loading area drops, which means that the capacity for a Bus stop with two loading areas is lower than two independent Bus stops with one loading area (Al-Mudhaffar, 2016).

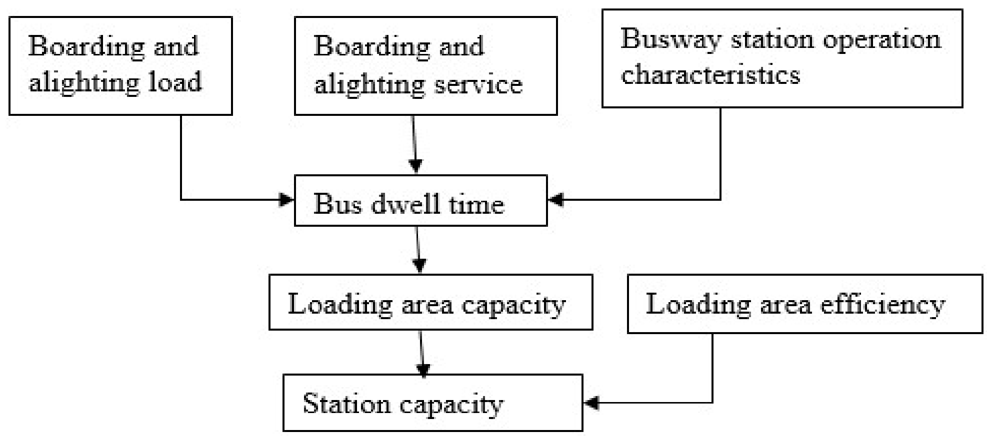

Figure2.5: Steps to calculate Bus station capacity. Source (Sumeet, 2010)

2.7.1. Dwell time

(TRB, 2013) and (HCM, 2010)define Bus dwell time as the amount of time a Bus spends at a stop or station to serve boarding and alighting passengers plus any time required for door opening and closing operation. Three methods can be used to estimate Bus dwell times:

1. Field measurements-best for evaluating an existing Bus route,
2. Default values-suitable for future planning when reliable estimates of future passenger boarding and alighting volumes are unavailable, and
3. Calculation-suitable for estimating dwell times when passenger boarding and alighting counts or estimates are available

Dwell time, t_d, can be measured in the field. Field measurement of dwell time is the best suited for determining the capacity and LOS of an existing transit line. An average (mean) dwell time and its standard deviation can be measured from a sequence of observation. For these research work field measurement methods should be used.

$t_d = p_a t_a + p_b t_b + t_\infty$ Equation 2.1

Where,

t_d = Severage dwell time(s),

p_a = Alighting passengers per Bus through Busiest door during peak 15 min(p),

t_a = Passenger alighting time (s/p),

p_b = Boarding passenger Bus through Busiest door during peak 15 min (p),

t_b = Passengers boarding time (s/p), and

t_∞ = Door opening and closing time (s).

Peak passenger volume estimates of hourly passenger volume are required for the highest-volume stops. The peak hour factor is used to adjust hourly passenger volumes to reflect 15-min conditions.

$$PHF = \frac{\mathrm{P}}{4P15}$$ Equation 2.2

Where,

PHF = Peak-hour factor,

P = Passengers volume during peak hour (p), and

P15= Passenger volume during peak 15 min(p),

(Sumeet, 2010)The boarding time per passenger and alighting passenger at the Bus station is estimated -

$$t_b = \frac{\text{Total boarding time}}{\text{Number of passengers boarded}}$$ Equation 2.3

$$t_b = \frac{\text{Total alighting time}}{\text{Number of passengers alighted}}$$ Equation 2.4

2.7.2. Coefficient Variation of Dwell Times

The effect of variability in Bus dwell time is reflected by the coefficient of variation af dwell times, which is the standard deviation of dwell time observations devided bythe mean. On the basis of reported field observations of Bus dwell times in several U.S. cities, the coefficient of variations of dwell times typically ranges from 40 to 80 percent, with 60 percent suggested as an appropriate value in the absence of field data (St. Jacques, 1997).

Just as the dwell times are key to determining capacity, passenger demand volumes and passenger service times are key to determining dwell times. Dwell time may be governed by boarding demand, alighting demand, or total interchanging passenger demand (i.e., at the major transfer point). In all cases, dwell time is proportionate to the boarding and alighting volumes timed the service time per passenger. There are six main influences on dwell time. Two relate to passenger demand; the others relate to passenger service time (HCM, 2010) and (TCQSM, 2013);

- Passenger demand and loading area. The number of people boarding and alighting through the highest-volume door determines how long it will take to serve all passengers.
- *Stop and station spacing*. The fewer the stops in the station, the greater number of passengers boarding at each stop. A balance must be found between too few stops and too many. Too few stops increase both the distance riders must walk to gain access to transit and the amount of time a vehicle occupies a loading area too many stops reduce overall travel speeds due to the time lost in accelerating and decelerating as well as weighting the traffic signals because stops were made.
- *Fare collection*. Fare collection affects dwell time in several ways. First, when fares are collected on board, each fare collection method has a passenger service time associated with its some methods are faster than others. Second, the fare collection policy may require all passengers with pre-paid fares (e.g., passes) or smart cards to interact with the driver, or the policy may allow these passengers to board any door, with smart card holders tagging their cards at one of the rear doors.
- *Vehicle types*. Low-floor Buses decrease passenger service time by eliminating the need to ascend and descend steps.
- *On-boarding circulation*. Encouraging people to exit via the near doors of Buses with more than one door decreases passenger's congestion at the front door and reduces passenger service times.
- *Wheelchair and bicycle boarding*. Dwell time also can be affected by the time to board and disembark passengers in wheelchairs and for a bicyclist to load and unload bicycles on to a Bus-mounted bicycle rack.

2.7.3. Design Bus Stop Failure Rate

Bus loading area capacity is maximized when a Bus is available to move into a loading area as soon as the previous Bus vacates it. However, this condition is undesirable for several reasons: (a) Bus travel speeds are reduced, due to the time spent waiting in a loading area to become available; (b) Bus schedule reliability suffers because of the additional delays; and (c) Buses block traffic in the street while waiting to enter the Bus stop. The more often that Bus stop failure occurs, the higher the Bus throughput over the course of the hour, but the more severe the operational problems (TCQSM, 2013)

The probability that a queue of Buses will not form behind a Bus stop, or failure rate can be derived from basic statistics. The value Z a represents the area under one "tail" of the normal curve beyond the acceptable levels of probability of a queue forming at a Bus stop. A design failure rate should be chosen for use in calculating a loading area's capacity. Higher design failure rates increase Bus stop capacity at the expense of schedule reliability. Capacity occurs under normal conditions at a 25% failure rate at CBD stop. Z_a values of 1.440 down to 1.040 should be used. Consequently, Bus capacity analysis incorporates the concept of a failure rate that sets how often a Bus should arrive at a stop only to find all loading areas occupied. In business district areas, design failure rates between 7.5 and 15% are recommended. At a 15% failure rate, queues form behind the Bus stop for about 10 minutes out of the hour (TCQSM, 2013).

Table 2.1. Value of percent failure Associated with Z_a (R29).

Failure Rate	Z_a
1.0%	2.330
2.5%	1.960
5.0%	1.645
7.5%	1.440
10.0%	1.280
15.0%	1.040
20.0%	0.840
25.0%	0.675
30.0%	0.525
50.0%	0.000

2.7.4. Bus Loading Area Capacity

Recommendations and estimations of Bus stop capacity with one loading area vary from one to another of the studied literature. Most studies limit the capacity for a loading area to 10–15 Busses/hour. Variations in arrival time and dwell time were in some cases considered indirectly by specifying the difference in capacity depending on the number of routes served by the Bus stop. Unlike other studies (HCM, 2010) considers how the queue risk, coefficient of variation and clearance time affect the capacity of a Bus stop (Al-Mudhaffar, 2016).

As the (TRB, 2013) notes, BRT station capacity is in turn governed by the capacities of individual loading areas. The Bus capacity of individual loading areas, in turn, depending on the Bus dwell times at these loading areas (TRB, 2013).

The maximum number of Buses per loading area per hour is determined as:

$$B_n = \frac{3600(\frac{g}{c})}{t_c+(g/c)t_d+Z_a C_v t_d} \qquad \text{Equation 2.5}$$

Where,

Bn = Maximum number of Buses per loading area per hour;

g/c = Ratio of effective green time to total traffic signal cycle length (1.0 for a stop not signalized intersection);

tc = Clearance time between successive Buses (s);

td = Average (mean) dwell time (s);

za = One-tail normal variety corresponding to the probability that queues will not form behind the Bus stop; and

cv = Coefficient of variation of dwell times.

The key factors influencing the number of loading areas that are required at Bus stops are the following:

- Vehicle types: Low-floor Buses decrease passenger service time by eliminating the need to ascend and descend steps.
- The coefficient of variation of dwell *time*: Is based on field observations of Bus dwell times. The coefficient of variation of dwell times (the standard deviation of dwell times divided by the mean dwell time) typically ranges from 40% to 80%, with 60% recommended as an appropriate value in the absence of field data. (HCM, 2010)

- The Probability of queue formation: The probability that queues of Buses will format a Bus stop, known as the failure rate, is a design factor that should be considered when sizing a Bus stop.
- Loading area design: Loading area designs other than linear (saw tooth, driver through, etc.) is 100% effective: the Bus stops vehicle capacity equals the number of loading areas times the vehicle capacity of each loading area, since Buses are able to maneuver in and out of the loading areas independently of other Buses.
- Traffic signal timing: The amount of green time provided to a street that Buses operate on affects the maximum number of Buses that could potentially arrive at Bus stops during an hour.

2.7.5. Capacity of Bus Stop

In the HCM2000 model Bus stop capacity is dependent on the individual capacities of the loading areas that form the Bus stop. The capacity of Bus stops with single and double loading areas is important for the accessibility and reliability of public transport. Lack of capacity of the loading area increases travel time for Busses (Al-Mudhaffar, 2016).

Both (HCM, 2010) and (ASHTOO, 2010)describe a model of capacity based on Bus dwell time for three key components:

1. Bus loading areas (berths): Curbside spaces where a single Bus can stop to load and unload passengers.
2. Bus stops: Can include one or more loading areas depending on how many Buses that use this Bus stop.
3. Bus facilities: Roadways used by Buses, may contain multiple Bus stops along their length.

The number of buses that can be served depends on the *Dwell time*, which represents the average amount of time a Bus is stopped at the curb to serve passenger movements, including the time required to open and close the doors. Another important factor is the *Clearance time*, which represent the average of the minimum time required for one Bus to accelerate out of and clear the loading area for the next Bus including any time spent waiting for a gap in traffic. The third factor is the *Failure rate* defined as the probability that one Bus will arrive at a loading area while another Bus already occupying it. The combination of dwell time variability and a design failure rate provides an additional margin of time in the capacity analysis to ensure that most Buses will be able immediately use the loading area upon arrival time (ASHTOO, 2010).

$B_s = \sum_{n}^{N}(B_n)$ Equation 2.6

Where, Bs = Bus stop capacity

Bn = Loading area capacity

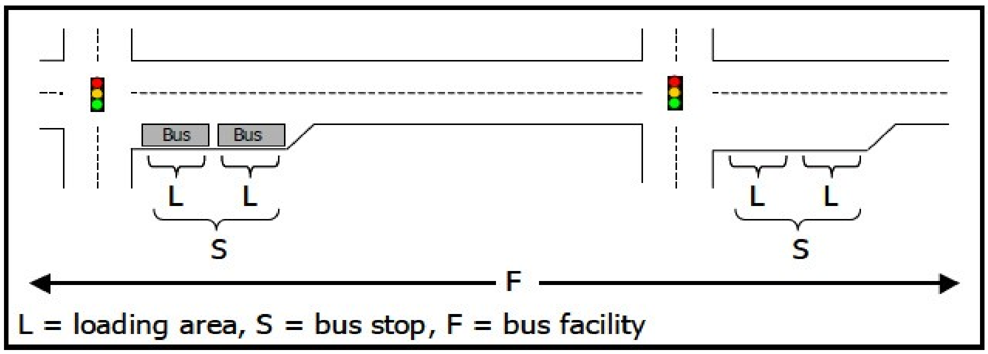

Figure 2. 6: Illustration of Bus loading areas, Stops and Facilities. *(ASHTOO, 2010)*

2.7.6. Bus Station Capacity

The vehicle capacity of a given transit route or facility is defined as follows:

The maximum number of transit vehicles (Buses, trains, vessels, etc.) that can pass a given location during a given period of time, typically 1 h. Transit vehicle/Bus capacity is commonly determined for three locations: loading areas or berth; transit stop and station; and Bus lanes and transit routes (TCQS and HCM).

To estimate Bus Station capacity two methods can be used:

1. **Empirical analysis**

Case 1: Independent Bus movements: If the terminal design permits all Buses to arrive and depart from their assigned Bus stop without any interference with Buses to and from other Bus stops in the terminal, the following simplified deterministic procedure can be applied: Calculate the capacity of each Bus stop is described. This calculation includes the effect of clearance time needed for a Bus to depart from the Bus stop including pedestrians crossing in front of the Bus. The calculation is usually made for the design time (rush hour), but can also be needed for other time periods depending on connections with other public transport modes. The results (number of Buses per hour) should be adjusted to fit the planned Bus timetable. Calculate total terminal capacity as the sum of all Bus stop capacities using in Bus terminal.

The total terminal capacity can then be determined as:

$Bt = \sum Bs$ Equation 2.7

Where: Bt = Bus station/terminal capacity

Bs = Bus stop capacity

Case 2: Dependent Bus movements

At higher traffic load the station capacity can be reduced by factors such as queuing Buses, blocking the entrance or exit from Bus stops for other Bus lines, passengers moving across the terminal, limited station entry or exit capacity etc. The total terminal capacity can then be determined as:

$Bt = \sum Bs$ *1-load factor (v/c) Equation 2.8

v/c= Volume to Capacity.

2.7.7. Factors Affecting Bus Station Capacity

Factors affecting Operation characteristic (Bus route cycle, location of Buses, type of vehicles and layout of loading positions frequency and the arrival of Buses) are;

Physical **(**number and layout of the loading positions, facilities for loading,

Behavioral **(**types of drivers and passengers),

Time scheduling (Percentage of lines that connect to train arrivals/departures.) and

Bus station design (turning possibilities, Bus movements needed to avoid conflicts between Buses and with passengers, Bus exit capacity)

According to (Al-Mudhaffar, 2016) studded based on Bus operators in Bus terminal increase driving time for Buses and travel time for travelers, but may also increase traveler comfort, reversing is usually perceived to be difficult and can lead to increased vehicle damage, especially problematic in times of stress, the berth must be wide enough and the island beside must be long enough to cover at least the area to middle door of the Bus, otherwise boarding of prams will be difficult.

Passenger amenities are provided at a Bus stop or transit station to enhance comfort, convenience, and security for transit patrons. Amenities include such items as shelters, benches, vending machines, trash receptacles, lighting, phone booths, art, and landscaping. Improvements to station amenities can reduce the perceived inconvenience of transferring and waiting time. Although the effect that a specific amenity may have on transit ridership is likely to be small, the cumulative impact of providing an overall good level of amenity may be significant. Amenities at most Bus stops or transit stations are placed in response to a human need or a need to address a local condition (HCM, 2010)

2.7.8. Design Person Capacity

The number of people that can be served by a particular transit facility depends on a number of factors, some under the control of the transit operator and some not. At its most basic level, person capacity (persons per hour) is the product of facility capacity (vehicles per hour) and vehicle passenger capacity (persons per vehicle) (TCQS).

Stop/Station Vehicle Capacity x Peak 15-min passenger volume /Vehicle x PHF = Person Capacity

2.7.9. Network Designs System at Transit station

(TCQSM, 2013)Quality of Service Concepts, planning transit service involves trade-offs between the area served by transit (service coverage), service frequency, and the time required to make a trip, given a fixed amount of resources for the service. Except in the smallest communities, where a loop route can provide (slow, circuitous) service to all major origins and destinations. Road network can be classified as the following:

1. Radial networks: where all routes focus on the downtown area, due to its role as a major source of trip destinations and-often-its central location. Major corridors can be served with high capacity transit routes. One-seat rides can be provided to downtown, as well as to selected other destinations when routes extend through and past downtown (interlining).
2. Hybrid networks*:* overlay key cross-town routes that directly connect selected major non-downtown origins and destinations and provide connection opportunities to radial routes. Faster, more direct trips are possible for trips involving non-downtown locations.
3. Hub-and-spoke networks*:* focus local Bus service around transit centers, where Buses meet on a timed transfer (pulse) basis to transfer passengers, minimizing the time required to make a connection. Other, potentially high-capacity, routes connect transfer centers and the downtown to each other.
4. Grid networks**:** provide frequent service along major streets and cover a large portion of the region. Many trips require a transfer, but transfer times are minimized due to the frequent service.

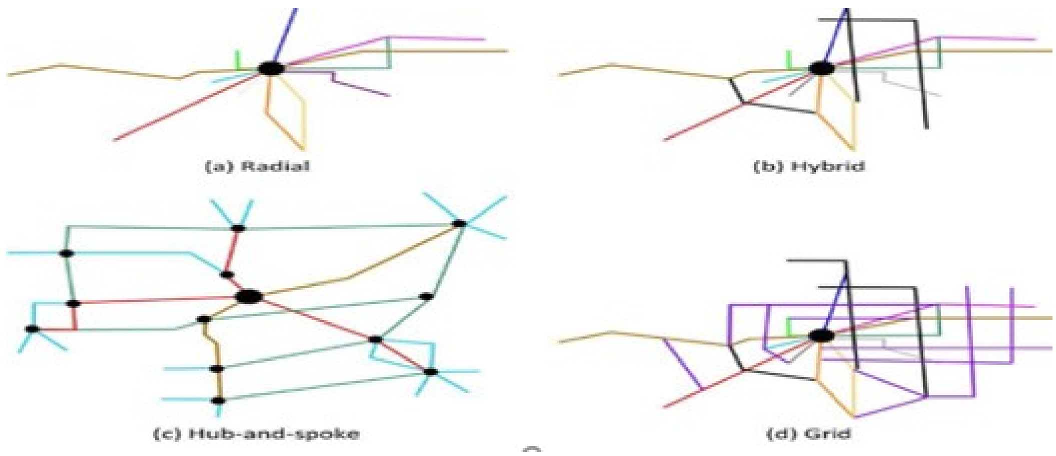

Figure 2.7: Example of fixed route network

2.8. Traffic Congestion

Currently, the traffic congestion problem has become the research agenda for a growing community of researchers, particularly in developing countries, like Ethiopia (Yared Haregewoin, 2010). In the Bus station, congestion can be formed by different factors such as lack of capacity, inefficient loading area, mixed traffic system, poor management system, poor quality of service, lack of management control etc.

2.9.1. Categories of Traffic Congestion and its Impact

Traffic congestion can be defined as the saturation of road network capacity due to increased traffic volume or interruptions on the road that cause an increase in travel times. It is characterized by slower speeds, longer trip times, and increased vehicular queuing. When traffic demand on a road facility is great, such that the interaction between vehicles slows the speed of the traffic stream, congestion results. Traffic congestion can be categorized into two:

1. Recurrent congestion*:* A regular congestion that occurs in hourly, daily, weekly or annual cycle. There are three main reasons that cause recurrent type of congestion. They include: Insufficient capacity, uncontrolled demand, Ineffective capacity management (TRC, 2007).
2. Non-recurrent congestion**:** -It is a natural type of congestion. It depends on the occurrence of events on traffic facilities such as accidents and disabled vehicles. Such events cause interruptions to free flow of traffic on the road (Yared Haregewoin, 2010).There are five main reasons that cause recurrent type of

congestion. They include: Incidents and accidents, Work zones, Bad weather condition, Special events, Emergency situations etc.

2.9.2. Measurement of Traffic Congestion.

Traffic congestion which is a result of excessive utilization of the transport infrastructures due to high number of pedestrians, small road network length, a high portion of the population engaged in the informal Business sector, and poor public transport supply which are not based on peak hour demand which result in long travel journey period. Congestion can be measured in various ways, including Service frequency LOS and Traffic Volume to Capacity (Litman, 2003).

2.9.3. Traffic Volume to Capacity Ratio and LOS

Congestion can also be measured by a volume-to-capacity ratio (V/C Ratio).The Victoria Transport Policy Institute report states that traffic congestion impacts can be measured in terms of volume to capacity ratio. For the purposes of congestion calculations, congestion levels are defined as:

V/C Ratio greater than 1.0 = Severe Congestion

V/C Ratio of 0.75 to 1.0 = Heavy Congestion

V/C Ratio of 0.5 to 0.74 = Moderate Congestion

V/C Ratio of less than 0.5 = Low or No Congestion

The volume to capacity ratio hence is requires computation of traffic volumes and determination of capacities of road facilities (VTP, 2000).

Table2. 2.Service frequency LOS for urban schedule transit service

LOS	Headway(min)	Bus/hr	Comments
A	< 10	>6	Passengers don’t need schedules
B	> =10-14	5-6	Frequent service; passengers consult schedules
C	>14-20	3-4	Maximum desirable time to wait
D	>=20-30	2	Service unattractive to choice riders
E	> 30-60	1	Service available during hour
F	>60	<1	Service unattractive to all riders

Source [Highway Capacity Manual 2010]

(Wall, 2017) Studded based on Evaluation of Bus terminals, the capacity of Bus terminal was evaluated based on several deferent measures, all indicating a low utilization. Even so, the utilization was uneven over time and congestion could be occurring when several Buses departed at the same time.

The capacity of Bus stops with single and double loading areas is important for the accessibility and reliability of public transport. Lack of capacity of the loading area increases travel time for Busses (Al-Mudhaffar, 2016).

(Felipe, 2013)Work represents an initial attempt to estimate running way capacity in a more complex environment than generally encountered in the US. It is more useful for the purpose of system planning than for operations analysis. That is, it can serve as a tool to assess a number of alternate station design schemes during preliminary design. It provides limited insight into the diagnosis of a facility operating at near capacity. More detailed simulation models, some of which are described previously in this paper are better suited to this task.

(Kong, 2014)Access to the terminal should be convenient, barrier free and facilitate streamlined internal circulation. Additionally, the ingress and egress points should be so located that they are not in conflict with traffic circulation at the peripheral road network. One way of achieving this is by creating alternative access/egress points by integrating multimodal facilities with the Bus terminal; this can further convenience commuters by providing access/egress choices.

There are several different factors affecting whether a Bus station is considered adequate. According to (kommuner, 2012), It is also desired that people with disabilities are taken into consideration when designing walkways and waiting areas within the terminal. The combination of urbanization and motorization has been placing an ever-increasing amount of pressure on the current transportation infrastructure. Therefore, it is consequential in such widespread problems as traffic congestion, traffic fatalities and injuries, traffic pollution and increased energy consumption (Liu & Ceder, 2015).

It is important to consider require space, dimensioning and functionality when planning a Bus terminal. The required space in the terminal can depend on for example the traffic load, the route network and the purpose of the Bus lines using the terminal. These aspects can be difficult to know in advance.

(kommuner, 2012) Brings up that terminals can be dimensioned considering articulated Buses when designing the Bus stops and bogie Buses when determining the geometry within the terminal.

Station area and the physical infrastructure design part of a station or stop plays a very important role in the travel of a commuter. Also, the increased efficiency of stations or stops is directly proportional to the increment in the ridership of the urban public transportation system (Elsevier, 2016).

According to TBR the capacity of Bus stops with single and double loading areas is important for the accessibility and reliability of public transport (TBR, 2000). In order to assist in the performance evaluation of the management of the Bus station, Passenger offering commuting, a set of indicators broken down into 5 dimensions was adopted (Dunham, 2008).

Many conceptual frameworks, explain the causes and the impact of vehicle traffic congestion in different ways. Most writers argued that traffic congestion has an impact on time delay and fuel consumption, among them traffic congestion can cause more fuel to be used (Ogundipe O.M, et al., 2007).

From the overall review of literature related to the assessing capacity of Bus station and identifying causes of traffic congestion the following observations are made.

Lack of sufficient capacity of Bus station has a major impact on the Bus and passenger demand emerged as one of the important service providers, the literature shows that not enough research has been carried out.

As reviewed in the previous literature, researchers were done on the models or the methods of calculating Bus dwell time and factor affect capacity of Bus stop. Any researchers are not considered capacity of a Bus stop depends on the number of the route, Bus dwell times, clearance times and possible variations of arrival times for entering as well as leaving the loading area. Their studies based on a single Bus stop along the roadside route and subway. There are no any researchers have undertaken regarding to the Bus Station in Harari city. In Harar cities, the Bus station has complex traffic system and it has more than 10 different Bus route line within the different distance. On such types of Bus station, no researchers are studded. By comparing existing Bus travel demand/volumes and capacity no researchers identify causes of congestion, especially in Harar city.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Description of the Study Area

The study was conducted on the Harar City Bus Station, which is located in the eastern part of Ethiopia. It's located in the central Business district around Kebele 14. It was constructed before 30 years ago and no any other Bus station was constructed by now. But, now a day it was contested by the increasing number of Busses and passengers. In this study, LOS of the existing Bus station was estimated which used to plan and design other station for the future, and also for now some urgent solution and recommendation was listed which is used to minimize existing congestion at the study area by determining existing geometric conditions, by comparing current Bus and passenger demand distribution at the station with estimated capacity.

3.1.1. Location and Topography of the Study Area Description

Harar city is located in the eastern part of Ethiopia and the capital city of the Harari Regional State. It is located at geographic coordinate of 9°11'49" - 9°24'42"N latitude and 42°03'30" - 42°16'24"E longitude at the distance of 515 kilometers to the east part of Addis Ababa with an elevation of 1750 meters above sea level. The region compasses 6 urban kebele and 3 rural local cable, 19 sub Kebele administration, and 17 farmer associations. The city has a total area of 20.6 km2. The Harari Regional state has common boundaries in the North, West, South and East of the Oromia Region.

Table3.1. Location and topography of Harar city (source Google Earth)

Location	Harar city
Latitude Coordinate	9°11'49"-9°24'42"N,
Longitude Coordinate	42°03'30" - 42°16'24"E
Country	Ethiopia
Regional	Harari
Kebele	14
Elevation	1417meters

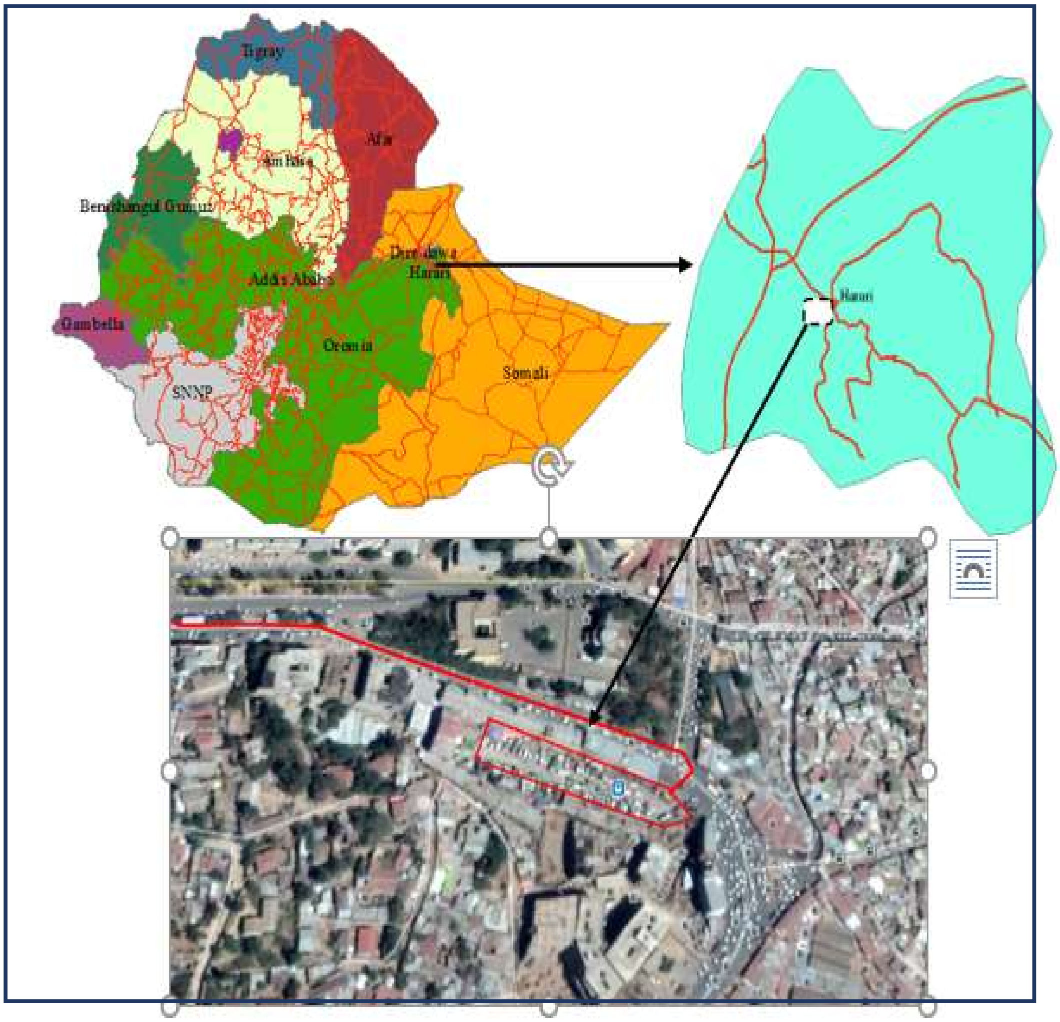

Figure 3.1: Location of study area (source: GIS and Google earth).

The Bus station in Harar city is located in the Central Business district and it has connected with route network which servicing for locals and long distance Buses transport. This station is serviced as an origin or destination for local, regional and long distance Buses which transport passenger from origin to destination and also passes through the station. The station is the general area where three roads join and the availability of nearby institutions such as Harari administration, the existing Bus Station which we studded is located in Kebele 14. This Kebele 14 is the main center of the city consisting of the Shewaber market, commerce and Businesses, services, administrative offices and dense residential areas.

Population

This research was assessed capacity of Bus station in Harar city. The total area of this station is about1000m^2 and also the Buses and Passengers at the study area are the population size of this study.

3.2. Study Design

The quantitative descriptive research design used for the purpose of this study, which enable the research to interpret the finding adequately and accurately. Therefore, the research methodology used for this research is consisted the relevant data collection, data extraction, data analysis by some suitable tools

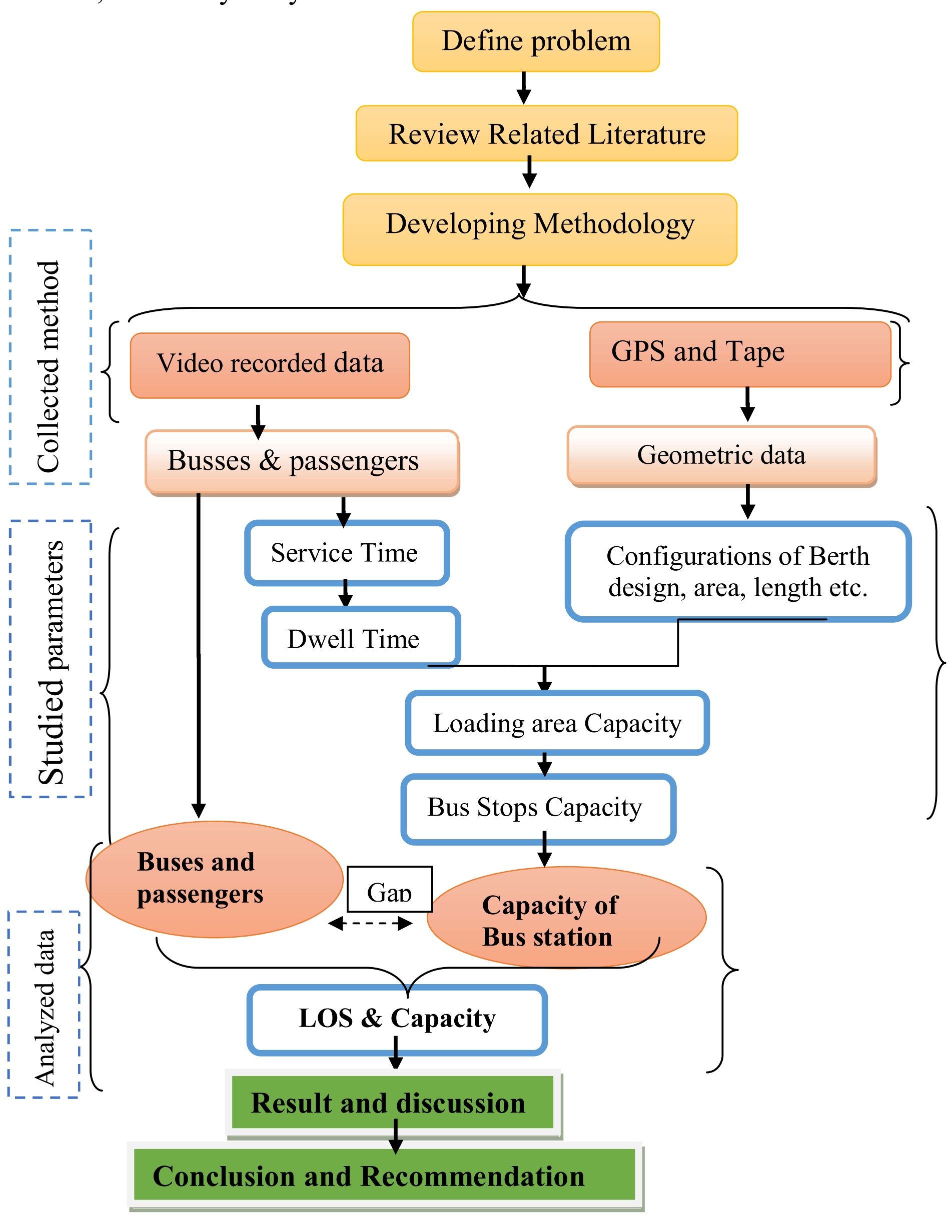

Figure 3.2: Study design flow chart for this study.

3.3. Sample Size and Procedures

Bus station in Harar city is located at the central Business district, which known as Shewaber market by local name. This station is using as a transit center for local and long distance Busses. Now a day it was formed congested by increasing Busses and passengers. Therefore, this study was chosen as purposive sampling to collect sufficient data which used to assess the objectives of this research in the study area. The sample size used for this research were the numbers of Busses and passengers those collected for weekdays. From the collected data during field observation the numbers of Busses and passengers were identified depending on Bus route lines and allowed Bus loading area the cause of congestion was identified under this research based on identifying research.

The public transit system in Harar city: The public transit system in Harar city consists of local Bus lines, public transport to rural areas and long distance transport. As can be seen in the following figure, now a day in the Harar Bus station there are 10 Bus stops which used to servicing public Busses as stops. This stops line names are Kombolcha, Dire Dawa, Ciro, Jigjiga, Adama, Haromaya, Babile and Gursum. Each stops contains 3-4 loading area. The distance from Harar city to each local, regional, city administrations and national are listed in the table.

Figure 3.3: Picture shows congestion in the study area (September, 2018)

The general activities of Harar in history have produced numerous tangible testimonies to their workmanship, disclosed the unique efforts of its people through time. One of these heritages is the ‘Walled City’ itself. In the Centre of a very beautiful and rich region of the Harar plateau, the principal city of Harar still commands great economic importance, while its own history gives it a political value of the first order in Eastern Ethiopia. Few of these economic and professional works elsewhere had manifested the cultural level to emulate the Hararis level of civilization (Cerulli, E., 1971).

Jugal is an old historical heritage, with a surface area of 48 hectares and encircled by a rampart of 6666 cubits 3442 meters in circumference. It has five portals (gates), symbolically unique in associative style. One could just imagine, art, the picture of the walled city of Jugal, resembling a praying person, who steps left foot on Badro Bari, the right foot on Suqtat Bari, the left hand on Asmaddin Bari and the right on ArgoBari, and the forehead certainly on Assum Bari for qiblah [direction to Mecca] (Van vo, D., and Guled, M., 2007)

Figure 3.4. A Section of Jogal Wall and Badri Bari.*(source: Harari culture and truism office)*

3.4. Data Collection Instrument

The materials used for the accomplishment of the thesis work are:

- Video cameras
- Measuring tape
- Hand GPS
- Stopwatch
- Data Sheets and pencil
- Computer

3.5. Study Variables

3.5.1. Dependent Variable:

Level of Service of Bus station and Traffic congestion

3.5.2. Independent Variables

- Geometric data
- Bus and passenger data
- LOS
- Traffic Congestion

3.6. Data Collection Process

Without permission you cannot obtain any data from concerned body specially the data obtained by video camera. First day of recorded data, a lot of passengers and drivers disturbed by asking (why you record people and vehicle?). But, permission letter which obtained from the Jimma Institute of Technology and Harar city administration was displayed for them immediately and permission was again obtained from them.

Data acquisition and field investigation provides an understanding of the design configuration of loading area in the bus station and identify the cause of traffic congestion. The aim of this study was to assess the capacity of bus station and to identify the cause of traffic congestion the Harar City Bus station. It is therefore important to collect primary data from field observation (geometric arrangement of loading area in the Bus station and record video camera) and secondary data (different books, journals, related thesis, data which explain availability of Bus station) were collected from different bodies, such as the Harar City Municipality and Transport office, Harar Bus Station manager, Internet, related thesis and Oromia Transport office. Then data collection was started from field to identify the current status of the Bus station.

The first observation of this research was based on Bus station geometric configuration of Bus Station condition data and the second was distributional variation of bus and passengers at the station. The first data was obtained by using tape and GPS, and also the second data was obtained by using a video camera.

1. **Field measured data**

After the permission letter that obtained from the Jimma Institute of Technology was taken to require concerned bodies. Existing schedule was obtained from Harar city Bus station manager and discussed with the based on the existing condition of the Bus station. Then reconnaissance survey and field measurement were continued with the identification of allowed Bus stop route line, width of entrance and exit of the Bus station was measured at the following.

Figure 3. 5: Bus stops measurement (September, 2018)

Figure 3.6. Entrance and exit of Bus station length (September, 2018)

2. Video recorded data

After completing the field measurement in the study area the second data was collected using two video cameras started from September Monday 14 to Friday 19/2018 during the hours of (6:00 am - 6:00 pm). The following data, such as Bus number, type of Busses that enters and exit from the station. Numbers of alighted and boarded passengers from the Busses were observed in the study area by using video camera according to identified to allow Bus stop during field measurement the data was copied in the computer. These data collection activities were carried out with permission of Harar city municipality and Harar Bus station manager. These cameras have stood on the top of the G-01 building near the side of the Harar Bus station to develop the quality of record passenger and Bus movement data in the station.

The following procedure was used to collect data by using a camera

1. Identify a suitable position to set up cameras
2. Establish camera angles to record movements of passengers and Busses
3. Conduct video recordings

Figure3.7. Picture shows when data was taken by a video camera in the study area (September, 2018)

3.7. Data Processing and Analysis

Typical data required for the study existing geometric condition Bus station, a distributional variety of Bus and passenger characteristics were processed and analyzed in required manner. The operational parameters of Bus station capacity determined based on empirical method using observed Bus and passenger volumes and cause of congestion as the study area was identified. Microsoft excel was used to analyze parking parameters and SPSS software was used for analysis cause of congestion in the study area.

The data collection process included field visual inspection, field measurements and traffic data video recording. Typical data required for the assessment of Bus station capacity and identify the cause traffic congestion were processed and analyzed based on empirical calculation of HCM.

Data processing includes, categorizing the data according to its population, category coding and type. Data which describe geometric conditions of Bus station condition was processed in GIS software. Capacity parameters, Busses and passenger data were processed and analysis using Empirical formula of HCM, TCQSM, Microsoft excel and SPSS.

3.7.1.Geometric Characteristics of Existing Bus Station

The geometric design of Bus stops involves the dimensioning and arranging of loading area to provide safe and easy access without restricting the flow of traffic on the adjacent traveling lanes (Hoel, 2009).

Geometric data those determined from field observation at the Harar Bus Station were the dimensions of entrance and exit of the Bus station, elevation and coordinates of four corners of the Bus station, arrangement of the loading area and total area of the Bus station were determined.

The Bus station in Harar city is located at the center of the city where several buildings are surrounded and high commercial/Business activities are highly practiced. And also, it was serviced for local, regional and national passenger Bus transport from different area which resulted of congestion.

The design configuration of the Harar Bus station was angle berth design and it has 10 Bus stop route line which contain 32 numbers of the loading area. The names of Bus stops are Kombolcha, Haromaya, Babile, Dire Dawa, Gursum, Ciro, Jigjiga, Adama, Addis

This research was determined the existing geometric condition and arrangement such as numbers of loading area based on each Bus stop, length and area of the Bus station, width of entrance and exit were determined by using hand GPS and tape measurement. The other data were obtained from Bus schedules to observe the number of allowed Busses, those servicing at the station, estimated number of passenger demand and distance from the Harar Bus station to each destination were observed in the study area. The location and arrangement of each Bus stop and number of loading area were indicated by Harar city Bus managers, the study was identified by using Arch GIS.

From extracted data from a video camera, the number of Busses and passenger varied per day, per time and operational capacity parameter was determined. At the last, estimated capacity, Bus demand and supply were compared to the identification of congestion at Harar city Bus station.

The following figure shows the existing road link with the Harar city Bus station that the Busses and passengers use to enter and exit from the Bus station.

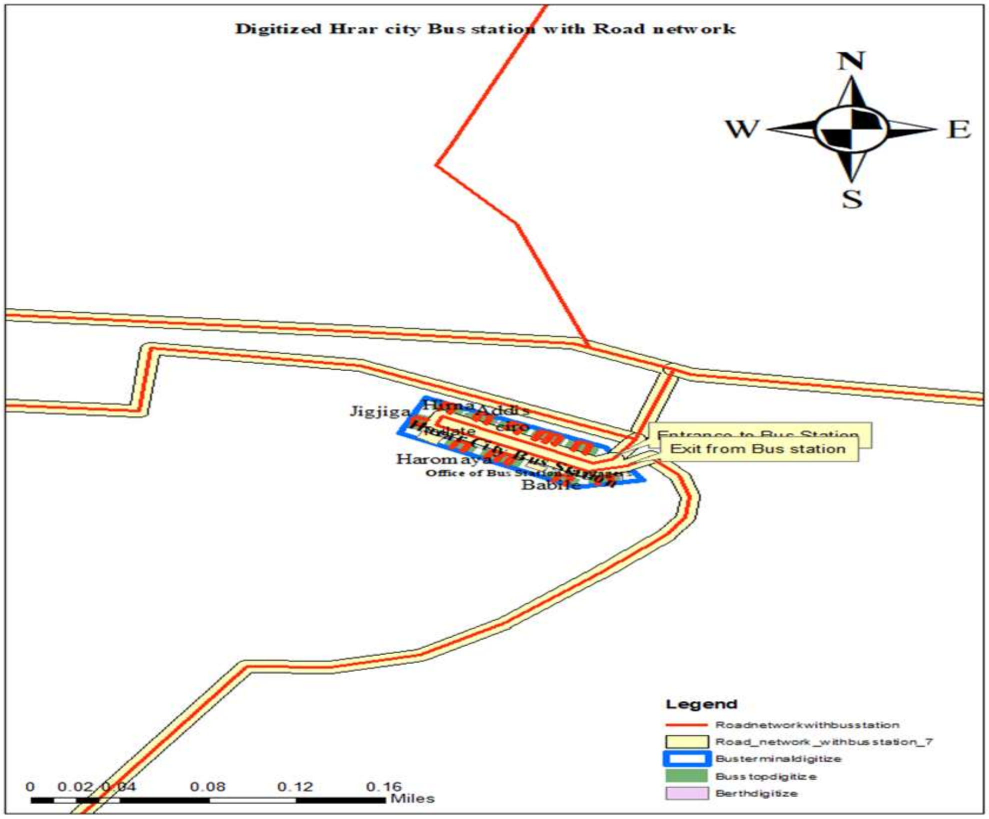

Figure 3. 8: Digitized road link network at the study area (by GIS Software)

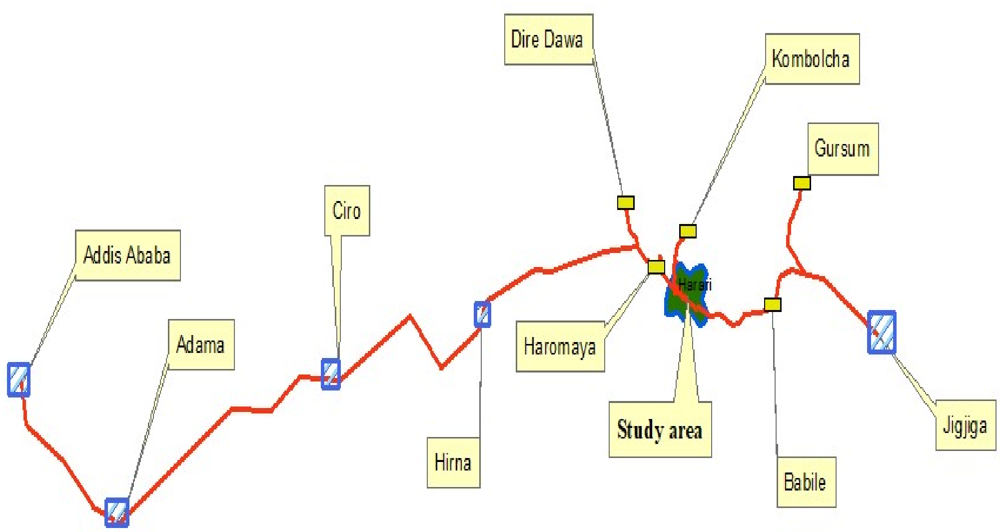

Figure 3.9. Name of route line network with Harar City Bus station

The above figure shows that the locations of Bus route line those uses in the Harar city Bus station.

3.7.2. Arrangement of Bus Stop and Loading Area

The existing Harar Bus station has ten route line Bus stops, which containing thirty-two number of loading areas. From the field observed data the arrangement of the existing loading areas in the study area shows angle berth design. During field measurement data, Harar city Bus station manager shows us the size of each loading area was the same to each other. Started from that information the numbers of existing loading area were digitized from aerial photograph through GIS software.

To identify Bus numbers according to the existing route line at the study area, this study was identified Bus to two parts those are local Busses if the distance from origin to destination is less than 70km or greater than 70km as the following table.

Table 3.2. Classification of Bus route line according to distance

Distance(km) from Harar	**Local Bus(<70)**	**Long distance Bus(>=70)**
Route lines	Kombolcha, Haromaya, Babile, Dire Dawa and Gursum	Jigjiga, Hirna, Ciro, Adama and Addis Ababa

The approach grade becomes important only when it is significantly steeper than 4 percent. The maximum grades encountered on urban streets typically range from 6 to 11 percent (HCM, 2010).

To determine the surface grade of the Harar city Bus station, we collected elevation of four points on the station by using GPS. As indicated in figure 4.1, two points were taken around the entrance and exit of the Bus station and also the other two points were taken around the Hirna and Jigjiga Bus stops as the following.

Figure3. 10: Picture shows when data was taken by hand GPS in the study area (September, 2018)

The elevation point of the entrance of Bus station was = 1869m

The elevation point of the exit of Bus station was = 1869m

The elevation point of the Hirna Bus stop was = 1870m

The elevation point of the Jigjiga Bus stop was = 1870m

The distance between two elevation point of entrance and exit =15m

The distance between two elevation point of Hirna and Jigjiga =20m

The distance between two elevation point of entrance and Hirna =150m

The distance between two elevation point of exit and Jigjiga= 160m

This study was determined the grade of elevation on the station for a bus which have a long distance between observed elevation. The grade of Bus station between two elevation points expressed as $G = \left(\frac{\Delta y}{\Delta x}\right)$

The grade elevation between Entrances of bus station to Hirna bus stop was determined as follow;

$G = \left(\frac{\Delta y}{\Delta x}\right) = \left(\frac{1870-1869}{150}\right) * 100 = +0.67\ \%$ Similarly, from the exit to Jigjiga Bus stop $G = \left(\frac{\Delta y}{\Delta x}\right) = \left(\frac{1870-1869}{160}\right) * 100 = +0.63\ \%$

The above values show positive value and the reverse of this value is a negative value. A positive value indicates that the Busses traveling upward and negative value shows the Busses traveled to downward, but the existing surface of Harar city Bus station is almost flat.

3.7.3. Distribution of Busses and Passengers Demand

A variation of the Busses was identified under this study, the research data those obtained from the Harar Bus station manager (Bus station schedule) were no identified variation of arrival and departure Busses relating to day and time. So, based on extracted data from the video camera variation of Busses were identified. Data were number Busses, those allowed to serve passengers, according to route lines, time of operation, the existing number of Bus stops and loading areas.

From these observations, the types of Buses which serviced passengers at the station were divided into two groups. These are Mini/small Buses which contain 12 seats up to 18 seats, Medium Busses which has 20 up to 32 seats and large Bus up to 44 seats. This information was obtained from Harar Bus station managers and design structure of these stations was consisted of 10 route link Bus stops which contain 32 loading area. The names of each stop are Kombolcha, Haromaya, Babile, Dire Dawa, Gursum, Jigjiga, Hirna, Ciro and Adama. Operational times of these stations were started from 6:00am-6:00pm.

Table3. 3. Harar city Bus station schedule information

Bus Route lines	Bus Types	Distance(Km)	No of loading	Estimated travel(min)	No. of Busses	Estimated No of Passenger/day	Bus arrival time	Bus departure time
Harar-Kombolcha	Medium	16	3	20-30	15	1000	randomly	randomly
Harar - Haromaya	Mini	17	4	20-30	20	1500	randomly	randomly
Harar - Babile	Medium	30	3	40-50	10	1000	randomly	randomly
Harar-Dire Dawa	Mini	50	4	60-90	20	1500	randomly	randomly
Harar–Gursum	Medium	68	3	90-120	10	1000	randomly	randomly
Harar - Jigjiga	Medium	100	3	150-200	12	1000	randomly	randomly
Harar - Hirna	Medium	150	3	200-250	8	1000	randomly	randomly
Harar - Ciro	Medium	200	3	300-350	10	1000	10:00am-5:00pm	8:00am-1:00pm
Harar - Adama	Large	420	3	600-650	8	500	6:00am-9:00am	4:00pm-6:00pm
Harar-Addis Ababa	Large	515	3	660-720	7	500	6:00am-9:00am	4:00pm-6:00pm
Total			32		120	10,000		

S*ource (Harar city Bus Station managers, 01/1/2010-01/12/2011 EC).*

Mini Bus (12-15seat), Medium Bus (28-32), Large Bus (>=44) and Bus station service time from 6am - 6pm. S*ource (Harar city Bus Station manager).*

The above table shows Bus schedule systems that serviced for the Harar Bus station. These stations are used for locals, regional and long distance Bus transport in which passengers transport from origin to destination vice versa. And also, the distance from Harar city to different destination are mixed. Generally, the study area was located almost at the center of the city where high commercial/Business activities are highly experienced which resulted congestion during the day of the week specially in the morning and afternoon. As we observed from the above schedule table inbound and outbound time of Kombolcha, Haromaya, Babile, Dire Dawa, Gursum, Jigjiga and

Hirna Busses are randomly arriving the station and it may be from congested at the Bus station. So, to calculate the capacity of stops, service time for each arriving Busses are important.

3.7.4. Methods of extracting data from Video Camera

After Busses and passenger data are recorded by using a video camera, the following methods were used to extract data from video.

1. From the study area the name of each Bus stop was identified.
2. Record the time that the vehicle comes to a complete stop.
3. Record the time that the doors have fully opened.
4. Count and record number of passengers alighting and boarding.
7. Record the time when doors have fully closed.
8. Record the time when the vehicle starts to move.
9. Note any special circumstances.

The following table extracted data for only one route line Bus stop (Jigjiga).

Table 3. 4. Sheet form used to extract data from a video camera. Source *(TCQSM, 2013)*

Bus No	**Bus type**	**Entering Times**	**Stop Berth #**	**Arrival & door opening time**	**Passengers Alighting**		**Door closing time**	**Re-opening the door time**	**Passengers Boarding**		**Re-closed & leaved**	**Exit ingTimes from Bus station**
					Front Door	Rear Door			Front Door	Rear Door		
1	SB	01:00	1	01:02	20	0	01:07	01:16	12	0	01:36	01:4
2	SB	01:36	2	01:38	20	0	01:41	01:58	15	0	02:08	02:14
3	SB	02:12	1	02:13	0	0	02:13	02:50	18	0	02:55	02:59
4	SB	02:19	2	02:25	20	0	02:27	02:55	12	0	03:05	03:14
5	LB	02:32	3	02:35	20	0	02:40	03:03	14	0	03:15	03:23
6	LB	03:00	1	03:03	15	0	03:07	03:18	18	0	03:25	03:34
7	LB	03:10	2	03:13	20	0	03:16	03:30	26	0	03:39	03:41
8	LB	03:24	3	03:28	18	0	03:32	03:42	32	0	03:48	03:54
9	SB	03:15	1	03:18	20	0	03:21	03:50	18	0	03:58	04:04
10	SB	03:45	2	03:48	20	0	03:50	04:05	16	0	04:12	04:14
11	LB	03:50	3	03:56	23	0	04:00	04:13	30	0	04:20	04:26
12	SB	04:01	1	04:05	20	0	04:07	04:20	11	0	04:25	04:32
13	LB	04:13	2	04:19	22	0	04:25	04:28	35	0	04:34	04:40
14	LB	04:30	3	04:33	28	0	04:38	04:52	20	0	05:00	05:04
15	LB	04:34	1	04:37	28	0	04:40	04:59	28	0	05:10	05:14

3.7.5. Methods of Determining Bus Station capacity

Transit vehicle capacity is commonly determined by three locations: loading areas or berth; transit stops and station; and Bus lanes and transit routes. Each location directly influences the next. The vehicle capacity of a Bus stops or station is controlled by the vehicle capacity of loading areas and transit route is controlled by the vehicle capacity of the critical stops along the lane or route. The two greatest influences on loading area vehicle capacity are dwell time and the ratio of the green time to the cycle length for the street on which the transit operates (HCM, 2010).

- **Factors affecting Bus station capacity**

The volume of mixed traffic sharing the curb lane with Busses affects Bus station capacity. The interference caused by other traffic in the lane, particularly at intersections, may block Buses from reaching a stop, the additional reentry delay encountered when the Buses leave a stop and reenter traffic may affect capacity. Therefore, mixed traffic factor is essential to adjust the capacity of Bus station for this study.

$B_t = f_m \sum(Bs) = \sum (f_{mn} * Bs)$ Equation 3.7

$Fm = 1 – fl(v/c)$

Where,

B_t = Bus station capacity

Bs = Bus stop capacity

Fm = mixed traffic adjustment factor,

Fl = Bus stop location factor,

V = volume of Bus at the critical Bus stop,

C = capacity of critical Bus stop

- **Scheduled person capacity**

Scheduled person capacity reflects the number of passengers that can be carried through the facility's maximum load section, given the existing schedule and Bus model(s) used. If a transit agency's policy is that passenger loading should not regularly exceed P_{max} passengers per Bus model during an hour, scheduled person capacity is calculated as follows (TCQS):

$$Ps = \sum_{t=1}^{n} \text{Pmax, i(PHF)Ni} \qquad \text{Equation 3.8}$$

Where,

Ps= scheduled person capacity (p/h),

Pmax,i = maximum schedule load for Bus model i (p/Bus),

Nbm = number of different Bus models operated at the facility, and

Ni = number of Buses of Bus model scheduled to use the facility during the hour (Bus/h).

- **Design person capacity**

Design person capacity is the number of people that could be carried through the facility's maximum load section, if Buses were scheduled to use the facility at its full capacity, under a specified set of conditions (e.g., design failure rate, vehicle types, fare collection method (TCQSM, 2013).

$$p = p_{max\ B} = p_{max\ (PHF)B} \qquad \text{Equation3.9}$$

Where,

P = Design person capacity (p/h),

P_{max} = Weighted average maximum schedule load for Buses (p/Bus),

B = Bus facility design capacity (Bus/h).

3.7.5.1. Dwell Time Estimation

Just as dwell times are a key to determine capacity, passenger demand volumes and passenger service time is a key to determine the dwell time (HCM, 2010).

The dwell time is the time required to serve passengers at the Busiest door, plus the time required to open and close the doors.

Three methods can be used to estimate Bus dwell times:

1. Field measurements-best for evaluating an existing Bus route,
2. Default values-suitable for future planning when reliable estimates of future passenger boarding and alighting volumes are unavailable, and

3. Calculation-suitable for estimating dwell times when passenger boarding and alighting counts or estimates are available.

The most accurate way to determine Bus dwell times at a stop is to measure them directly. Based on HCM dwell time was based on the number of alighted and boarded passengers at peak 15 minute and passenger service time, and also door opening and closing time. For this research Bus Dwell times were observed from field by identifying the peak hour from recorded data. Because, Existing Harar Bus Station transport system was consisted of local Bus and long distance Bus route lines. One of the data elements collected by, these systems is the time between the door opening and the door closing of arriving Bus loading area which used to determine Bus dwell time. Once a Bus comes to a stop at the loading area, it takes about 2-5 seconds to open the door open and also it takes 2-5 second to close the door. Generally, the times taken from Bus door opening and closing for this study were 5 second

During video record the peak hour was determined based on the number of Buses and passengers were determined to identify the maximum number of dwell time which used to calculate the capacity of each loading area. Empirical formula that used to calculate dwell time for this study was as follows.

$$t_d = p_a t_a + p_b t_b + t_\infty \qquad \text{Equation 3.1}$$

Where,

t_d = Average dwell time(s),

p_a = Alighting passengers per Bus through Busiest door during peak 15 min(p),

t_a = Passenger alighting time (s/p),

p_b = Boarding passenger Bus through Busiest door during peak 15 min (p),

t_b = Passengers boarding time (s/p), and

t_∞ = Door opening and closing time (s).

Estimates of hourly passenger volume are required for the highest-volume stops. The peak hour factor is used to adjust hourly passenger volumes to reflect 15-min conditions.

$$PHF = \frac{P}{4P15} \qquad \text{Equation 3.2}$$

$$P15 = \frac{P}{4(PHF)} \qquad \text{Equation 3.3}$$

Where,

PHF = Peak-hour factor,

p = passenger volume during peak hour (p), and

P15= passenger volume during peak 15 min(p),

3.7.5.2. Passenger Boarding and Alighting Time

(Sumeet, 2010)The boarding time per passenger and alighting passenger at the study station was estimated as the following;

$$t_b = \frac{\text{Total boarding time}}{\text{Number of passenger boarded}} \qquad \text{Equation 3.4}$$

$$t_b = \frac{\text{Total alighting time}}{\text{Number of passenger alighted}} \qquad \text{Equation 3.5}$$

Capacity and other traffic analyses focus on the peak hour of the volume, because it represents the most critical period for operations and has the highest capacity requirements. The peak-hour volume, however, is not a constant value from day to day or season to season (HCM, 2010). For this study HCM was used to estimate capacity of Bus station, because of the study area was mixed traffic station.

3.7.5.3. Determining Loading Area, Bus stop and station capacity

The loading area capacity calculation was based four parameters those are average dwell time, coefficient variation of dwell time, effective green ratio (g/c) and failure design rate. All the definition of the above variable was explained in chapter two.

$$B_s = \frac{3600(\frac{g}{c})}{t_c+(g/c)t_d+Z_a C_v t_d} \qquad \text{Equation 3.6}$$

Where,

Bs is the capacity of Bus stops

tc = Clearance time

td = Dwell time

za = Design failure rate

Cv = Coefficient variation of dwell time

(g/c)= Effective green ratio is equal to one for none linier loading area

CHAPTER F0UR

ANALYSIS, RESULT AND DISCUSSION

4.1. Introduction

Different types of data which are used to determine the existing geometric configuration of Bus berth design in Bus station, distribution variable of Buses and passenger demand, Bus station capacity parameters and the cause of traffic congestion were collected. The analyses, result and discussion are presented as follows.

4.2. Geometric Configuration of Bus Berth Design

To simple understand digitizing of the study area is very important for any infrastructure. For this study digitized Bus station is helped to simply understand about loading area configuration and how many numbers of Buses are occupied at the same time on allowed berth. As indicated in the following figure Harar city Bus station is digitized by using GIS software based the information obtained from Harar city Bus station managers, field recorded data and aerial photograph that shows study area. Based on HCM the existing geometric configuration Bus berth design in the Bus station is shown Sawtooth and Pull in buck angle berth design. But, from field observed data the allowed berth design configuration of the Harar Bus station affects Buses and passengers during Bus enters and returned from the loading area.

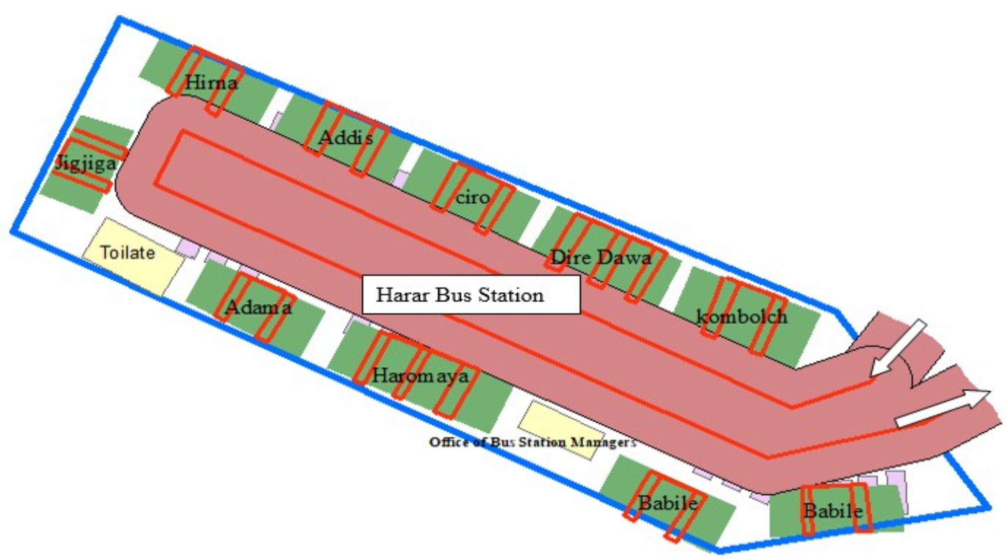

Figure 4.1: Configuration of loading area in the study area digitized by GIS software

The existing Bus station in Harar city is located at the center of the city where several buildings are surrounded and high commercial activities are highly practiced. And also, it is servicing for local, regional and long distance Bus route lines. The above figure 4.1 shows the existing Bus station in Harar city consisting of 10 Bus route line stops which contain 32 loading area. The names of each stop are Kombolcha, Haromaya, Babile, Gursum, Dire Dawa, Gursum, Hirna, Ciro, Adama and Addis Ababa. Geometric data those determined from field observation on Bus Station are the width of entrance and exit of the Bus station, elevation, level of the surface, arrangement of the loading area and total area of the Bus station are shown in the following tables.

Table 4.1.Geometric condition at Bus station

Table

Busterminaldigitize

OBJECTID *	SHAPE *	SHAPE_Length	SHAPE_Area	Busterminal_Name	Busterminal_Surface	X_Coordinate	Y_Coordinate
4	Polygon M	430.16542	8184.133755	Haraar city Bus terminal	coable ston	843897	1030495

1 (0 out of 1 Selected)

Busterminaldigitize

The shape of the Bus station shows polygon and the surface conditions of Bus station is cobble stone.

Table 4.2. Names of Bus stop route line available at the station

Table

Busstopdigitize

OBJECTID *	SHAPE *	SHAPE_Length	SHAPE_Area	Busstop_Name	Berth_numbers	X_Coordinate	Y_Coordinate
11	Polygon M	67.87534	243.487466	Adama	3	843853	1030504
12	Polygon M	86.124876	354.206402	Haromaya	4	843888	1030487
16	Polygon M	74.48266	297.993094	Dire Dawa	4	843923	1030498
18	Polygon M	73.515792	295.344684	kombolch	3	843866	1030524
20	Polygon M	57.211561	190.512328	Jigjiga	3	843840	1030524
26	Polygon M	67.87534	243.487466	ciro	3	843853	1030504
27	Polygon M	67.87534	243.487466	Addis Ababa	3	843853	1030504
28	Polygon M	67.87534	243.487466	Hirna	3	843853	1030504
30	Polygon M	66.541112	226.537086	Babile	3	843853	1030504
31	Polygon M	61.106926	198.267767	Gursum	3	843853	1030504

1 (0 out of 10 Selected)

Busstopdigitize

The above table shows the names of Bus stop route lines available at the station, the existing number of Bus loading area, shape, length, area and coordinates of each Bus stop in the study area.

Generally, based on TCQSM the existing geometric configuration of Bus berth design in Harar city Bus station is shown sawtooth and pull in buck angle berth design. The surface of the level is almost flat based on the observed grades and also the width of the entrance of the Bus station was 7.5m similar to the exit. Because of the absence of passengers walk away at the exit and entrance location the Bus station cannot travel more than one Bus at the same time.

4.3. Distribution of Bus and Passenger in Harar City Bus station

Table 4.3. Distribution of Bus and Passenger per year in Harar City Bus station

Source (Harar city Bus Station managers)

Year .E.C	Bus number	Passengers
2006 - 2007	89	7,000
2007 - 2008	95	7,500
2008 - 2009	100	8,000
2009 - 2010	112	9,000
2010 - 2011	120	10,000

The above table shows that the estimated average number of Buses and passenger demand distributed per year in Harar city Bus station.

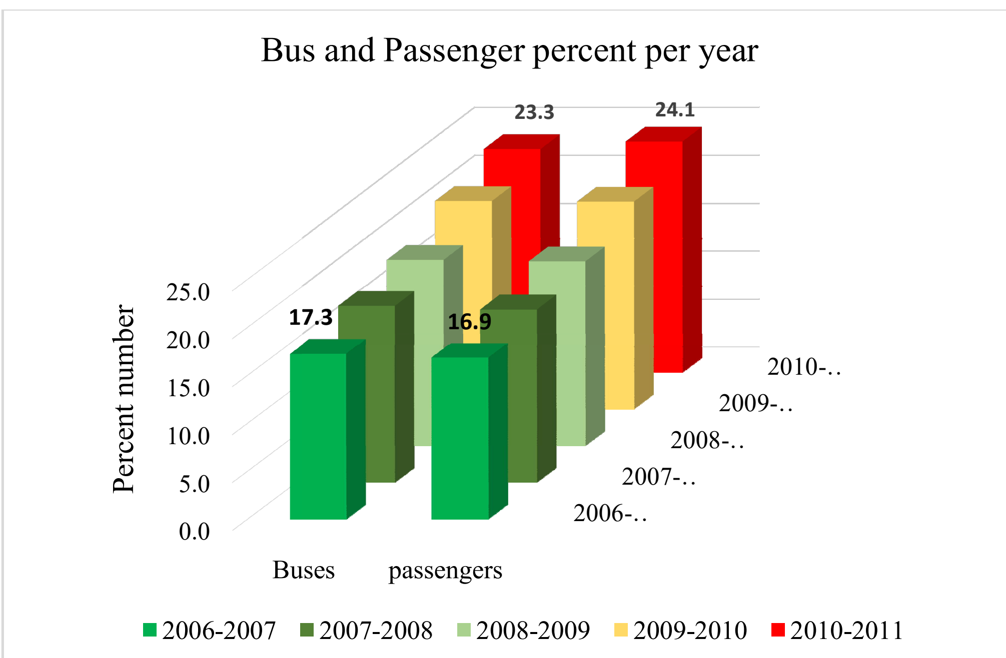

Figure 4.2. The percent of Buses and passengers per year

This study was indicated the distribution of Bus and passing numbers in terms of percent as shown on figure 4.2. The number of Bus services in Harar city Bus station is increased by 1.2 percent per year and the number of passengers increased by 1.5 percent per year. After ten years the estimated number of Bus and passenger demand in Harar Bus station will be 182 and 16,224 respectively

Based on extracted Bus data from video recorded at the study area the number of observed Buses for weekday are identified by percent, Total number of Buses, those entered to the station is indicated by 100%. From this percent, 73.4% is indicates that the Buses which enters to the station and gave services for passengers (alighted and boarded passengers) at the allowed Bus stops and 26.6% of Buses is shown that the Buses those entered and turned back immediately from the station by the lack of free Bus stop. This indicates that the traffic congestion is existed in a Bus station.

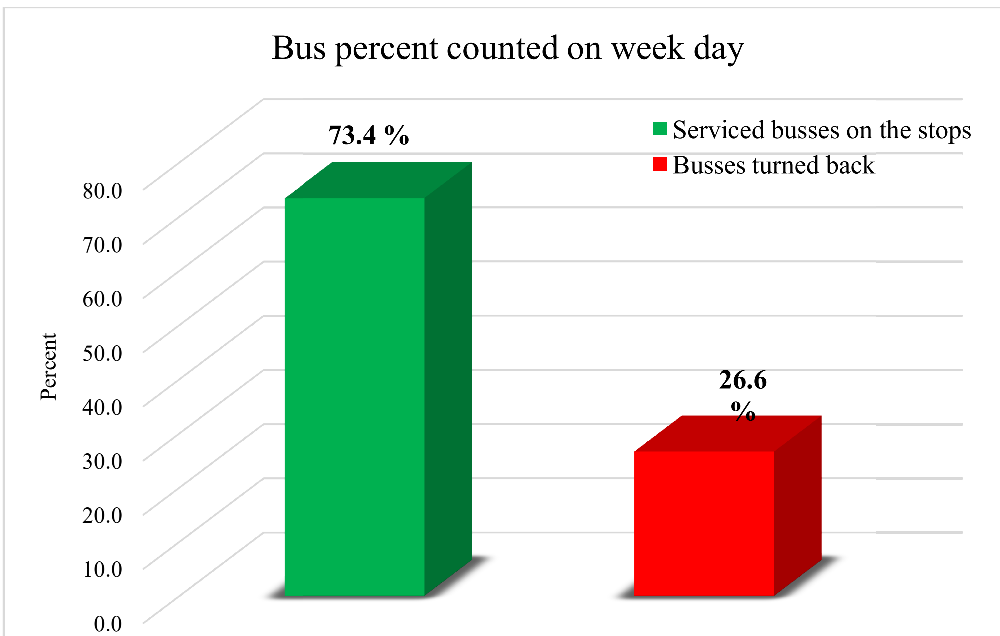

Figure 4.3: Bus percent serviced and not serviced at allowed Bus stops

4.3.1.Variations of Busses on Weekday

After extracting Bus data from video recorded in the study area, the total number Buses those gave the services for passengers (alighted and boarded) at the study area are expressed in the form of a percent. As shows on the figure passenger service Buses are varied according to weekday This shows that the number of Buses is available on Monday and the smallest are available on Friday.

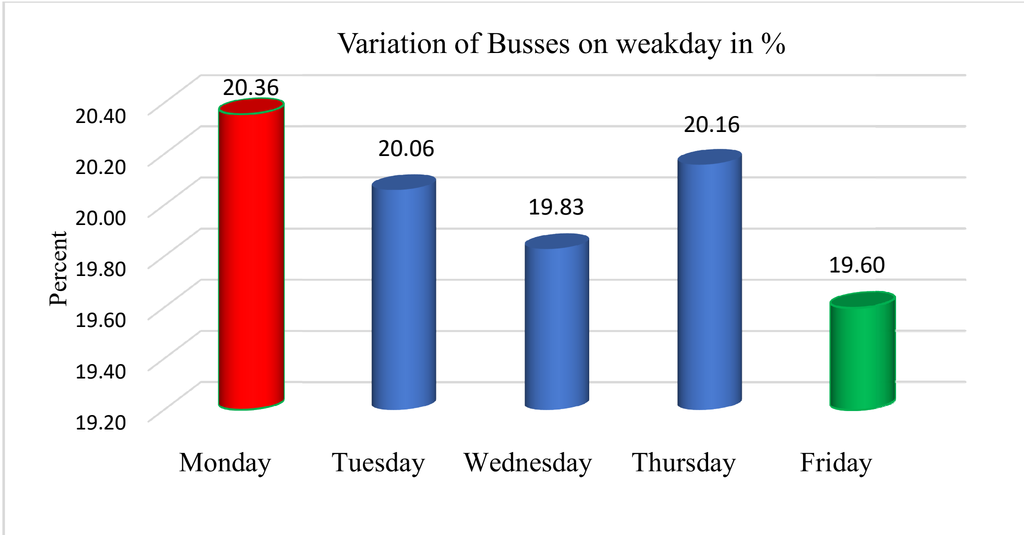

Figure4.4: Percent of observed Busses per weekday at the study area

4.3.2. Variations of Busses by Bus Route Line on Weekday

The following figure shows the average number of Busses available at the station from Monday to Friday through Bus route lines. So, the more numbers of Buses are found in the local Bus route lines like Kombolcha, Haromaya, Babile, Gursum, Jigjiga, Ciro, Dire Dawa line and the minimum number of Buses are found in the long distance route lines like Adama and Addis Ababa.

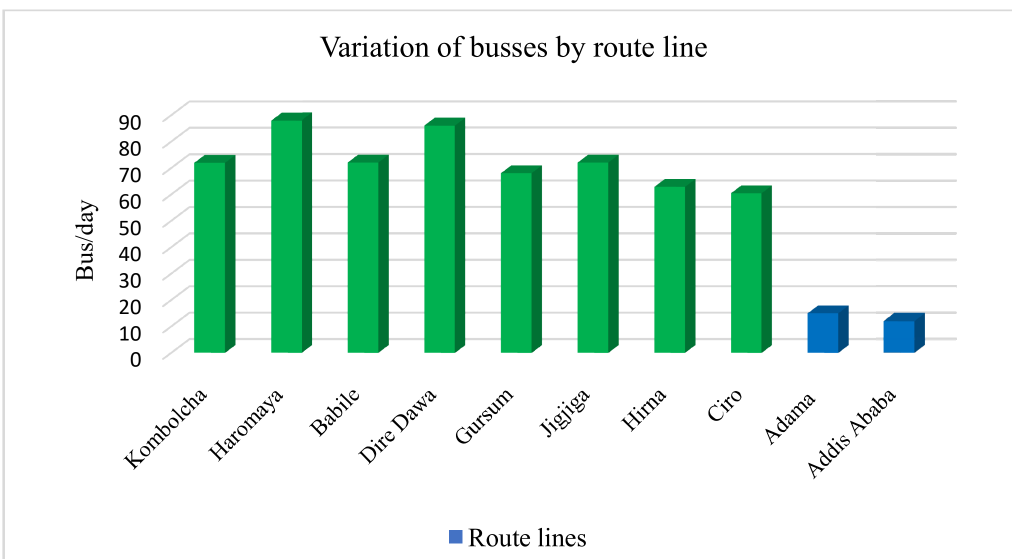

Figure 4.5. Variation of Bus route line on week day

4.3.3. Variations of Arrival and Departure Busses by one Hour Intervals

The following figure show maximum and minimum numbers of arrival (demand) and departure (volume) Busses on the allowed stops within one-hour interval. As we can see from the following figure 4.8, In the morning time the arrival number of Busses is dominated by departure Busses from 6:00am-7am by the cause of long distance Busses such as Addis Ababa, Adama, Ciro and Jigjiga where traveled in the morning, and from 7:00am -11:00am the departure Buses were dominated by arrival Busses by the cause of local Busses where bring passengers to the city. In the afternoon from 1:00pm-10:00pm departure Busses are dominated by arrival Busses, from 4:00pm-5:00pm the numbers of arrival Busses are dominated by departure Busses by the cause of local passenger Busses are travelling at this time, and from 5:00pm-6:00pm long distance Busses such as Adama and Addis Ababa A Busses are brought passengers to the city.

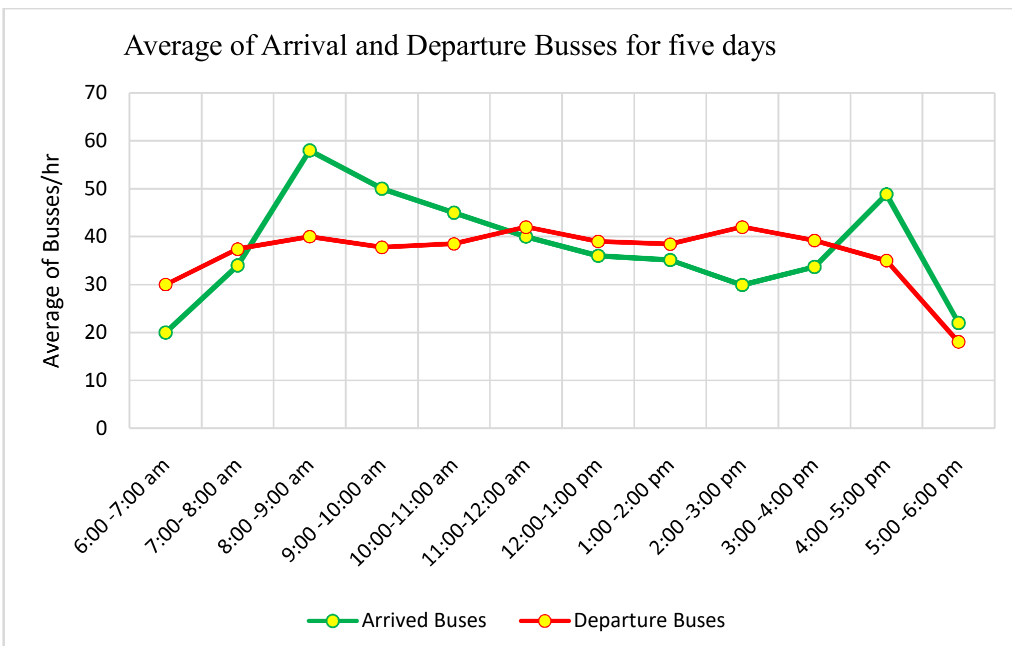

Figure 4.6. Average of arrival and departure Busses by one-hour interval

4.3.4. Variations of Busses by 30 min Intervals

To show the time in which the greatest amount Buses are giving service for passengers and the time of congestion, determining the variation of Buses by 30 min intervals is more important rather than one-hour interval. So, as shows from the following figure the greatest numbers of Buses by 30 min intervals in the study area are obtained in the morning from 8:30am-9:00am and in the afternoon 04:30pm-5:00pm.

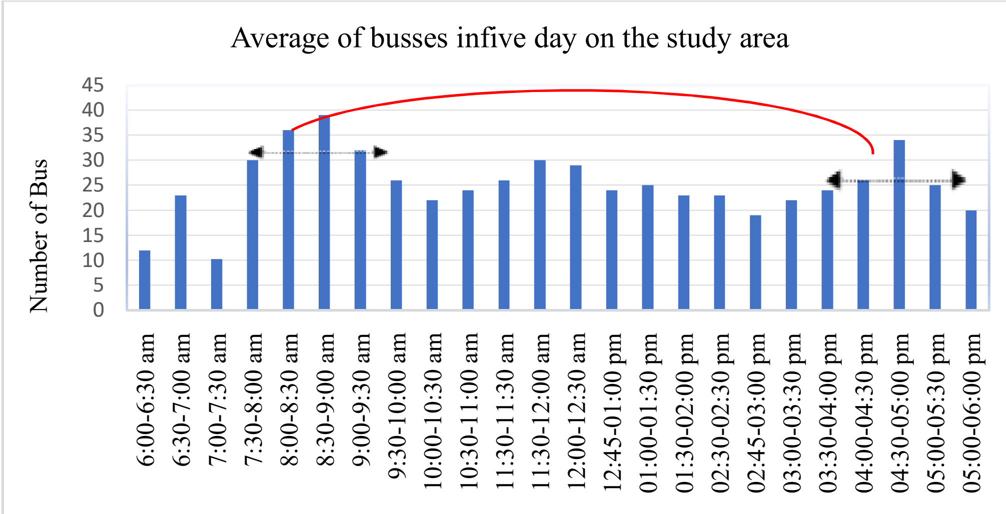

Figure 4.7. Average number of Busses at the peak and off- peak hour in 30 min

4.3.5. Variations of Busses by 15 min Intervals

Determining the average of 15 min in peak hour is important to determine peak hour factor, Bus dwell time, to estimate the capacity of the Bus station and to identifying the time on which the maximum number of Buses are gives service for passengers, and the time of Bus congestion is very important rather than 30min interval. So, the following diagram maximum peak hour at the study area is obtained in the morning from 8:00am-9:00am and at the afternoon 04:00pm-5:00pm. From this two period in the morning from 8:15am-9:30am has shown that the maximum peak of 15min.

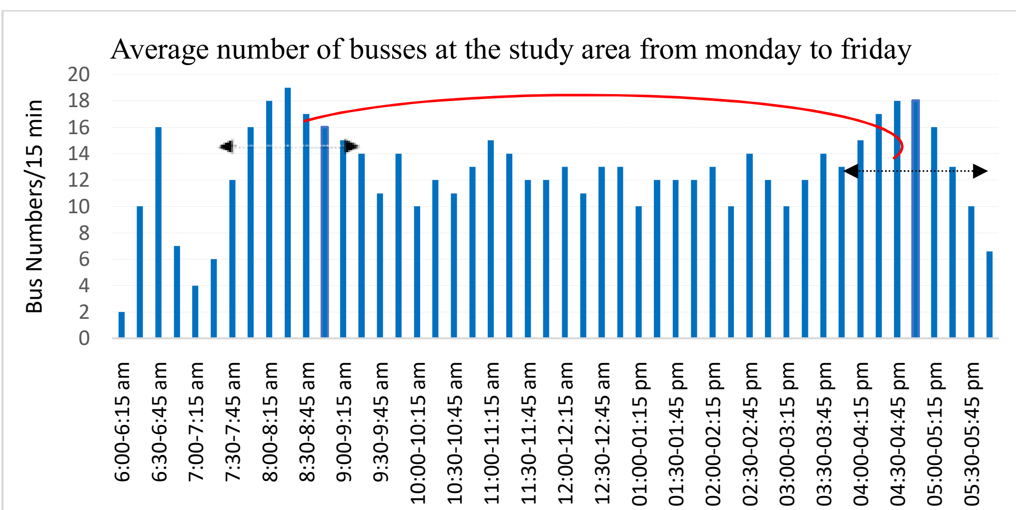

Figure 4.8. Average variation number of Busses by 15 min interval

4.3.6. Daily Variation of Bus Types at the Study Area

In the Harar Bus station there are three types of Bus which give the services for passengers. As shows from the following diagram mini-Bus numbers are greater than medium and large Bus numbers. Because, local Buses are repeated at the station more than two times per day. These shows unbalance types of Buses at the station.

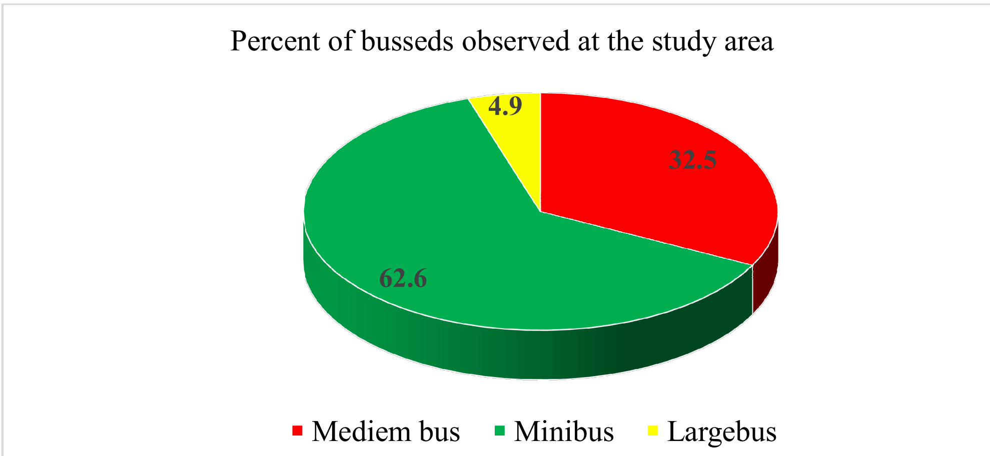

Figure 4.9. Percent of observed Busses at the study area

4.4. Distribution of Passenger in Harar Bus Station

Harar Bus Station users include tourists, hospital employers, students, merchants, patients, long distance travelers and employees of surrounding Businesses.

4.4.1.Variations of Alighting and Boarding Passengers according to Route lines

Alighting and boarding number of passengers vary according to observed data at the study area. In Harar city the purpose of the number of alighting and boarding passengers is varied according to Bus route lines. In Harar city Bus station there are ten Bus route lines those give services for passenger. As the following figure shows the numbers of alighting and boarding passenger with respect to route lines are displayed by the present. From this the alighting passengers are greater than boarding passengers for the Kombolcha, Babile and Dire route lines. But percent boarding passengers are greater than alighting passengers for the Jigjiga, Hirna, Ciro and Adama. In general, the number of alighting passengers is greater than boarding passengers for local Busses and the numbers of boarding passengers are greater than alighting for long distance route lines.

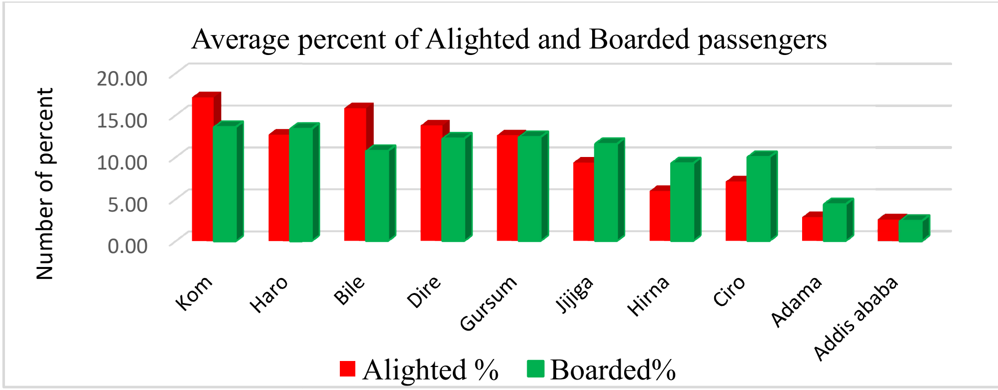

Figure 4.10. Average percent of alighted and boarded passengers at the study area

4.4.2. Variations of Alighted and Boarded passengers by one hour intervals

Service hour of Harar city Bus station start from 6:00am-6:00pm. Determining alighting and boarding passengers based on the time interval is very important to determine the Bus dwell time and to identify congestion time. The following figure shows at the morning time the number of boarding passengers is greater than alighting from 6:00am-7am by the cause of long distance Busses such as Addis Ababa, Adama and Jigjiga are traveling in the morning, and also from 7:00am -11:00am the alighting number of passengers are greater than boarding passengers by the case of local passengers are brought to the city for different purpose. In the afternoon from 11:00am-10:00pm the number of boarding passengers is greater than alighting passengers and also from 4:00pm-5:00pm the numbers of a lighted passenger are greater than boarding passengers by the cause of long distance Buses are traveling at that evening time.

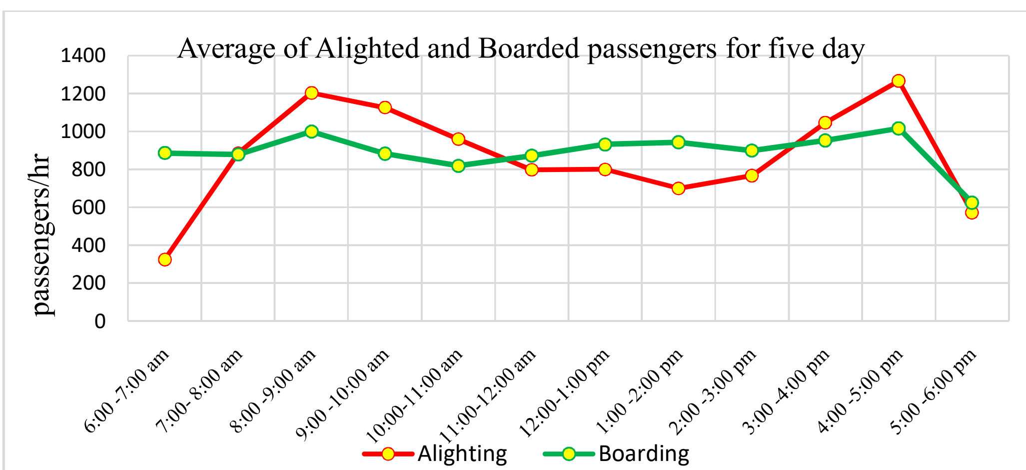

Figure 4.11: Alighted and Boarded passengers based on the time interval

Generally, Bus and Passenger distribution in the study area. Harar city is one of the most historical and commercial city in the Eastern Hararge and also for Harari region. Many numbers of passenger users such as tourists, hospital employers, students, merchants, patients, long distance travelers and employees of surrounding Businesses are traveling to the city by Buses for different purpose. The variation in numbers of passengers are related to the varying amount of the Buses and sometime the numbers of passengers are not related to the passengers at the study area. Generally, the distributional of Buses and passengers in Harar city Bus station through the time of the day, Bus route line, weekday and types of the Buses are varied.

- **Peak hour:** The number of passenger alighting and boarding at the Bus stops are the factors which used to determine the Bus dwell time and also that can affect the capacity of the Bus station. For this research Passenger and Bus data were collected according to each Bus route line for five-day from 6:00 am - 6:00 pm and the identification of PHF and P15 were determined for each Bus stop at the study area as follows.

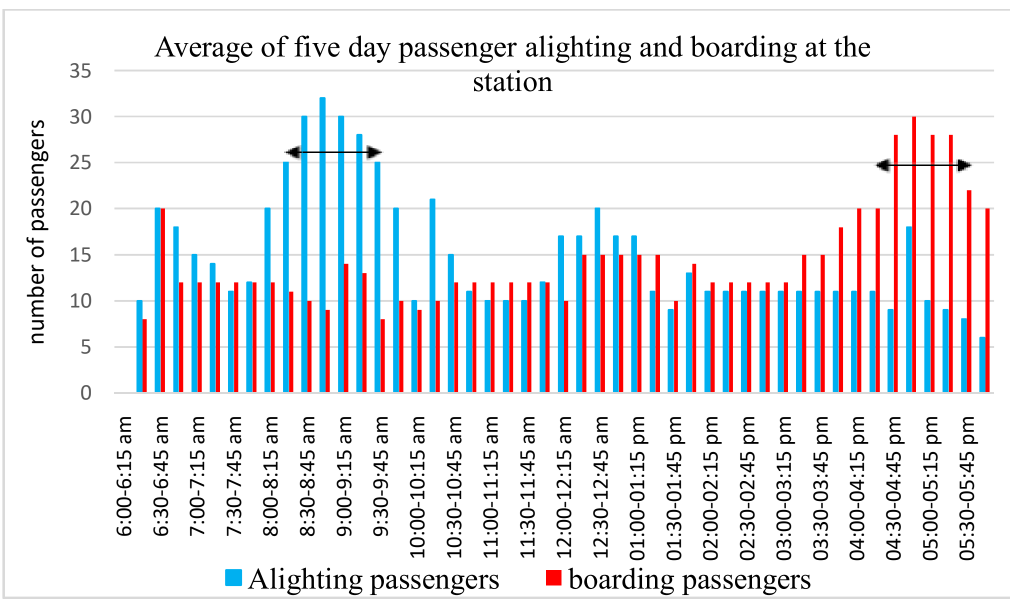

Figure 4.12. Alighted and Boarded passengers at the peak and off-peak hour

Based on the above figure, average of 15minute passenger alighting and boarding volume are varied from time to time. The largest value (32 alighting passenger per 15 minutes) at the morning 8:45am - 9:00am and the other largest value (30 boarding passenger per 15 minutes) is obtained at the afternoon from 4:45pm - 5:00pm. The

Bus dwells time calculation based on passengers alighting and boarding at the Kombolcha Bus stop is determined as follows:

Morning Pak hour volume (PHV) is start from 8:00am – 9:00 = sum of four peak 15 minutes=30+32+30+28=120 alighting passengers

Peak 15minutes' volume (p15min) = 32

Peak hour factor (PHF) =PHV/(4*P15) =120/ (4*32) = 0.94

P15 = 120 / (4*0.94) =32

When alighting passenger time per Bus is 5.6 sec based on HCM 2000

Dwell time is = 32*5.6 = 180 sec at the morning

Morning Peak flow rate = 4*32=128 alighting/hr

For the remained Bus route line, the peak flow rates are listed in the following table.

Table 4.4. Peak hour factor and Peak flow rate of Bus stops

Stop name	PHV (alighted passengers /Bus)	Pa_{15min} (alighted passengers)	PHF	Peak flow rate (4* Pa_{15min})
Kombolcha	120	32	0.94	128
Haromaya	45	15	0.75	60
Babile	90	32	0.70	128
Dire Dawa	45	15	0.75	60
Gursum	60	32	0.94	128
Jigjiga	60	32	0.94	128
Hirna	82	32	0.85	128
Ciro	60	32	0.94	128
Adama	83	44	0.94	176
Addis Ababa	160	44	0.94	176

4.5. The Estimation of Bus Station Capacity

The parameters which used to estimate Bus station capacity in the study area where Dwell time, Clearance time, failure rate, coefficient variation of loading area, Loading area and Bus stop capacity and person capacity.

4.5.1. Design failure rate

In these study design failure rate was observed based on average Bus arrival time headway at the station. The observed average Bus headway in the study area was 9.3 minutes and it was nearer to 10 minutes, however, for this research, 7% design failure rates were used to determine the capacity of the Bus station.

Table 4. 5. Design failure rate

Characteristics	**No queue**		**Medium**		**High**	
Failure rate	1%	5%	7.50%	10%	25%	50%
Za	2.33	1.645	1.44	1.28	0.675	0
∑(La Capacity)	48	57	60	64	79	108
Bus-station Capacity	161	192	204	214	265	361

As listed in the literature review, HCM recommends the design failure rate in the central Business district should be 7.5 %. The Bas station in Harar city is located in the central Business district of Harar city. Therefore, the design failure rate which used to determine capacity of bus station under this study was 7.5 %.

4.5.2. Dwell time Estimation

Dwell time is the time on which the Bus used to serve passengers during alighted and boarded. In HCM dwell time value is based on passenger's service time and numbers of the passengers at the peak. At the Harar city Bus station mixed traffic congestion at the study area passenger service time is calculated based on field observed data.

$$t_d = p_a t_a + p_b t_b + t_\infty \qquad \text{Equation 4.1}$$

$$t_b = \frac{\text{Total boarding time}}{\text{Number of passengers boarded}} \qquad \text{Equation 4.2}$$

$$t_a = \frac{\text{Total alighting time}}{\text{Number of passengers alighted}} \qquad \text{Equation 4.3}$$

Where,

td= Dwell time

ta = Passenger alighting time

tb = Passenger boarding time

Based on extracted data from vidio camera, Alighting and boarding passengers time are calculated as the following process.

Table 4. 6. Estimated alighted and boarded time for Kombolcha Bus stop

Alighted and Boarded passengers/Bus	**Number of passengers per Bus**										**Sum**
Alighted Passengers/Bus	30	30	32	32	26	28	30	31	22	28	289
Alighted time/Bus (min)	2	2	3	3	1	2	2	2	1	2	20
Boarded time/Bus	30	13	13	20	16	19	10	16	16	20	169
Boarded Passengers/Bus	3	1	1	2	1	2	1	1	2	2	16

From the above table the total number of alighted and boarded passengers from 10 Buses was 289 and 169 respectively. The total serves time used for alighted and boarded passengers from 10 Buses were 20 min and 16 min respectively. Based on this value the alighting and boarding time for each passenger was estimated by dividing the total alighted time by total alighted passengers. For the boarded the calculation process is the same. t_a = 20min / 289 passengers = 4.2 sec/passenger.

t_b = 16 min / 169 passengers = 5.7 sec / passenger.

The above the estimated amount of alighting and boarding passengers' time was calculated for the only Kombolcha Bus route line. For the other Bus route lines those are gave services for passengers at the Harar city Bus station were calculated according to the following table 4.7.

Table 4.7. Passenger alighting and boarding time

Bus route line	**Morning peak hour**						
	Passengers						
	Alighting time(min)	Alighted	Alighted tine (sec/pas)	Boarding time(min)	Boarded passengers	Boarded time (sec/pas)	Average Bus queue time(min)
Kombolcha	20	289	4.2	16	169	**5.7**	27
Haromaya	10	142	4.2	16	169	5.7	31
Babile	15	214	4.2	13	140	5.6	32
Dire Dawa	13	188	4.1	13	155	5.0	26
Gursum	14	178	4.7	12	132	5.5	34
Jigjiga				18	188	5.7	44
Hirna				11	120	5.5	37
Ciro				15	160	5.6	41
Adama				16	160	6.0	46
Addis Ababa				9	80	6.8	32
Average	72	1011	4.3 ≈**4.5**	139.0	1473	5.7≈**6**	**35**

According to HCM and TCQSM, the average alighting and boarding time for each passenger are based on situation at the Bus station. by the cause of different factors in Harar city Bus station such as passenger age, uploading things up on the Buses, communicating passenger with driver at the station, interaction between Bus and passengers etc. In this the average of alighting and boarding at the station were estimated by adding total number of time taken to alighting or boarding and dividing for the total number of passengers alighted or boarding from the Bus.

The above table shows that the estimated average of alighted and boarded time in the study area. As indicated on the table 4.6 the average of alighting passenger from each Bus stop is 4.3 second and we extend this number in to 4.5 second. And also, the number of boarding time is 5.7 second and we extend this number in to 6 second. The estimation of alighting and boarding passengers is one of the base to deter mine dwell time and estimating data from field observation is better than the estimated value which taken from the manual estimation than manual. So, for this study the estimation of alighting and boarding passengers from field observation is selected. Calculated Bus dwell time that used to determine capacity of loading area under this study was determined based on this time and maximum numbers of alighted and boarded passengers per Bus respect to allow loading area.

4.5.3. Determining Loading Area, Bus Stop and Station Capacity

Most studies limit the capacity for a loading area to 10–15 Busses/hour. Variations in arrival time and dwell time were in some cases considered indirectly by specifying the difference in capacity depending on the number of routes served by the Bus stop. Unlike other studies (HCM, 2010) considers how the queue risk, coefficient of variation and clearance time affect the capacity of a Bus stop (Al-Mudhaffar, 2016).

Loading area capacity calculation is based on four parameters those are average dwell time, coefficient variance of dwell time, effective green ratio (g/c) and failure design rate. Calculation of Bus stops capacity is obtained from calculated loading area capacity multiplying by existing numbers of berth in the Bus route line and also the obtained Bus station capacity is obtained from the summation of calculated Bus stops capacity. For this calculation the data such as (opening and closing time = 10 Sec, CV =60% and design failure rate = 1.440 for CBD) are taken from HCM and the other data, such as passenger alighting and boarding time, number of loading area, numbers of passengers and Buses are determined from field observation. The capacity of loading areas, Bus stops and station are calculated based on empirical formula as indicated in the following table.

$$B_n = \frac{3600(\frac{g}{c})}{t_c + (g/c)t_d + Z_a C_v t_d}$$ Equation 4.4

Table4.8. Estimated /an Adjusted capacity of Bus station

Bus stops name	t_a= 4.5sec	t_b=6sec	Pa_{15}	Pb_{15}	t_a* Pa_{15}	t_b* Pb_{15}	t_d (Dwell time)	Loading area Capacity	No. of Berth	Calculated Bus stop Capacity
Kombolcha	4.5	6	32	32	144	192	346	5	3	16
Haromaya	4.5	6	15	15	67.5	90	167.5	11	4	42
Babile	4.5	6	32	32	144	192	346	5	3	16
Dire	4.5	6	15	15	67.5	90	167.5	11	4	42
Gursum	4.5	6	32	32	144	192	346	5	3	16
Jigjiga	4.5	6	32	32	144	192	346	5	3	16
Hirna	4.5	6	32	32	144	192	346	5	3	16
Ciro	4.5	6	32	32	144	192	346	5	3	16
Adama	4.5	6	44	44	198	264	472	4	3	12
Addis Ababa	4.5	6	44	44	198	264	472	4	3	12
										204

From the above table, 204 value indicates that the estimated capacity of the Harar City Bus station. On the other hand, the result obtained under capacity parameters shows that one parameter depends on the other. E.g.

- ✓ Dwell time is based on the numbers of the passengers and Bus seat
- ✓ Dwell time was directly proportional with the number of passengers.
- ✓ Dwell time was inversely proportional to the capacity of loading area, Bus stop and Bus station.
- ✓ Generally, capacity of the Bus station was based on the numbers of passengers or Busses and the number of loading area.

Note: There is no Standardized boundary numbers in HCM and TCQSM to say the observed value of capacity was accepted or rejected.

4.5.4. Adjusted and Unadjusted Capacity of Bus Station

At higher traffic load the station capacity can be reduced by factors such as queuing Buses, blocking the entrance or exit from Bus stops for other Bus lines, passengers moving across the station, limited station entry or exit capacity etc. Therefore, adjusting calculated capacity of the Bus station is important for this study.

Load factor: The load factor is the number of passengers occupying a transit vehicle divided by the number of seats in the vehicle. During field observed in the study area the number of lighted passengers of the vehicles were more than boarded at the morning peak hour and vice versa at the afternoon peak period for local Buses. But, for long distance Buses the number of boarded passengers was higher in the morning than afternoon. Therefore, the load factor for these studies was determined for each Bus stop route line by taking the average of morning and afternoon alighted and boarded passenger as shows in the following table.

Table 4.9. Adjusted and unadjusted Bus station capacity

Bus stop route line	**Average of alighted and boarded passenger**	**Average Busses/hr**	**Number of Bus seat**	**Load factors**	**v/c ratio**	**1- (fl* v/c)**	**Un adjusted capacity**	**Adjusted capacity**
Kombolcha	226	10	32	0.70	0.62	0.57	16	11
Haromaya	141	12	15	0.81	0.27	0.78	42	33
Babile	177	9	32	0.61	0.56	0.66	16	11
Dire Dawa	149	11	15	0.90	0.26	0.77	42	32
Gursum	153	6	32	0.79	0.37	0.71	16	11
Jigjiga	97	6	32	0.50	0.37	0.82	16	13
Hirna	81	8	32	0.32	0.50	0.84	16	13
Ciro	67	5	32	0.47	0.28	0.87	16	14
Adama	100	4	44	0.78	0.34	0.73	12	9
Addis Ababa	50	4	44	0.45	0.29	0.87	12	10
Total	1241	75	310	0.53	0.36	0.81	**204**	**167**

Un adjusted Bus station capacity = $B_t = \sum (f_m * Bs) = \sum (1 - fl(v/c) * Bs)$

From the above table, 204 value is indicated that the unadjusted capacity of the Harar City Bus station and also 167 indicated that is the adjusted capacity of the Bus station. As indicated on the table 3.4, the estimated number of passengers available in Harar city Bus station is 10,000 per day. But, the maximum numbers of the passengers at the peak hour are not known. So, under this study the current maximum numbers of passengers at the peak hour in Harar city Bus station are calculated as the following table 4.12.

$$Ps = \sum_{t=1}^{n} \text{Pmax, i(PHF)Ni} \qquad \text{Equation 4.5}$$

Table 4.10. Scheduled Person Capacity

	Morning peak hour Bus/hr	**p15**	**PHF**	**Person capacity at the morning**	**Afternoon Peak hour** Bus/hr	**Person capacity at the afternoon**	**Schedule Person capacity**
Kombolcha	10	32	0.71	226	10	226	226
Haromaya	12	15	0.72	129	11	119	124
Babile	9	32	0.66	189	9	189	189
Dire Dawa	13	15	0.68	133	9	92	112
Gursum	6	32	0.67	129	6	129	129
Jigjiga	6	32	0.63	120	6	120	120
Hirna	8	32	0.68	173	8	173	173
Ciro	5	32	0.69	110	4	88	99
Adama	4	44	0.65	114	4	114	114
Addis Ababa	2	44	0.45	40	5	100	70
Total	75	310	0.65	1363	72	1350	**1,356**

The current maximum number of passengers at the peak hour in Harar city Bus station is 1,356. Then we can calculate the maximum numbers of passengers per day as the following. 1,356 * 12hr = 16,272 Passengers/day.

Design person capacity is the number of people that could be carried through the facility's maximum load section (TCQSM, 2013).

$$p = p_{\max B = p_{\max (PHF)B}} \qquad \text{Equation 3.6}$$

Table 4.11.Design person capacity

Bus route line	Bus stop capacity	p15	PHF	Design person capacity
Kombolcha	11	32	0.71	250
Haromaya	33	15	0.72	356
Babile	11	32	0.66	231
Dire Dawa	32	15	0.68	327
Gursum	11	32	0.67	236
Jigjiga	13	32	0.63	260
Hirna	13	32	0.68	281
Ciro	14	32	0.69	308
Adama	9	44	0.65	257
Addis Ababa	10	44	0.45	200
Average	167	310	0.65	**2,706**

Determining design person capacity is very important to design the new Bus station. The estimated Design person capacity of Harar city Bus station is 2,706. Then we can Design the maximum numbers of passengers per day as the following. 2,706 * 12hr = 32,472passengers/day. When we compare 10,000 Passengers/day that taken from Harar city managers with the calculated 16,272 passengers/day from this study there are varied value.

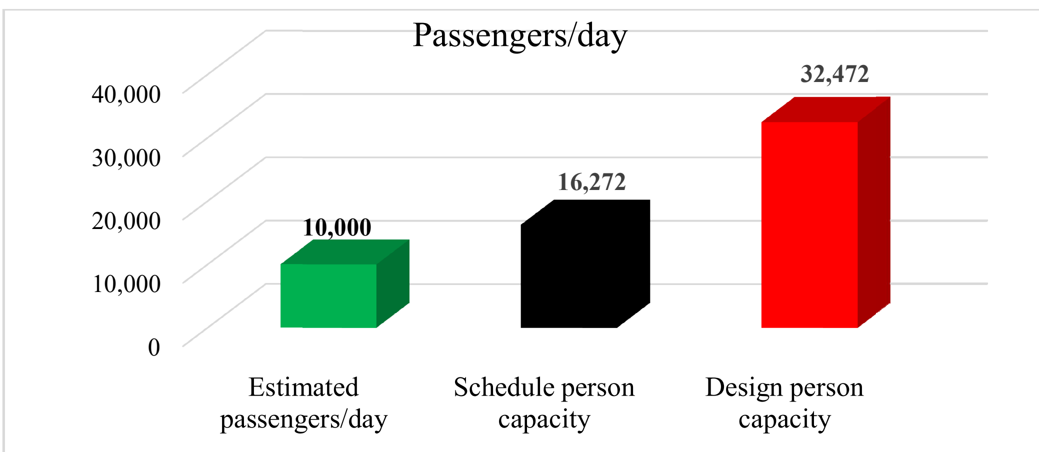

Figure 4.13. Comparison between Estimated, Schedule and Design person capacity

The above figure shows that the total estimated number of passengers per day which is taken from Harar city Bus station schedule, the calculated schedule person capacity per day and design person capacity in the study area.

The value of the blue color is not based on the peak hour and it is the existing Bus station schedule which is taken from Harar city Bus station manager. The value of the black color is shown that the total numbers of passengers which is calculated based on the peak hour multiplying by 12 hours. And also the red color shows that the design person capacity, which is obtained from based on calculated Bus station capacity and its used for the future Bus station design.

4.5.5. Evaluation of Service Frequency LOS

As indicated in the Harar city Bus station schedule table 3.4 the arrival and departure time of Kombolcha, Haromaya, Babile, Dire Dawa, Gursum, Jigjiga and Hirna Bus route lines are random. And also that of the Ciro, Adama and Addis Ababa are fixed.

Table 4.12. Evaluation of Service frequency LOS for each Bus stop route line

Stop name	Existing No of Berth	Average Bus Arrival head way (min)	Peak Arrival Bus /hr	LOS	Comments
Kombolcha	3	6	10	A	Passengers don't need schedules
Haromaya	4	5	12	A	Passengers don't need schedules
Babile	3	7	9	A	Passengers don't need schedules
Dire Dawa	4	5	13	A	Passengers don't need schedules
Gursum	3	10	6	B	Frequent service; Passenger consult schedules
Jigjiga	3	10	6	B	Frequent service; Passenger consult schedules
Hirna	3	8	8	A	Passengers don't need schedules
Ciro	3	12	4	B	Maximum desirable time to wait
Adama	3	15	4	C	Maximum desirable time to wait
Addis Ababa	3	20	4	D	Maximum desirable time to wait
Total	***32***		***75***		

This study evaluated Service frequency LOS of all Bus route lines based on HCM as indicated on the table 2.2. Based on observed average Bus arrival headway time and number of arrival Busses per hour the LOS of Bus route lines are evaluated as the above table 4.11. Based on this table the comment for the local Bus route line Passengers there are no need schedules and for long distance Bus route line schedule passenger will require scheduling

4.6. Traffic Congestion in Harar City Bus Station

The transportation system in Harar city Bus station is a mixed traffic system which causes for traffic congestion. The other causes of traffic congestion in the Harar City Bus station are insufficient capacity of the Bus station, narrow space, lack of good amenity service, lack of passenger waiting area, increasing passenger and Bus demand, incorrect Bus berths distribution, unbalance number of passenger and Bus distribution through time of the day etc.

4.6.1. Measurement of Cause Traffic Congestion

There are many causes which can form traffic congestions. But, to know the cause of traffic congestion deeply in Harar city Bus station, this study was focused on estimated capacity, arrival and departure Busses. Therefore, the measurement of traffic congestion in Bus station is determined by comparing estimated capacity, Bus demand and volume and also by comparing volume to capacity ratio as the following table.

Table 4.13. Comparisons between Demand, Volume and Capacity

	Morning			Afternoon		Morning		Afternoon	
Bus route line	**Demand(arrival)**	**Volume (departure)**	**Capacity**	**Demand (arrival)**	**Volume (departure)**	**d/c**	**v/c**	**d/c**	**v/c**
Kombolcha	10	8	11	10	12	0.91	0.73	0.91	1.09
Haromaya	12	11	33	10	15	0.36	0.33	0.30	0.45
Babile	10	8	11	5	7	0.91	0.73	0.45	0.64
Dire	11	9	32	6	8	0.34	0.28	0.19	0.25
Gursum	4	6	11	9	11	0.36	0.55	0.82	1.00
Jigjiga	4	6	13	6	3	0.31	0.46	0.46	0.23
Hirna	4	5	13	5	3	0.31	0.38	0.38	0.23
Ciro	5	6	14	5	3	0.36	0.43	0.36	0.21
Adama	0	5	9	5	0	0.00	0.56	0.56	0.00
Addis Ababa	0	5	10	5	0	0.00	0.50	0.50	0.00

I. **By Comparing Capacity, Demand and Volume**

Determining the cause of congestion by comparing estimated capacity, the number of the Busses arrived at the station from different Bus route line and Busses departed on time. Based on HCM when the number of Bus arrival Busses is greater than the number of the departure Busses, traffic congestion can be formed. The number of Bus route line in Harar city Bus station is ten. From these Bus route lines which Bus route lines are more cause for congestion. To know this the number of Busses which arrival number is greater than departure Busses can cause for congestion in the study area as the following figure.

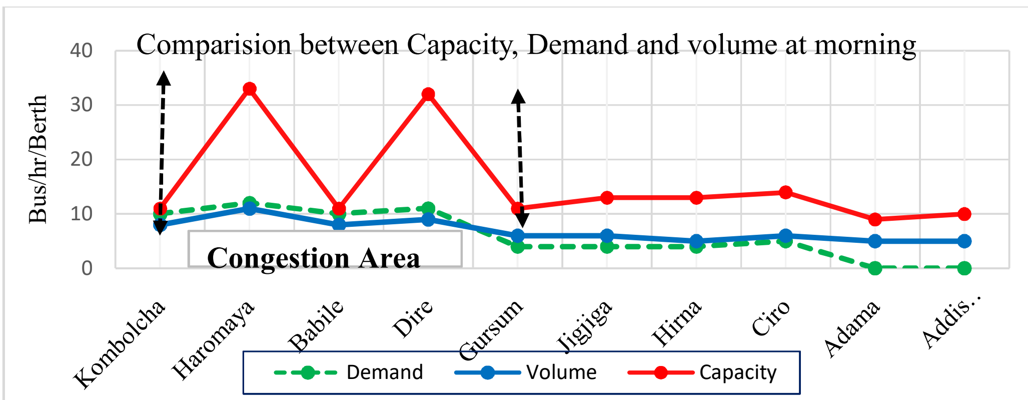

Figure 4.14: Comparison between capacity, demand and volume at the morning

The above figure shows the comparison between demand, volume and capacity at the morning peak hour. So, the result shows that the cause of congestion at the morning time was formed by local Busses like Kombolcha, Haromaya, Babile and Dire Dawa. Because, the arrival Bus number of these four route lines are greater than the number of departure Busses at the station.

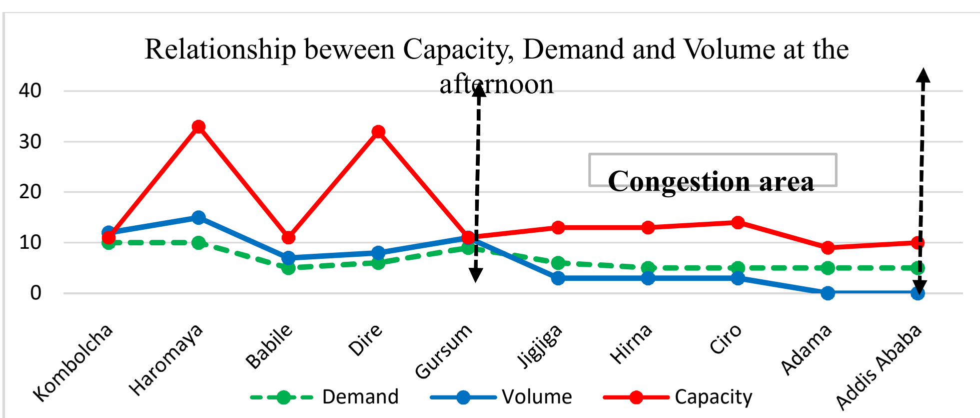

Figure 4.15. Comparison between Capacity, Demand and Volume at the afternoon

The above figure shows the comparison between demand, volume and estimated capacity in the afternoon. So, the result obtained from this figure shows that the cause of congestion at the afternoon time is formed by long distance Busses like Jigjiga, Hirna, Ciro, Adama and Addis Ababa. Because, the arrival Bus number of these five route lines are greater than the number of departure Busses at the station.

II. By comparing the ratio of demand/capacity and volume/capacity

Based on HCM causes of congestion can be measured by comparing v/c or by d/c ratio and also, when the range of v/c value is greater than 1, it indicates severe congestion. Between 0.75-1.0 heavy, between 0.75-0.5 moderate and less than 0.5 low congestion.

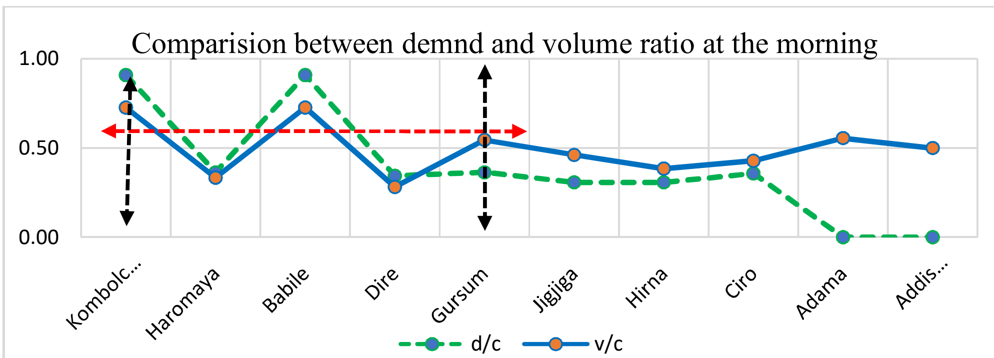

Figure 4.16. Comparison between d/c and v/c at the morning

The above figure is used to know deeply by asking which Bus route lines is more causes congestion at the morning time as indicated on figure 4.15? To answer this question comparison of d/c or v/c is required. As shows on the figure 17, The result of Kombolcha and Babile at the morning is between 0.75-1.0 and that of the Haromaya and Dire Dawa is less than 0.5 low congestion. Therefore, Kombolcha and Babile Bus route lines are more causes of congestion in the morning.

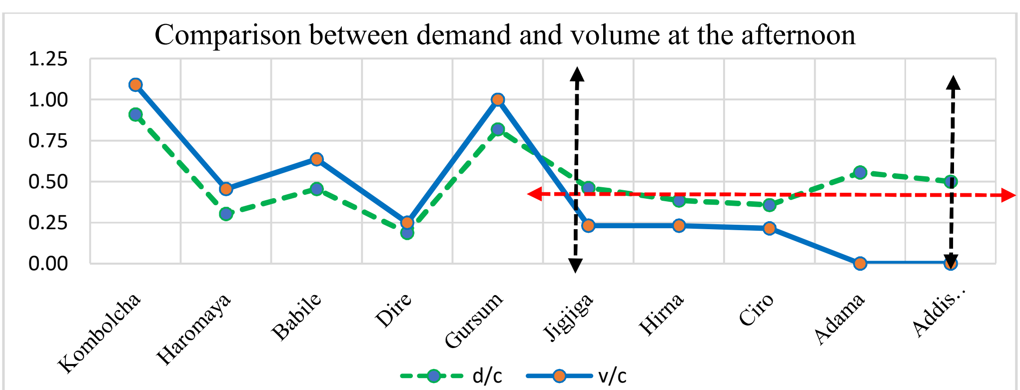

Figure 4.17: Comparison between d/c and v/c at the morning

The above figure is the same with the previous figure 17 it is used to know which Bus route lines are more causes of congestion from previous five route lines that are listed on the afternoon. Therefore, the result indicates that the value of Adama and Addis Ababa at the afternoon is between 0.5- 0.75 and it shows under moderate congestion. So, the major cause of congestion of the afternoon is Adama and Addis Ababa rather than the other.

Generally, the cause of congestion in the study area is identified based on the comparisons of arrival, departure and capacity, and also by comparing d/c or v/c ratio. The result shows that at the morning time local Busses such as Kombolcha, Haromaya, Babile, Dire Dawa and Gursum are the cause of congestion. Of them Kombolcha and Babile Bus route lines are more causes for traffic congestion in the morning.

In the afternoon the long distance Bus route lines such as Jigjiga, Hirna, Ciro, Adama and Addis Ababa more cause of congestion and also long distance Busses such as Adama and Addis Ababa are the cause of congestion. Of them Adama and Addis Ababa Bus route line are more causes at the afternoon rather than the other. To solve this problem some of the suggested solutions were listed as the following.

4.7. Suggested Possible Solution for Harar city Bus station

Based on the result obtained from this study, some of the possible solutions which used to minimize congestion in the study area are indicated as the following.

Under this study, the average Bus headway and recovery times were determined. Based these time required number of Bus berth can be determined for each Bus route line as the following. It is known if the amount of Bus recovery in the Bus station is greater than the Bus headway time the Busses can for the queue at the stop and it can form congestion. But if the amount of Bus recovery in the Bus station is less than the Bus headway time the probability to form congestion is less. Therefore, based on this formula (No of loading area = (average Bus recovery time*1. 2) /Bus headway time). The modified number of loading area can be used as a solution for the Harar Bus station as indicated in the following table.

Table4.14. Existing and Modified number of Loading Area

Bus Route lines	**Distance(Km)**	**Average Recovery at peak hour**	**Average Bus Arrival head way (min)**	**Modified No. of loading area**	**Existing No. of loading area**
Kombolcha	16	20	6	4	3
Haromaya	17	20	5	5	4
Babile	30	20	7	3	3
Dire Dawa	50	20	5	5	4
Gursum	68	25	10	3	3
Jigjiga	100	30	10	4	3
Hirna	150	20	8	3	3
Ciro	200	20	12	2	3
Adama	420	20	15	2	3
Addis Ababa	512	30	20	2	3
Total				32	32

Modified No of loading area = (average Bus recovery time*1.2)/Bus headway time

The above solution can be used urgently for Harar Bus station. The other solutions are recommended in next chapter.

CHAPTER FIVE

CONLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study assessed the capacity of Bus station and analyzed the causes of traffic congestion in Harar city Bus station. The result of this study was obtained through the determination of geometric condition, Bus and passenger variation, and also by determining Capacity and the LOS of Bus station and finally by comparing demand, volume and capacity cause of traffic congestion in the bus station were determined. In order to achieve the objective of this research, the necessary data were collected for a weekday in the study area. And the data collection process included field visual inspection, field measurements and traffic data video recording. Typical data required for this were processed and analyzed based on empirical calculation of HCM, GIS, Microsoft Excel and SPSS software. The result obtained through this study was concluded as the following.

The result obtained through the geometric condition in the study area contains 10 numbers of Bus Stops which consists of 3-4 number of loading area. The design configurations of the existing loading area in Bus station shows pull in back angle berth design. The area of the Bus station was 1000 square meter and the width of entrance and exit of the Bus station was equal to 7.5 m.

In Harar city Bus stations, the Bus number are increasing by 1.2 percent per year and the number of passengers is increased by 1.5 percent per year. After ten years, the estimated number of Bus and passenger demand in Harar Bus station will be 182 and 16,224 respectively. Based on extracted data from video camera in the study area, from the total number of the Busses 73.4% indicate that the Buses which enters to the station and gave services for passengers and 26.6% of Buses is shown that the Buses those entered and turned back immediately from the station by the lack of free Bus stop and also, The number of the Buses on Monday and Thursday are greater than that the other day and local Busses arrived are more than departure Bus at the morning peak hour and vice versa in the afternoon. Generally, the distributional variations of Busses and passengers through the time of the day are not the same at the study area.

For the calculation of the LOS and Bus stop capacity, the numbers of Bus stops capacity are the key under estimated Bus station capacity. The unadjusted and adjusted estimated capacity of Bus station was 204 and 167 respectively. Generally, one capacity parameters are depending on the other.

Lastly cause of traffic congestion is identified based on the number of the arrival and departure Busses, and also demand or volume to capacity ratio based on HCM and TCQSM. The comparison between capacity, demand and volume is used to analyses cause of congestion. But, demand to capacity and volume to capacity ratio is used to know the cause of congestion deeply. The result obtained from this study shows, the local Bus such as Kombolcha, Haromaya, Babile and Dire Dawa are indicated the cause of congestion at the morning peak hour. From them Kombolcha and Babile are indicated the more cause than the other. At the afternoon the long distance Busses such as Jigjiga, Hirna, Ciro, Adama and Addis Ababa are indicated the cause of congestion at the afternoon peak hour. From them Adama and Addis Ababa are shows the most cause at the afternoon. Generally, Local Busses are more causes for congestion problem in the morning rather than long distance Busses and vice versa in the afternoon. Based on the result obtained from this study some of the possible solution which used to minimize congestion at the study area are indicated and based on average Bus head way and recovery times required number of Bus berth were determined.

5.2. Recommendations

Based on the result obtained through this study the important recommendations which used to minimize traffic congestion in the study area a reported as the following;

- The Harar City Municipality would have to arrange the required number of loading area for each bus stop based on the average Bus headway and Bus recovery time (refer to modified a number of loading area in the findings of the study). The current loading area in the Bus Station is distributed based on the estimation than following well defined method and procedures.
- Harar City Transport Authority and Municipality would have to be design a new Bus station based on the result (design person capacity) which was determined under this research. Because, the number of Buses and passengers demand were increasing to the Bus station from time to time and it may stop the service after some years.
- This research recommended that the Harar City Bus station manager would have to Prepare billboard schedule for local and long distance Buses. Because, the result of this study shows that the local Buses are more causes for traffic congestion problem at the morning and long distance Buses at the afternoon.
- The capacity of the Bus Station under this study was determined based on HCM; this research also recommends that further research would have to be required to determine the capacity of the Bus station by using a micro - simulation model to support the result of Bus station capacity suggested under this research.
- Further research is required to prepare Bus Station design manual for Harar City and Ethiopia. Because, there is no Bus Station design manual as Ethiopia.

REFERENCES

1. Abdeniz. (2016, September 22). Effect of different passenger characteristics and bus types on boarding times at bus-stops. *stady on parking spase analysis and guiding system based on vidio* .
2. Admin. (2015). *Field under Transportation.* Delhi Metro, India: admin.
3. Al-Mudhaffar, A. (2016, April 18-21). Bus stop and bus terminal capacity. *6th Transport Research Arena* , pp. 1762 – 1771.
4. ASHTOO. (2010). Geometric Design Guide for Transit Facilities on Highways and Streets. In A. s. AASHTO (Ed.), *Chapter5 Off-Line Transit Facilities.* Washington: Washington.
5. Bussen. (2011.). *Traficselskabet Movia.Bussen pa veg. vaalby, Denmark,January 2011.* Denmark: http://www.
6. Cameron J.W.M., &. K. (2003). Urban Activities, Movement and Parking: A time of Hard desition. proceding of 22nd . TRC Africa (Pty) Ltd. Pretoria-South Africa: Southern African Transport Conference (SATC2003). No.0-958 – 460965. .
7. Changshan, W. a. (2005). Optimizing Public transit quality and system acces: the multiple-route, maximul covering/shortest-path problem. *Changshan , 32* (Enviromental and planning B: Planning and Design), 163-178.
8. Cohen.B. (2004.). Urban growth in developing countries: A review of current trends and a caution regarding existing forecasts. . World Development (32): 23-51.
9. CSA. (2008). *Population and Housing Census Results he Federal Democratic Republic of Ethiopian Central Statistical Authority Annual Abstract Country Summary.* Addis Ababa.
10. CSA. (2010). *The Federal Democratic Republic of Ethiopian Central Statistical Authority Annual Abstract Country Summary.* Addis Ababa May,.
11. Dunham, J. (2008). Simulator for Intercity Passenger Bus Terminals. *Contribution to the Performance Evaluation of Bus Terminals in the State of Rio de Janeiro. MSc* .
12. Elsevier, B. (2016). STATION AREA DESIGN APPROACH FOR ENHANCING,NEW DELHI. *Procedia, Transportation Research* , 16 – 31.
13. ERA. (2010). *Ethiopian National Urban Transport Policy, Urban Transport Study and Preparation of Pilot Project of Addis Ababa Final Report Addis Ababa.* Addid Ababa.
14. Fekadu K, A. (2016). Long Distance Bus Transport: Its Structure, Service Adequacy and the Role It Plays in Linking the Coreto the Periphery of Ethiopia. *Supervisor: Ashley Gunter (PhD) , University of South Africa*, 18-40.

15. Felipe, A. v. (2013, January). Estimation of Capacity of High Volume Bus Rapid Transit. *Transportation Research Board Anual Meeting Washington,DC*.

16. Harar City Municipality. (2012). *Local development plan (LDP).* Harar City: not published.

17. HCM. (2010). *Highway Capacity Manual HCM2000. TRB.* Washington D.C.: Transport research board.

18. Herdis. (2017). Capacity Analysis Of Parking Lot And Volume vehicle. aero: IOP.

19. Hoel, N. G. (2009). *Traffic and Highway Engineering* (4rth ed.). University of Verginia: Canada.

20. IBS. (2005). *Study of urban public transport conditions* . Transport Consultants Ltd March .

21. Jain, A. (2013). *Sustainable urban mobility in southern Asia. Technical report, UN Habitat,.* Nairobi, Kenya.: URL http://www. unhabitat. org/grhs.

22. Kanagaraj**, P. D. (2014). A Study on Problems and Prospects of Transport in Ethiopia- Special Reference with Auto Rickshaw's (Bajaj) in Hawassa City, SNNPRS, East Africa . *IFSMRC AIJRM , 2* (03 Jan-Jun-2014).

23. Kittelson, A. (2013). Transit capacity and quality of Service manual. In 3rd (Ed.), *Quality of service method* (p. 522). Washington D.C.: Transportation research board.

24. kommuner, S. (2012). *ISB Planeringshandbok f¨or en attraktiv och effektiv* , 978-91-7164-842-6.

25. Kong, P. D. (2014). *Planning Standards and Guidelines hong kong.* Hong-Kong: The Governmant of the Hong Kong special Adminstration Region.

26. Landsting, S. k. (2012). Planeringshandbok f¨or en attraktiv och effektiv. *ISB* , 978-91-7164-842-6.

27. Litman. (2003). *Mobility Management: A Sourcebook for Policy-makers in Developing Cities.* GTZ Transport and Mobility Group.

28. Liu & Ceder, T. ,. (2015). Analysis of a new public-transport-service concept. *Customized bus in China. Transport Policy, 39,* , pp. 63-76.

29. Ogundipe O.M, etal. (2007). *Appropriate Traffic Congestion Mitigation for an Unplanned Urban City.* Nigeria.: Department of Civil Engineering. University of Ado-Ekiti, Nigeria.

30. Oluwoye, J. (2000.). An Investigation of the Factors of the Design of Roads. That Affect Planning For Traffic (Pedestrian) Safety in the Third World. South Africa.: South African Transport Conference.

31. Rajbhandari et al, R. C. (2003). Estimation of bus dwell times with automatic passenger counter information. *Transportation Research Records 1841,* , 120-127.

32. SLK. (2013). *Accessibility Measures for Public Transport* . Swedish: Stockholm.

33. St. Jacques, K. H. (1997). *TCRP Report 26: Operational Analysis of Bus Lanes on Arterial.* Washington, D.D.: National Research Council,.

34. Sumeet, J. (2010). Busway Platform Bus Capacity Analysis. *Queensland university of Technology* , 162-164.

35. TBR. (2000). *Highway Capacity Manual.*

36. TCQSM, T. r. (2013). *Transit Capacity and Quality of Service Manual* (3 ed.). Washington, D,C.: Federal Transit Adminstrator.

37. Traficvetake. (2013). Station shandbok. In E. resource. Borlange: ISBN.

38. Translink. (2011). *Public Transport Infrastructure Manual.* Bristone: Transit Authority.

39. TRB. (2013). *Transit Capacity and Quality of Service Manual* (3rd ed.). Washington ,D.C.: Transportation Research Board of the National Acadamiv.

40. TRC. (2007). *Congestion: Summary Document Managing Urban Traffic.* European Conference of Ministers of Transport,: European Conference of Ministers of Transport,.

41. VTP. (2000). *Strategies:, Congestion Reduction Identifying and Evaluating Strategies to Reduce Traffic Congestion.* Victoria Transport Policy Institute,.

42. Wall, C. A. (2017, 06 16). Evaluation of bus terminals using microscopic traffic simulation. pp. 1-3.

43. Wang, D. Z. (2018). Optimal bus service design with limited stop services in a travel. *journal homepage: www.elsevier.com/locate/tre , Transportation Research Part E*, 70-86.

44. Wehib, A. (. (2015). *History of Harar and the Hararis* (1 Ed.). Harar: Harari People Regional State Culture, Heritage and Tourism Bureau.

45. World Bank. (2002.). *A Worlds Bank Urban Transport Strategy. Review.* . Washington D.C.Cities on the Move:: A Worlds Bank.

46. Yared Haregewoin. (2010). *Impact of Vehicle Traffic Congestion in Addis Ababa:(The caseof Kolfe sub city).* Addis Ababa:: Civil Service university.

47. Zhang et al. (2014, November 15). Influences of Various Types of Bus Stops on Traffic Operations of Bicycles, Vehicles, and Buses. *Transportation Research Board* .

APPENDIX A: BUS AND PASSNGER DATA EXTRACTED FROM VIDEO CAMERA

Field Data

Bus No	Types of bus	Bus Entering Times in the Bus station	Stop Berth #	Arrival in the Berth & door opening time	Passengers Alighting		Door closing time	Re opening the door time	Passengers Boarding		Re-closing the door and leaving the berth time	Bus Exit Times
					Front Door	Rear Door			Front Door	Rear Door		
1	SB	07:00AM	1	07:02AM	20	0	07:07AM	07:16AM	12	0	07:36AM	07:40AM
2	SB	07:36AM	2	07:38AM	20	0	07:41AM	07:58AM	15	0	08:08AM	08:14AM
3	LB	08:15AM	1	08:18AM	28	0	08:20AM	08:50AM	16	0	08:55AM	08:59AM
4	SB	08:19AM	2	08:25AM	20	0	08:27AM	08:55AM	12	0	09:05AM	09:14AM
5	LB	08:32AM	3	08:35AM	20	11	08:40AM	09:03AM	14	0	09:15AM	09:23AM
6	LB	09:00AM	1	09:03AM	15	28	09:07AM	09:18AM	18	0	09:25AM	09:34AM
7	LB	09:10AM	2	09:13AM	20	0	09:16AM	09:30AM	26	0	09:39AM	09:41AM
8	LB	09:24AM	3	09:28AM	18	20	09:32AM	09:42AM	32	0	09:48AM	09:54AM
9	SB	09:15AM	1	09:18AM	20	0	09:21AM	09:50AM	18	0	09:58AM	10:04AM
10	SB	09:45AM	2	09:48AM	20	0	09:50AM	10:05AM	16	0	10:12AM	10:14AM
11	LB	09:50AM	3	09:56AM	23	21	10:00AM	10:13AM	30	0	10:20AM	10:26AM
12	SB	10:01AM	1	10:05AM	20	0	10:07AM	10:20AM	11	0	10:25AM	10:32AM
13	LB	10:13AM	2	10:19AM	22	16	10:25AM	10:28AM	35	0	10:34AM	10:40AM
14	LB	10:30AM	3	10:33AM	28	0	10:38AM	10:52AM	20	0	11:00AM	11:04AM
15	LB	10:34AM	1	10:37AM	28	0	10:40AM	10:59AM	28	0	11:10AM	11:14AM
16	SB	10:45AM	2	10:50AM	20	0	10:53AM	11:20AM	11	0	11:26AM	11:31AM
17	SB	11:10AM	3	11:16AM	20	0	11:20AM	11:50AM	12	0	11:56AM	12:00AM
18	LB	11:30AM	1	11:36AM	28	0	11:40AM	12:02AM	28	0	12:15AM	12:21AM
19	LB	11:40AM	2	11:43AM	28	0	11:46AM	12:14AM	28	0	12:26AM	12:30AM
20	SB	12:03AM	3	12:05AM	20	0	12:08AM	12:30AM	20	0	12:38AM	12:40AM
21	SB	12:08AM	1	12:13AM	20	0	12:16AM	12:36AM	20	0	12:40AM	12:46AM

22	LB	12:25AM	2	12:38AM	14	12	12:46AM	12:50AM	44	0	12:56AM	01:01PM
23	SB	12:40AM	3	12:43AM	28	0	12:45AM	12:55AM	20	0	12:59AM	01:04PM
24	LB	12:44AM	1	12:48AM	20	0	12:54AM	01:01PM	28	0	01:09PM	01:14PM
25	LB	01:02PM	2	01:05PM	28	0	01:07PM	01:11PM	28	0	01:19PM	01:26PM
26	LB	01:13PM	3	01:15PM	28	0	01:19PM	01:28PM	28	0	01:38PM	01:42PM
27	SB	01:28PM	1	01:30PM	12	0	01:33PM	01:50PM	20	0	01:58PM	02:02PM
28	SB	01:30PM	2	01:33PM	12	0	01:37PM	02:05PM	20	0	02:18PM	02:22PM
29	SB	01:46PM	3	01:48PM	10	0	01:50PM	02:23PM	18	0	02:30PM	02:34PM
30	LB	02:06PM	1	02:08PM	24	0	02:14PM	02:40PM	28	0	02:52PM	02:55PM
31	LB	02:26PM	2	02:30PM	21	0	02:34PM	03:00PM	28	0	03:12PM	03:15PM
32	LB	02:32PM	3	02:35PM	13	15	03:40PM	03:20PM	44	0	03:29PM	03:35PM
33	SB	02:55PM	1	03:00PM	11	0	03:04PM	03:40PM	18	0	03:49PM	03:55PM
34	SB	03:30PM	2	03:34PM	12	0	03:38PM	04:04PM	20	0	04:09PM	04:15PM
35	SB	03:50PM	3	03:54PM	10	0	03:58PM	04:20PM	20	0	04:30PM	04:35PM
36	LB	04:00PM	1	04:04PM	15	10	04:10PM	04:35PM	44	0	04:40PM	04:45PM
37	LB	04:10PM	2	04:14PM	20	8	04:18PM	04:45PM	44	0	04:51PM	04:55PM
38	LB	04:33PM	3	04:35PM	15	0	04:40PM	04:53PM	28	0	04:58PM	05:05PM
39	LB	04:40PM	1	04:42PM	15	0	04:46PM	05:00PM	28	0	05:08PM	05:15PM
40	SB	04:48PM	2	04:53PM	10	0	04:57PM	05:10PM	20	0	05:16PM	05:20PM
41	SB	04:58PM	3	05:00PM	15	0	05:02PM	05:15PM	20	0	05:20PM	05:26PM
42	LB	05:05PM	1	05:10PM	12	8	05:15PM	05:18PM	44	0	05:26PM	05:35PM
43	LB	05:15PM	2	05:18PM	15	11	05:24PM	05:29PM	44	0	05:40PM	05:46PM
44	LB	05:30PM	3	05:33PM	10	9	05:38PM	05:45PM	44	0	05:53PM	05:58PM
45	LB	05:37PM	1	05:40PM	16	0	05:41PM	05:55PM	28	0	06:00PM	06:06PM
46	LB	05:42PM	2	05:55PM	13	0	05:56PM	05:58PM	20	0	06:04PM	06:09PM

Bus No	**Types of bus**	**Bus Entering Times in the Bus station**	**Stop Berth #**	**Arrival at the Berth & door openin g time**	**Passengers Alighting**		**Door closing time**	**Re-opening** the door time	**Passengers Boarding**		**Re-closing** the door and leaving the berth time	**Bus Exit Times**
					Front Door	Rear Door			Front Door	Rear Door		
1	SB	01:00	1	01:02	20	0	01:07	01:16	12	0	01:36	01:4
2	SB	01:36	2	01:38	20	0	01:41	01:58	15	0	02:08	02:14
3	SB	02:12	1	02:13	0	0	02:13	02:50	18	0	02:55	02:59
4	SB	02:19	2	02:25	20	0	02:27	02:55	12	0	03:05	03:14
5	LB	02:32	3	02:35	20	11	02:40	03:03	14	0	03:15	03:23
6	LB	03:00	1	03:03	15	28	03:07	03:18	18	0	03:25	03:34
7	LB	03:10	2	03:13	20	0	03:16	03:30	26	0	03:39	03:41
8	LB	03:24	3	03:28	18	20	03:32	03:42	32	0	03:48	03:54
9	SB	03:15	1	03:18	20	0	03:21	03:50	18	0	03:58	04:04
10	SB	03:45	2	03:48	20	0	03:50	04:05	16	0	04:12	04:14
11	LB	03:50	3	03:56	23	21	04:00	04:13	30	0	04:20	04:26
12	SB	04:01	1	04:05	20	0	04:07	04:20	11	0	04:25	04:32
13	LB	04:13	2	04:19	22	16	04:25	04:28	35	0	04:34	04:40
14	LB	04:30	3	04:33	28	0	04:38	04:52	20	0	05:00	05:04
15	LB	04:34	1	04:37	28	0	04:40	04:59	28	0	05:10	05:14
16	SB	04:45	2	04:50	20	0	04:53	05:20	11	0	05:26	05:31
17	SB	05:10	3	05:16	20	0	05:20	05:50	12	0	05:56	06:00
18	LB	05:30	1	05:36	28	0	05:40	06:02	28	0	06:15	06:21
19	LB	05:40	2	05:43	28	0	05:46	06:14	28	0	06:26	06:30

20	SB	06:03	3	06:05	20	0	06:08	06:30	20	0	06:38	06:40
21	SB	06:08	1	06:13	20	0	06:16	06:36	20	0	06:40	06:46
22	LB	06:25	2	06:38	14	12	06:46	06:50	44	0	06:56	07:01
23	SB	06:40	3	06:43	28	0	06:45	06:55	20	0	06:59	07:04
24	LB	06:44	1	06:48	20	0	06:54	07:01	28	0	07:09	07:14
25	LB	07:02	2	07:05	28	0	07:07	07:11	28	0	07:19	07:26
26	LB	07:13	3	07:15	28	0	07:19	07:28	28	0	07:38	07:42
27	SB	07:28	1	07:30	12	0	07:33	07:50	20	0	07:58	08:02
28	SB	07:30	2	07:33	12	0	07:37	08:05	20	0	08:18	08:22
29	SB	07:46	3	07:48	10	0	07:50	08:23	18	0	08:30	08:34
30	LB	08:06	1	08:08	24	0	08:14	08:40	28	0	08:52	08:55
31	LB	08:26	2	08:30	21	0	08:34	09:00	28	0	09:12	09:15
32	LB	08:32	3	08:35	13	15	08:40	09:20	44	0	09:29	09:35
33	SB	08:55	1	09:00	11	0	09:04	09:40	18	0	09:49	09:55
34	SB	09:30	2	09:34	12	0	09:38	10:04	20	0	10:09	10:15
35	SB	09:50	3	09:54	10	0	09:58	10:20	20	0	10:30	10:35
36	LB	10:00	1	10:04	15	10	10:10	10:35	44	0	10:40	10:45
37	LB	10:10	2	10:14	20	8	10:18	10:45	44	0	10:51	10:55
38	LB	10:33	3	10:35	15	0	10:40	10:53	28	0	10:58	11:05
39	LB	10:40	1	10:42	15	0	10:46	11:00	28	0	11:08	11:15
40	SB	10:48	2	10:53	10	0	10:57	11:10	20	0	11:16	11:20
41	SB	10:58	3	11:00	15	0	11:02	11:15	20	0	11:20	11:26
42	LB	11:05	1	11:10	12	8	11:15	11:18	44	0	11:26	11:35
43	LB	11:15	2	11:18	15	11	11:24	11:29	44	0	11:40	11:46
44	LB	11:30	3	11:33	10	9	11:38	11:45	44	0	11:53	11:58

Total number of Arrival and Departure busses on **Monday** at the Harar bus station

Time	**Kombolcha**	**Haromaya**	**Babile**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**Ada ma**	**Addi Ababa**	**Total arrive**	**Kombolcha**	**Haromaya**	**Babi le**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**A da m a**	**Ad dis Ab aba**	**Total departure**
6:00 -7:00 am	3	4	1	4	0	0	0	0	0	0	**12**	3	4	0	4	0	0	0	0	3	5	**1**
7:00- 8:00 am	3	5	3	5	2	6	0	0	0	0	**24**	3	4	2	4	2	6	0	0	2	0	**2**
8:00 -9:00 am	9	13	10	12	4	3	4	5	0	0	**60**	10	11	11	10	3	2	3	4	4	0	**5**
9:00 -10:00	6	9	7	9	5	2	5	6	0	0	**49**	6	8	6	9	4	2	4	5	0	0	**4**
10:00 -11:00	5	7	4	7	4	6	2	3	0	0	**38**	6	8	5	8	5	7	4	4	0	0	**4**
11:00 -12:00	3	3	3	4	3	5	2	3	0	0	**26**	3	4	3	4	2	4	2	3	0	0	**2**
12:00 -1:00	5	5	5	5	4	4	5	6	0	0	**39**	5	5	6	6	5	4	4	6	0	0	**4**
1:00 -2:00 pm	5	5	5	6	4	3	5	6	0	0	**39**	5	6	4	7	4	3	4	6	0	0	**3**
2:00 -3:00 pm	4	4	4	5	3	3	3	4	0	0	**30**	4	3	3	4	2	3	4	4	0	0	**2**
3:00 -4:00 pm	3	3	2	4	2	6	4	3	2	0	**29**	3	3	3	4	3	6	5	4	0	0	**3**
4:00 -5:00 pm	9	12	8	6	5	5	3	4	5	5	**62**	10	7	8	7	5	5	5	4	0	0	**5**
5:00 -6:00 pm	6	6	5	5	3	2	0	0	0	1	**28**	6	6	5	6	4	2	0	0	0	0	**2**
Total	**61**	76	56	72	39	45	33	40	7	6	**435**	**64**	**73**	**56**	**73**	**39**	**44**	**33**	**40**	**9**	**5**	**434**

Total number of Arrival and Departure busses on **Tuesday** at the Harar bus station

Time	**Kombolcha**	**Haromaya**	**Babile**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**Ada ma**	**Addi Ababa**	**Total arrive**	**Kombolcha**	**Haromaya**	**Babi le**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**A da m a**	**Ad dis Ab aba**	**Total departure**
6:00 -7:00 am	2	4	0	4	0	0	0	0	0	0	**10**	2	4	0	4	0	0	0	0	2	5	**1**
7:00- 8:00 am	5	5	3	5	2	5	0	0	0	0	**25**	4	4	2	4	2	5	0	0	2	0	**2**
8:00 -9:00 am	11	12	10	10	4	3	4	5	0	0	**59**	10	13	9	9	3	2	3	4	4	0	**5**
9:00 -10:00	6	9	6	9	5	2	4	6	0	0	**47**	6	8	6	9	4	2	4	5	0	0	**4**
10:00 -11:00	5	6	4	7	4	6	3	3	0	0	**38**	4	7	5	8	3	6	4	4	0	0	**4**
11:00 -12:00	3	4	3	4	3	5	2	3	0	0	**27**	3	5	3	4	3	4	2	3	0	0	**2**
12:00 -1:00	5	5	5	5	3	4	3	4	0	0	**34**	4	5	4	6	4	4	4	4	0	0	**3**
1:00 -2:00 pm	5	5	5	5	4	4	5	6	0	0	**39**	5	5	4	6	4	3	4	6	0	0	**3**
2:00 -3:00 pm	4	5	4	5	3	3	4	4	0	0	**32**	4	3	3	4	3	4	4	4	0	0	**2**
3:00 -4:00 pm	3	4	3	4	3	5	3	3	2	0	**30**	4	4	3	4	3	6	3	4	0	0	**3**
4:00 -5:00 pm	10	11	5	6	4	5	3	4	4	4	**56**	7	8	8	6	5	4	3	4	0	0	**4**
5:00 -6:00 pm	6	5	8	6	3	3	0	0	0	2	**33**	5	6	6	6	4	4	0	0	0	0	**3**
Total	**65**	75	56	70	38	45	31	38	6	6	**430**	**58**	**72**	**53**	**70**	**38**	**44**	**31**	**38**	**8**	**5**	**417**

Total number of Arrival and Departure busses on **Wednesday**

Time	Kombolcha	Haromaya	Babile	Dire Dawa	Gursum	Jigjiga	Hirna	Ciro	Adaa	Addi Ababa	Total arrive	Kombolch	Haromaya	Babi le	Dire Dawa	Gursum	Jigjiga	Hirna	Ciro	A da m a	Ad dis Ab aba	Total departure
6:00 -7:00	2	3	0	3	0	0	0	0	0	0	8	2	3	0	3	0	0	0	0	2	4	1
7:00- 8:00	4	5	3	5	2	5	0	0	0	0	24	4	4	2	4	2	5	0	0	2	0	2
8:00 -9:00	10	12	10	1	4	3	3	5	0	0	57	11	13	7	8	3	2	3	5	3	0	5
9:00 -10:00	6	8	5	9	5	3	4	6	0	0	46	6	7	6	9	4	2	3	4	0	0	4
10:00 -11:00	4	6	4	7	3	5	3	3	0	0	35	4	6	4	8	3	5	4	4	0	0	3
11:00 -12:00	4	4	3	4	3	5	2	3	0	0	28	4	4	3	4	3	4	3	3	0	0	2
12:00 -1:00	5	5	4	4	4	4	3	5	0	0	34	4	5	4	5	4	4	3	4	0	0	3
1:00 -2:00	4	5	5	5	4	3	5	4	0	0	35	4	5	4	6	3	3	4	6	0	0	3
2:00 -3:00	4	4	4	5	3	3	4	4	0	0	31	4	4	3	4	3	3	4	4	0	0	2
3:00 -4:00	4	5	3	5	2	5	4	3	0	0	31	5	5	3	4	3	6	5	3	0	0	3
4:00 -5:00	10	12	7	6	4	4	3	4	5	5	60	11	13	8	7	5	5	4	4	0	0	5
5:00 -6:00	5	5	5	5	3	3	0	0	0	1	27	6	7	6	6	4	4	0	0	0	0	3
Total	62	74	53	6	37	4	3	37	5	6	416	65	76	5	6	37	43	33	37	7	4	42

Total number of Arrival and Departure busses on **Thursday**

Time	**Kombolcha**	**Haromaya**	**Babile**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**Ada ma**	**Addi Ababa**	**Total arrive**	**Kombolcha**	**Haromaya**	**Babi le**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**A da m a**	**Ad dis Ab aba**	**Total departure**
6:00 -7:00 am	3	4	0	4	0	0	0	0	0	0	**11**	3	4	0	4	0	0	0	0	3	5	**19**
7:00- 8:00 am	3	5	3	5	2	5	0	0	0	0	**23**	2	4	2	4	2	5	0	0	3	0	**22**
8:00 -9:00 am	8	10	11	10	4	3	4	5	0	0	**55**	10	12	7	9	4	2	3	4	3	0	**54**
9:00 -10:00 am	7	9	7	10	5	2	4	6	0	0	**50**	6	8	6	9	4	2	4	5	0	0	**44**
10:00 -11:00 am	4	7	4	7	4	6	3	3	0	0	**38**	5	8	5	8	5	7	4	4	0	0	**46**
11:00 -12:00 am	3	3	3	4	3	5	2	3	0	0	**26**	3	4	3	4	2	4	3	3	0	0	**26**
12:00 -1:00 pm	5	5	5	5	4	4	3	6	0	0	**37**	5	5	5	6	4	4	4	6	0	0	**39**
1:00 -2:00 pm	5	5	5	6	4	3	5	6	0	0	**39**	5	6	4	7	4	3	4	6	0	0	**39**
2:00 -3:00 pm	4	4	4	5	3	3	5	4	0	0	**32**	4	3	4	4	2	3	4	4	0	0	**28**
3:00 -4:00 pm	3	4	2	4	3	6	3	2	0	0	**27**	3	3	3	4	3	6	4	3	0	0	**29**
4:00 -5:00 pm	13	14	7	6	4	4	3	4	5	6	**66**	11	13	6	6	5	4	3	4	0	0	**52**
5:00 -6:00 pm	6	6	5	6	3	3	0	0	0	1	**30**	7	7	6	7	4	4	0	0	0	0	**35**
Total	**64**	76	56	72	39	44	32	39	5	7	**434**	**64**	**77**	**51**	**72**	**39**	**44**	**33**	**39**	**9**	**5**	**433**

Total number of Arrival and Departure busses on **Friday** at the Harar bus station

Ti me	**Kombolc ha**	**Haromay a**	**Babile**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**Ada ma**	**Addis Ababa**	**Total arrive**	**Kombolc ha**	**Haromay a**	**Babi le**	**Dire Dawa**	**Gursum**	**Jigjiga**	**Hirna**	**Ciro**	**Adama**	**Ad dis Ab aba**	**Total**
6:00 -7:00 am	2	4	1	4	0	0	0	0	0	0	**11**	2	4	2	4	0	0	0	0	2	6	**2**
7:00- 8:00 am	4	5	3	5	2	5	0	0	0	0	**24**	3	4	2	4	2	5	0	0	3	0	**2**
8:00 -9:00 am	8	11	9	10	4	3	4	5	0	0	**54**	10	12	6	9	3	2	3	4	3	0	**5**
9:00 -10:00	6	8	6	9	5	2	4	6	0	0	**46**	5	7	6	9	4	2	4	5	0	0	**4**
10:00 -11:00	4	6	4	7	4	6	3	3	0	0	**37**	5	6	5	8	3	6	4	4	0	0	**4**
11:00 -12:00	4	5	3	4	3	5	2	3	0	0	**29**	5	5	3	4	3	4	3	3	0	0	**3**
12:00 -1:00	5	5	4	5	3	4	3	4	0	0	**33**	4	5	4	5	4	4	2	4	0	0	**3**
1:00 -2:00 pm	5	5	5	5	4	3	4	5	0	0	**36**	4	5	4	6	3	3	4	6	0	0	**3**
2:00 -3:00 pm	5	4	4	5	3	3	5	4	0	0	**33**	5	3	3	4	3	3	5	4	0	0	**3**
3:00 -4:00 pm	4	5	3	4	2	5	3	3	0	0	**29**	5	4	4	4	3	6	4	3	0	0	**3**
4:00 -5:00 pm	8	11	8	6	4	5	3	4	4	5	**58**	9	12	8	6	5	5	3	4	0	0	**5**
5:00 -6:00 pm	5	5	5	5	3	2	0	0	0	0	**25**	6	7	6	6	3	2	0	0	0	0	**3**
Total	**60**	74	54	69	37	43	31	37	4	5	**414**	**63**	**74**	**51**	**69**	**36**	**42**	**32**	**37**	**8**	**6**	**418**

Table: Delay time at the stop and bus travel time between origin – destination. (Source; from drivers)

Bus Route lines	Road link characteristics	Distance in Km	Estimated travel time	delay time at the stop
Harar - Kombolcha	9km asphalt & 7km aggregate	16	30min	10-30min
Harar - Haromaya	Asphalt	17	30min	10-30min
Harar - Babile	Asphalt	30	1hr	10-30min
Harar - Dire Dawa	Asphalt	50	2hr	10-30min
Harar - Gursum	58km asphalt & 10km aggregate	68	3hr	30min-1hr
Harar - Jigjiga	Asphalt	100	4hr	30min-1hr
Harar - Hirna	Asphalt	150	5hr	30min-1hr
Harar - Ciro	Asphalt	200	7hr	30min-1hr
Harar - Adama	Asphalt	420	8hr	30min-1hr
Harar -Addis Ababa	Asphalt	515	10hr	30min-1hr
Total				

Table: shows total numbers of bus serviced at the station from April 1-30/7/2010 EC

Sn	Association	Level	Mini bus	Medium bus	Total
1	Andinet	3	186	12	198
2	Arfanqello	1	21	11	32
3	Boset	1	6	1	7
4	Gada	2	93	21	114
5	Haromaya	1	34	13	47
6	Hawwi Guddina	1	41	22	63
7	Kinferufael	3	102	6	108
8	Misraq	2	61	17	78
9	Yeegna	1	19	24	43
			563	127	690

APPENDIX B: SCHEDULE FOR BUS TRANSPORT IN HARAR CITY BUS SATATION

Sagantaa bobbii

Waldaa –Aabboottii qabeenyaa deddebiisa Umataa konkolata Xixxiqaa fiJ-Galeesa hawwi gudina sadarka Iffaa

Yero bobbii hagayyaa guyyaa 16/12/10 irraa hanga hagayyaa 30 pagumee (1 - 5)/12/10 ti

guyyaa	Adaamaa – harar																d/dawaa - jijjgaa		Harar – cinaksan/Gursum	
16/12/10	3-352820r	24	3-452110r	24	3-453130r	24	3-60188or	29	3-31147or	24	3-544600r	28	3-53230or	24	3-57648 or	24	3-502680r	28	3-60802or	24
17/12/10	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	28	3-53230or	24	3-502680r	28	3-60802or	24
18/12/10	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	28	3-502680r	28	3-60802or	24
19/12/10	3-544600r	28	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-502680r	28	3-60802or	24
20/121/10	3-31147or	24	3-544600r	28	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-502680r	28	3-60802or	24
21/12/10	3-601880r	29	3-31147or	24	3-544600r	28	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r		3-502680r	28	3-60802or	24
22/12/10	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	28	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-502680r	28	3-60802or	24
23/12/10	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	28	3-53230or	24	3-57648 or	24	3-352820r	24	3-502680r	28	3-60802or	24
24/12/10	3-352820r	24	3-452110r	24	3-453130r	24	3-60188or	29	3-31147or	24	3-544600r	28	3-53230or	24	3-57648 or	24	3-502680r	28	3-60802or	24
25/12/0	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	28	3-53230or	24	3-502680r	28	3-60802or	24
26/12/10	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	24	3-502680r	28	3-60802or	24
27/12/10	3-544600r	24	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-502680r	28	3-60802or	24
28/12/10	3-31147or	24	3-544600r	24	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-502680r	28	3-60802or	24
29/12/10	3-601880r	29	3-31147or	24	3-544600r	24	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-502680r	28	3-60802or	24
30/12/10	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	24	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-502680r	28	3-60802or	24
									pagumee 1 - 5 2010											
01/12/201	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	24	3-53230or	24	3-57648 or	24	3-352820r	24	3-502680r	28	3-60802or	24
02/12/10	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	24	3-53230or	24	3-57648 or	24	3-502680r	28	3-60802or	24
03/12/10	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	24	3-53230or	24	3-502680r	28	3-60802or	24
04/12/10	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-544600r	24	3-502680r	28	3-60802or	24
05/12/10	3-544600r	24	3-53230or	24	3-57648 or	24	3-352820r	24	3-452110r	24	3-453130r	24	3-601880r	29	3-31147or	24	3-502680r	28	3-60802or	24

Saiantaa kan qophesee
Mallatto--
Guyyaa 16/12/10
Gose Farde
Hogganaa Oporeeshina

kan ragaasissee
mallatto ----
Guyyaa 16/12/10
Alemayehu Abebe
Manager

kan mirkaneessee
mallatto
Guyyaa

SAGANTA BOBBII

Waldaa Abboottii Qabeenyaa Daddeebiisa Uummataa Xixxiqaa fi G/Galeessa Sadrkaa 3ffaa Kinfa-rufa'eel

Yeroo bobbii Guyyaa Hagayyaa 16 irraa hanga Hagayyaa 30ti

		Harar - Jijjiga								Harar - Koombolcha		D/Dawaa - Harawacha		Harar - Adaamaa	
T/L	Guyyaa	Lakk.gabatee	H/F	Lakk.gabatee	H/F	Lakk. Gabatee	H/F	Lakk. Gabatee	H/F	Lakk. Gabatee	H/F	Lakk. Gabatee	H/F	Lakk. Gabatee	H/F
1	16/12/2010	3-34753 OR	44	3-42242 OR	25	3-50339 OR	25	3-41715 OR	20	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
2	17/12/2010	3-41715 OR	20	3-34753 OR	44	3-42242 OR	25	3-50339 OR	3-50	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
3	18/12/2010	3-50339 OR	25	3-41715 OR	20	3-34753 OR	44	3-42242 OR	25	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
4	19/12/2010	3-42242 OR	25	3-50339 OR	25	3-41715 OR	20	3-34753 OR	44	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
5	20/12/2010	3-34753 OR	44	3-42242 OR	25	3-50339 OR	25	3-41715 OR	20	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
6	21/12/2010	3-41715 OR	20	3-34753 OR	44	3-42242 OR	25	3-50339 OR	25	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
7	22/12/2010	3-50339 OR	25	3-41715 OR	20	3-34753 OR	44	3-42242 OR	25	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
8	23/12/2010	3-42242 OR	25	3-50339 OR	25	3-41715 OR	20	3-34753 OR	44	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
9	24/12/2010	3-34753 OR	44	3-42242 OR	25	3-50339 OR	25	3-41715 OR	20	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
10	25/12/2010	3-41715 OR	20	[redacted]		3-42242 OR	25	3-50339 OR	25	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
11	26/12/2010	3-50339 OR	25	3-41715 OR	20	3-34753 OR	44	3-42242 OR	25	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
12	27/12/2010	3-42242 OR	25	3-50339 OR	25	3-41715 OR	20	3-34753 OR	44	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
13	28/12/2010	3-34753 OR	44	3-42242 OR	25	3-50339 OR	25	3-41715 OR	20	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
14	29/12/2010	3-41715 OR	20	3-34753 OR	44	3-42242 OR	25	3-50339 OR	25	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24
15	30/12/2010	3-50339 OR	25	3-41715 OR	20	3-34753 OR	44	3-42242 OR	25	3-36592 OR	44	3-15688 OR	24	3-21866 OR	24

Sagantaa kan qophese
Guyyaa---------------
Mallattoo---------------

Kan ragaasise
Guyyaa---------------
Mallattoo---------------

kan mirkaneesse
Guyyaa---------------
Mallattoo---------------

Sangaanta Bobbii Waldaa Abbotii Qabeenya Deddebisa Uummata X fi G\ Galeesa Misraaq Sad 2ffa yeroo Bobbii Guyyaa Hagayyaa 16 Hangaa Hagayyaa 30/2010 ti

Harer-Jijjiiga														
Guyyaa	Lakk. Gabatee		Lakk. Gabatee		Lakk. Gabatee		Lakk. Gabatee		Lakk. Gabatee		Lakk. Gabatee			
	1	H.F	2	H.F	3	H.F	4	H.F	5	H.F	6	H.F	7	H.F
16/12/2010	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24
17/12/2010	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24
18/12/2010	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24
19/12/2010	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24
20/12/2010	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44
21/12/2010	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28
22/12/2010	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24
23/12/2010	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24
24/122010	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24
25/12/2010	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44	[redacted]	[redacted]	3-37053OR	24
26/12/2010	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24
27/12/2010	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28	3-35885OR	44
28/12/2010	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24	3-44745OR	28
29/122010	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24	3-23440OR	24
30/12/2010	3-23440OR	24	3-44745OR	28	3-35885OR	44	3-28887OR	24	3-37053OR	24	3-44517OR	24	3-16358OR	24

Sagantaa Kan Qophessee Kan Ragasiise ---------------- Kan Mirkaneesse ------------------------

Mallattoo ---------- Mallattoo ---------- Mallattoo ----------

Guyyaa 17/12/2010 Guyyaa .... Guyyaa ------

Ambissa Waldee