Evaluation of Public Bus Stops Location and Spacing: The Case of Selected Routes of *Anbessa* City Bus Service Enterprise

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ABSTRACT

Currently, the primary challenges in Addis Ababa include traffic accidents, comfort issues, travel delays, and productivity problems for travelers. To address these issues, it is recommended to enhance public services by incorporating suitable geometric features, particularly for bus stops. This study focused on evaluating existing bus stop locations and spacing and put remedial measure for any existing drawbacks on public transport Road networks particular on Anbessa City Bus Service Enterprise (ACBSE) routes. Observation, field measurement, GPS method tracking location of bus stops and GIS method produced point mapping were the methodologies used for the study. Travel speed, bus stop location, its configuration and service coverage radius data were acquired. The maximum travel speed that was determined during the study period was 26km/hr. Based on the analysis result, 29% of Mid-Block pullout bus stops should be changed to mid-block curb-side and mid-block bus bulb bus stops on-street having vehicle parking. Generally, 8% of bus stop locations needs future modification. From the research finding, the final bus stops location and spacing depend on the combined effect of location with respect to the nearest intersection, travel speed, service coverage radius, topographical limitation, safety issues and passenger loading of the surrounding area.

Keywords: *Anbessa* City Bus Service Enterprise Bus stop location; Bus Stop Optimization; Passenger loading; Public Bus Transport Routes; Spacing.

1 . INTRODUCTION

Transportation infrastructure, as a complex network, connects cities and accommodates human activities coupling the social, economic and environmental systems with the urbanization and population growth. Additionally, the transportation network contributes to the socioeconomic development and the increased quality of life through generating inter- or intra-city connections [1].

Due to the economic growth of the community, the number of car ownerships increase through time which results in increasing of fuel consumption, traffic accident, congestion and reduction of the mobility of the city. Mass transport facilities are efficient ways to address these problems with less cost in the developed world.

It serves the public at a cheaper operating cost, with less amount of fuel, safe and environmentally friendly as compared to the private cars, small and collective taxicabs [2, 3].

A bus stop is the first point of contact between the passenger and the bus service which define as a designated place where buses stop for passengers to get on or off from bus. According to Bachoket et al. [4] bus stop is defined as a linear curbside area that is specially designated for buses stopping to board and alight passengers. It is usually implemented on the right side of urban streets. Buses usually travel in the curbside traffic lane and make frequent stops to pick up and drop off passengers. Therefore, it is important to keep these areas clear of potential obstructions [5, 6]. To tackle the huge transportation demand and to provide a sustainable environment, there is a need for the provision of better public transportation facilities. To fulfill the high demand for better public transport system, there is a need to establish attractive, safe and highly sophisticated public transport systems. In this regard, it is essential to conduct a detailed evaluation of public transport modes [7].

Providing and improving urban public transport service is becoming highly important to meet the demand of rapidly growing mass mobility due to high population growth. However, Transportation system has gained very fast growth in recent decades; still now we cannot address the accident, congestion and mobility problems in the capital city of Addis Ababa.

Even though, there are small number of public transport services which cannot accommodate the current demand, there is no standard and consistent bus stops and terminals on the given road networks. In addition to that the total travel time and at what time the bus reach at the bus stop (cycle time) are not briefly explained.

Limited research has been conducted on the performance evaluation of public transportation in Addis Ababa, focusing on the quality of service using efficiency measures, special analysis, and improvement strategies. Recent studies, such as the research by Demelash Abate [8] in 2007, analyzed the efficiency of *Anbessa* city bus transport service and identified deficiencies in the bus route network to ensure equitable service for all societal groups in Addis Ababa, Ethiopia. Another study by Muktar Husein in June 2021 evaluated the performance of *Anbessa* City Bus on the Bethel to *Merkato* route based on quality of service. Additionally, studies like the one by Mesfin Tsegaye [9] in 2018 have proposed modes for evaluating the quality of service in public bus transportation and improvement strategies in Addis Ababa, specifically focusing on *Sheger* Mass Transport Enterprise, considering factors such as Level of Service (LOS) and passenger loading parameters.

However, as previously mentioned, there is a significant lack of research focusing on the impact of efficient public bus stop location and spacing on the quality of public transport, specifically analyzing the performance of public transport in terms of public bus transport quality.

Furthermore, these studies have not explored the correlation between public bus quality and the location of public bus stops, nor have they examined the combined effect of these factors on evaluating public bus transport performance. Additionally, these studies have not addressed the influence of public bus stop location and spacing quality in alignment with the demand for public buses and international design guidelines. Therefore, the primary objective of this study was to consider the impact of public bus stop location and spacing on public bus transport quality.

The aim of this paper is to describe, characterize and evaluate the existing bus stop locations, spacing and put an engineering remedial measure for the defects according to the international design guideline by taking into account the local context. The study is based on the following initial assumption:

Anbessa public bus transport network of Addis Ababa offers a territorial coverage which differs between the various areas of the city. This implies improper lay out and unequal conditions of accessibility to public transport services for different surrounding areas.

Improper location and spacing of public bus stops have versatile impact on performance of public bus transport. This situation alters the efficiency and spatial coverage of the public transport network.

To supplement the study questions of a desk study and address the study objective three ACBSE operational routes that have representative characteristic were selected. Travel speed, bus stop location with respect to the intersection, bus stop configuration and service coverage radius data were acquired.

2 MATERIALS AND METHODS

In order to obtain the applicable data both primary and secondary sources were used to address the specific details under the study. The primary data were obtained through Observation, field measurement, GPS method of tracking and identifying co-ordinate of bus stop locations. Secondary data were obtained from published and unpublished documents, different relevant research papers, books, journals, internet sources and archival documents such as design guide- line of bus stop location, reports, and principles of locating, placing and spacing of bus stops [10]. These were collected from different organization such as: ACBSE, Addis Ababa city Road Authority (ACRA) [11], different literatures, and relevant documents collected from different websites. Observation, field measurements, GPS method tracking location of bus stops and GIS method produced point mapping were the methodology used for the study.

2.1 Type and Data Sources

Quantitative and Qualitative data were collected from primary and secondary sources.

The data collection mechanism of primary data was Observation, Felid measurement, GPS method of tracking identifying co-ordinate of bus stop locations. Sufficient information was acquired and achieved through the subject routes by observations, field measurement and GPS tracking methods and identifying the coordinates of bus stops (Figure 1).

During site observation, there were chances to communicate with passengers and staff members on prevailing service provisions and operational problems of *Anbessa* city bus routes related with bus stop locations and spacing. Data acquired by site observations were bus stop locations with respect to the nearest intersections (near-side, far-side and mid-block), bus stop configuration (curb-side, turnout, bus bulb, on-street transfer center and shared cycle), direction of travel of buses (on street travel, Right or left turn at the intersection), conveniences of bus stop placement upstream or downstream of the intersection [12, 13].

Data acquired by field measurements were bus stop distance from nearest intersection, pedestrian crosswalk and parking area, dimension of deceleration and acceleration zone, travel distance and travel time. In relation to this, the data recorded and measured should be taken in consideration the type of bus stop locations and its configuration. Travel distance between terminal points of bus routes, travel time, distance between two consecutive bus stop and coordinate of bus stops locations (x, y, z) data were recorded from GPS navigation system. In parallel with this, along the GPS survey Passenger loading (number of passenger boarding and alighting) data count were conducted through administered routes at each bus stop points.

Figure 1 Routes Selected for the study[11]

i. On-board survey

During the on-board survey for the purpose of observing the bus route, enumerators identified the name and the distance between bus stops or other points of bus stops.

Since *Anbessa* city buses have one door for passengers to embark and disembark, therefore only one enumerator is required to be located at the front door of the bus to record the number of passengers' boarding or alighting at or between bus stops, excluding him/herself as a passenger. Another enumerator was assigned to read and record the GPS co-ordinate of passengers' access and egress points. The enumerator traveled in different buses in the morning and the afternoon at peak hours in both directions of flow. Travel time and travel distance were recorded using the GPS apparatus that was harmonized with the mobile satellite. Three bus routes were navigated with GPS on both directions of travel. Track points were recorded and the bus stops were marked as way points.

ii. Plotting of GPS points using GIS

The main purpose of the GPS survey was to identify co-ordinates of bus-stops locations, travel distance and travel time. The GPS data were then converted into shape files as way points and tracks whereas GIS software was used to make a point map for the spatial analysis.

iii. Bus stop locations and configurations

The types of bus stop locations in relation to the intersections were Near-side (upstream) of the intersection, Far-side (downstream) of the intersection and Mid-block (midway between intersections) [14, 15]. These locations were evaluated and selected based on site observation of facilities on segment, passenger volume of the surrounding area, traffic volume at the upstream and downstream of the intersection and direction of the travel bus (Figure 2).

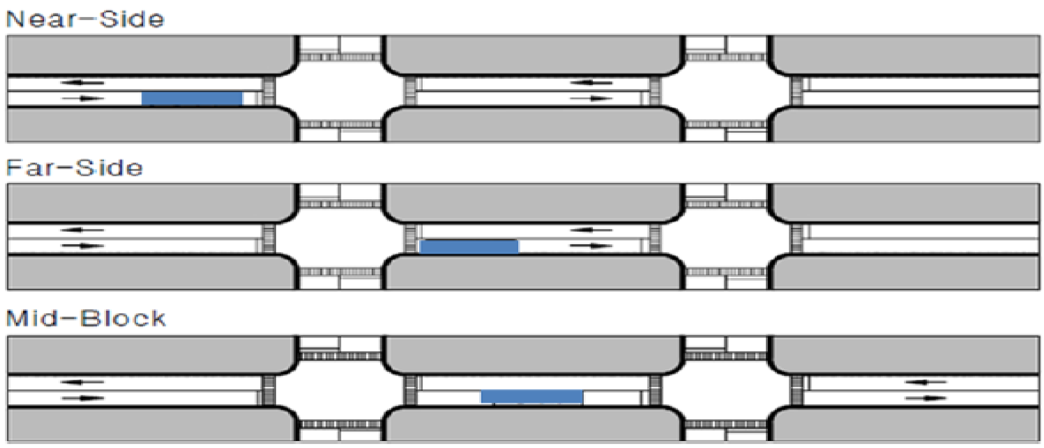

Figure 2 Bus stops location with respect to intersection [15]

According to SEPTA Bus Stop Design Guideline [16], the preferred configuration is based on the local site condition and the bus network conditions. There are six bus stop configurations (curb-side, pullout, bus bulb, shared cycle track stop, Boarding Island, on-street transfer center), each characterized and selected based on the travel speed and the existence of on-street vehicle parking. These bus stops are either inline or off-line with respect to the traffic lane.

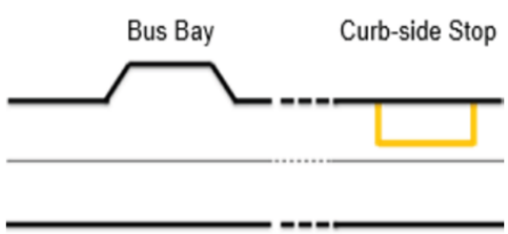

Figure 3 Bus stops configuration [16]

iv. Service Coverage at Stop Level

The general process described below for calculating service coverage at a system level can also be used to calculate coverage at an individual stop level. The objective of this level of analysis was to identify how much of the area within theoretical walking distance of the stop could actually access the stop. According to Transit Capacity Quality Service Manual [17], the optimized bus stop location can be determined using equation (1) at each stop ends up with an individual service radius;

$$r = ro * fsc * fpop * fpx \qquad (1)$$

where:

r= transit stop service radius (mi, m)
ro= ideal transit stop service radius (mi, m), 0.25 mi (400 m) for bus stops. When accurate bus stop location data are not available,
f_{sc}= street connectivity factor, When GIS software is used path-tracing functionality, fsc = 1.0
f_g= grade factor;
f_{pop}= population factor
f_{px}= pedestrian crossing factor

Table 1 Corresponding grade factor for average grade

Average grade	Grade Factor, fg
0-5%	1
6-8%	0.95
9-12%	0.8
12-15%	0.65

This factor assumes that pedestrians will have to walk uphill either coming or going. If the transit route network provides service on parallel streets, such that a person could walk downhill to one route on an outbound trip and downhill from another route back to one's origin on the return trip, use a grade factor of 1.00 is used.

$$fpx = \sqrt{\frac{-0.0005(dec)^2 - 0.1157dec + 100}{100}} \quad (2)$$

where:

f_{px} = pedestrian crossing factor, and

d_{ec} = pedestrian crossing delay exceeding 30 s (s).

The factor is 1.00 whenever pedestrian crossing delay on the street with transit service is less than or equal to 30 s. When d_{ec} exceeds 345 s, fpx should be automatically set to 0.0 which describes from the curves below [17].

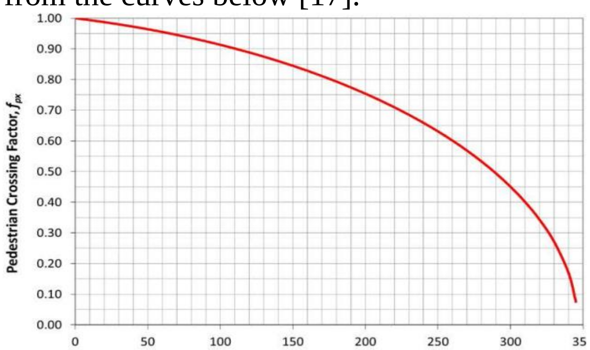

Figure 4 Pedestrian crossing delay Vs. Pedestrian crossing factor

At signalized pedestrian crossings, average crossing delay is based on the cycle length and the amount of time available for pedestrians to begin crossing the street (Eq. (3)).

$$dp = \frac{(\mathbf{c} - \mathbf{gwalk})^2}{\mathbf{2c}} \quad (3)$$

where:

d_p = average pedestrian delay (s),

C = traffic signal cycle length (s) = and

G_{walk} = effective green time for pedestrians (WALK time+ 4 s of flashing DON'T WALK) (s).

For transit stops where 20 % more of the boarding volume consists of elderly pedestrians (65 years or older), a population factor, F_{pop}= 0.85.

2.2 Method of analysis

The research methodology applied has intended to answer the research questions and objectives. The research was designed to address evaluation of the existing urban public bus stops location and spacing as per the specified standard. Observation, field measurement and Global Positioning system are the methods used to collect the impute data of the study. The collected GPS co-ordinates were tracked at GIS software to make a point map of bus stops. Finally, the existing bus stop location and spacing parameters such as distance from origin/destination to the bus stops, bus stop location with respect to the nearest intersection, parking area, pedestrian cross walk and bus stop configuration, accessibility, safety and appropriateness of passengers boarding and alighting points, average travel speed and its geometric lay out were analyzed and an engineering remedial measure were outline for any exiting problems.

2.2.1 Assessment of bus stop location with respect the intersection

Bus stop locations with respect to the intersection were assessed by comparing the traffic volume of the road in relation to the downstream, upstream and at the mid of the intersection area, facility on the road segment and direction of travel bus at the intersection such as left turn, right turn and on – street direction, This method is simply understood by field observation which bus stop location has less traffic interruption for placing bus stop on the near-side, far-side and mid-block with respect to the intersection.

Based on SEPTA Bus Stop Design Guideline, far-side bus stop is recommended when Primary trip generator is upstream from the intersection, existing pedestrian facility greater than the near-side, Vehicular traffic is heaver on the near-side and when the route requires left turn.

Near-side bus stop location is efficient alternative when Primary trip generator is downstream of the intersection, existing pedestrian facility greater than the far-side, vehicular traffic is heaver on the far- side and the route requires right turn.

Mid-block bus stop is mostly recommended when major trip generator is at the mid-block and existing pedestrian facility is safe at the mid-block than the far-side and the near-side of the intersection.

2.2.2 Assessment of bus stop configuration

The major parameters for evaluation of the existing bus stop configuration (curb-side, pullout, bus bulb, shared cycle track stop, boarding island, on-street transfer center) are travel speed and existence of on-street vehicle parking. As stated on highway capacity Manuel the travel speed for the facility is the ratio of facility length to facility travel time [18] as shown by equation (4).

$$VT = \frac{DT}{tT} \tag{4}$$

where:

V_T=facility travel speed,
D_T = facility travel length and
t_T= facility travel time

In-line bus stop is the best option of bus stop configuration for streets that are at or near vehicle capacity, with long traffic signals and having no vehicle parking [18]. Pullout bus stop is the second option for streets with vehicle parking next to bus bulb and on-street when travel speed exceeds 70 km/hr. Bus bulb is most effective for streets that have vehicle parking, moderate traffic volume and for travel speeds lower than 48 km/hr [18]. On-street transfer center is designed to better organize bus stops on busy downtown areas and congested areas with many bus routes serving the same street.

After determining and evaluating travel speed of specified road segment, the right type of bus stop configuration was recommended by incorporating existence of on-street vehicle parking as one evaluation criterion.

2.2.3 Bus stop location with respect to parking area and pedestrian crosswalk

As recommended by SEPTA Bus Stop Design Guideline, the minimum required distance between the bus stop and the pedestrian cross walk is 3 m and its distance with respect to the parking area depends on the type of bus stop configuration (Table 2).

Table 2 Bus stop location from parking area

Bus Stop configuration	Bus stop location	Distance from vehicle parking (m)
Pull out	Far-side pull out	7
	Near-side pull out	15
	Mid- block pullout	15
In-line	Far-side in-line	Vehicle parking is not allowed
	Near-side pull out	
	Mid- block pullout	
Boarding bulb stop	Far-side Boarding bulb	No need additional spacing; the bulb by itself is enough
	Near-side Boarding bulb	
	Mid- block Boarding bulb	7

2.2.4 Determination of passenger loading

During the on- board surveys, the bus route enumerators have identified the name and the distance between bus stops. The main purpose of the GPS survey was to identify coordinates of bus stops location, recorded travel distance and travel time. The GPS data were then converted into shape files as way tracks points. The sum of passengers' boarding or alighting at each bus stop was taken as passenger loading.

GIS software was used to make a point map of bus stops for spatial analysis to apply bus stop modification such as keep on the existing situation, required additional infrastructure for the passengers such as shelter and seat bench, adding bus stops, relocation bus stop, increase the trip rate removing or used as it is based on time peak hour volume of the day.

3 RESULTS AND DISCUSSION

3.1 Location of bus stop with respect to the intersection

Out of the three representative selected routes, 52 bus stops were taken for the evaluation from which 13 (25 %) were near-side, 20 (38 %) far-side and the remaining 19 (37 %) were mid-block bus stops.

From these bus stops, BS3 on *Legehar to Jemo 3* and BS4 on *Megenagna to Piasa* road segment near-side bus stops are located on high traffic volume at the downstream direction, the travel buses make left turn at the intersection, high passenger's volume at the upstream direction. Due to this, it is more appropriate to change to Far-side bus stop location. On *Gurara to Merkato* a road segment, BS10 (on St. Georgas) mid- block bus stop has no minimum required space to accommodate the arriving public bus and has heavier vehicular traffic at the mid-block. Hence, it is preferable if it changes to near-side bus stops since near-side has enough facility to install the bus stop and less vehicular traffic.

Totally, 8% of the bus stops throughout the selected routes need further modification on their location. Traffic marking of the bus stops, distance from parking area and pedestrian crosswalk were continued as a general problem throughout the road segments.

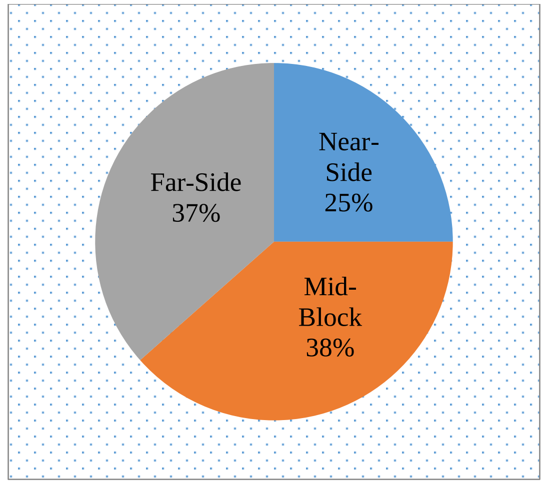

Figure 5 Bus stops location with respect to the intersection

3.2 Bus stops configuration

As stated above the major parameters for evaluation of the existing bus stop configurations were travel speed and existence of on-street vehicle parking. The determined value of travel speed on *Legehar-Jemo3*, *Gurara-Merkato* and *Megenagna-Piasa* road segments were 10.64 km/hr-20 km/hr., 13km/hr-26km/hr. and 12km/hr-16km/hr. respectively. The maximum travel speed that was determined during study period was 26 km/hr. on *Gurara-Merkato* road segment.

Based on the analysis result, 29 % of Mid-Block pullout bus stops should be changed to mid-block curb-side bus stops and mid-block bus bulb bus stops on-street that has vehicle parking.

Table 3 Bus stop configuration on three routes

Bus Stop Configuration	Number of Bus stop	Percent (%)
Pull-out/Turnout	15	29
Crub-side	29	56
Bus-Bulb	0	0
Boarding Island	0	0
Shared Cycle	0	0
On-street Transfer	8	15
Sum	**52**	100

3.3 Passenger Loading

Passenger loading data were recorded by local time. Based on the analysis result of passenger loading, relatively the total number of passengers loading at the intermediate bus stops was low as compared to the starting and ending point bus stops.

At the starting and ending point bus stops on both direction of travelling, passenger

loading was high which needs provision of special infrastructure that accommodates waiting passengers such as seating bench, shelter, minimum optimized distance, safe from climate change impact, and security issue.

Passengers at the intermediate bus stops did not get on time service as the bus grasped to its capacity at the starting point. To counter balance this effect providing enough bus frequency is the best option.

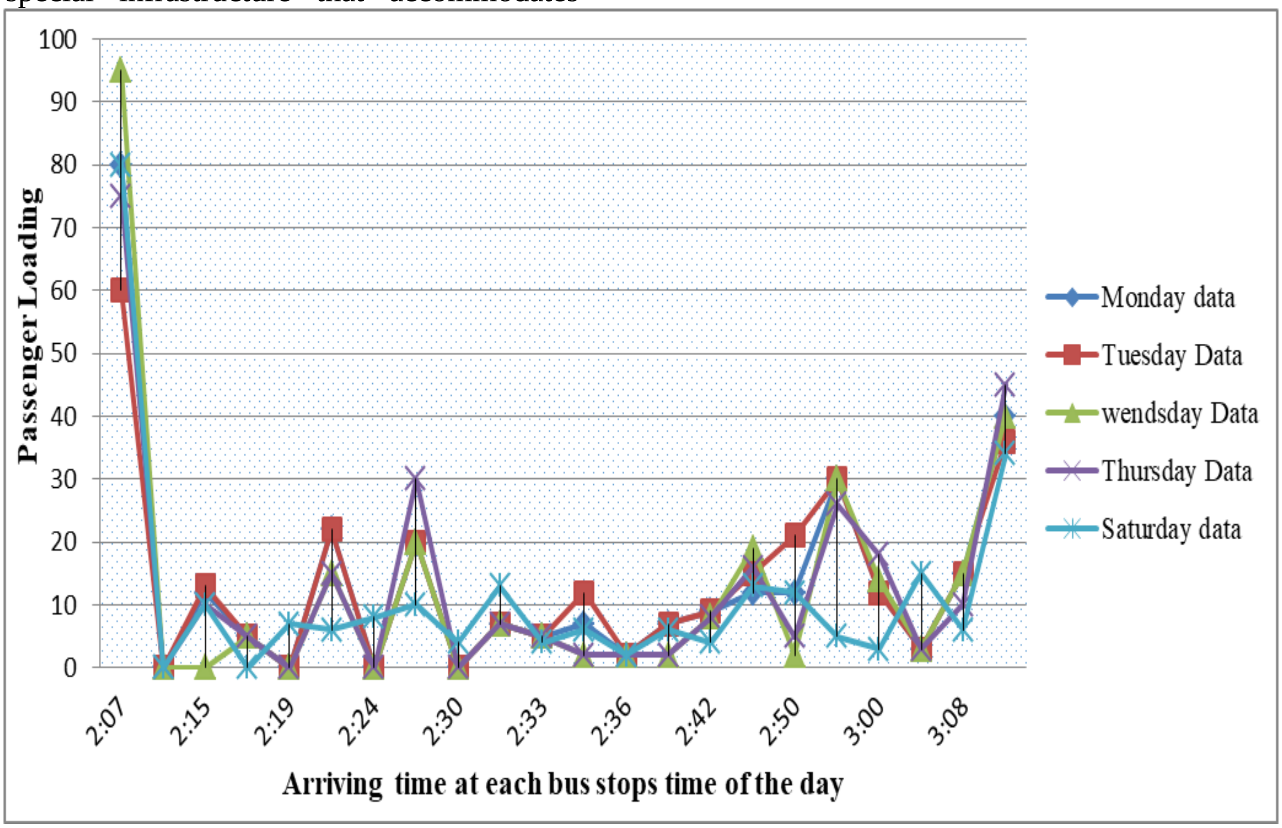

Figure 6 Passenger loading at bus stops morning peak hour from *Jemo* 3 to *Legehar*

According to the field observation during data collection and the passengers loading analysis result, most of the residential areas are located at the periphery and large institutions and economic activities are found in the central parts of the city.

Hence, special attention and remedial measure should be given by government officials to counter balance the passengers demand and location of institutions and economic activity zones.

3.4 Bus stop optimization

As per the analysis result from the data obtained from hand GPS recorded, some bus stops have large spacing that may be due initial consideration of parameters for bus stop spacing or due to topographical limitation and security issues. The minimum and maximum bus stop spacing were 200m and 1300 m at *Jemo-Legehar* and *Megenagna- Piasa* bus routes, respectively.

Based on the analysis result, the final optimized bus stops spacing is between the interval of (170 m-1 km), which shows that the minimum and the maximum service radius are 170m and 1km respectively. Transit Capacity Quality Service Manual acquired that in order to maintain operating speed; bus stops, normally, should not be placed closer than 200 m apart. Hence, the result is more preferable which guided by Transit Capacity Quality Service Manual.

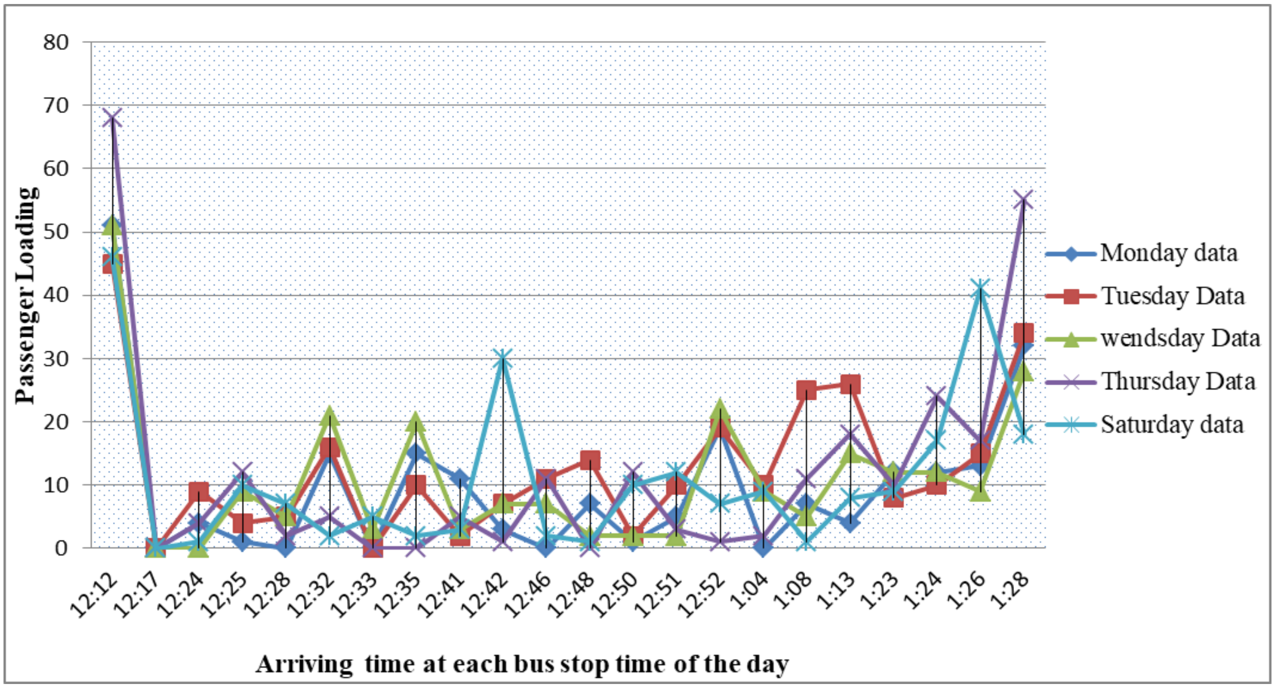

Figure 7 Passenger loading at afternoon peak hour from *Legehar* to *Jemo* 3

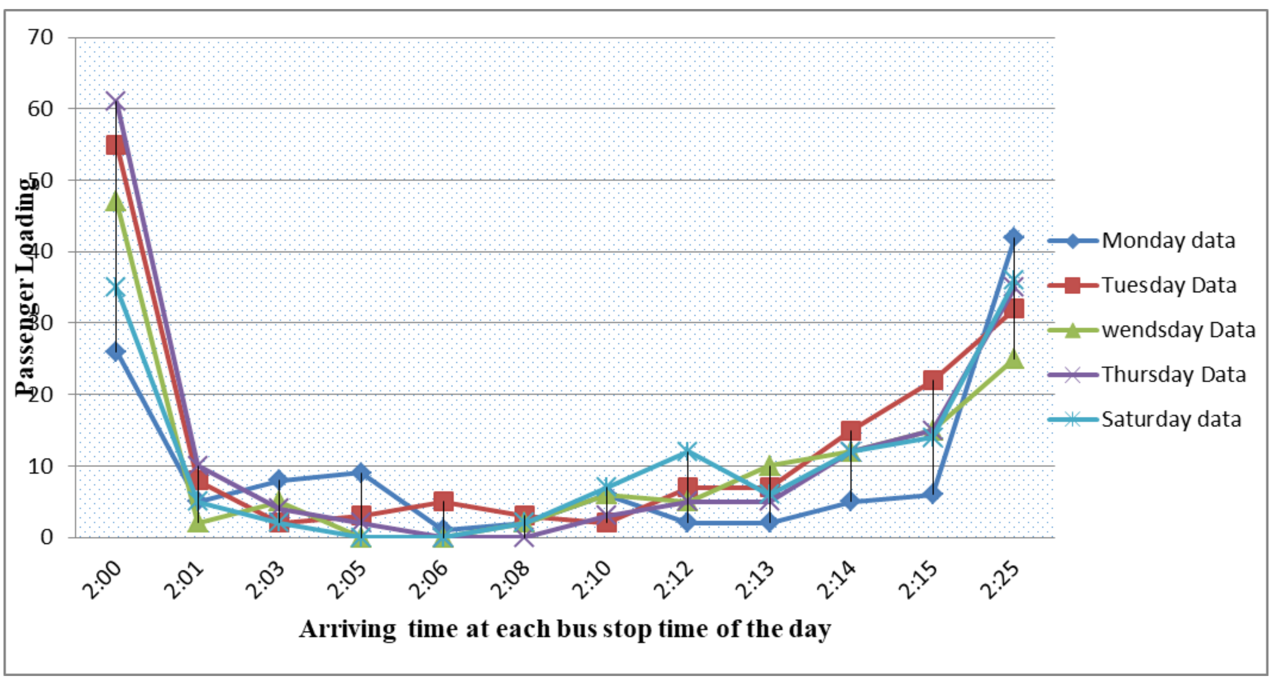

Figure 8 Passenger loading at bus stops at morning peak hour *Megenagna* to *Piasa*

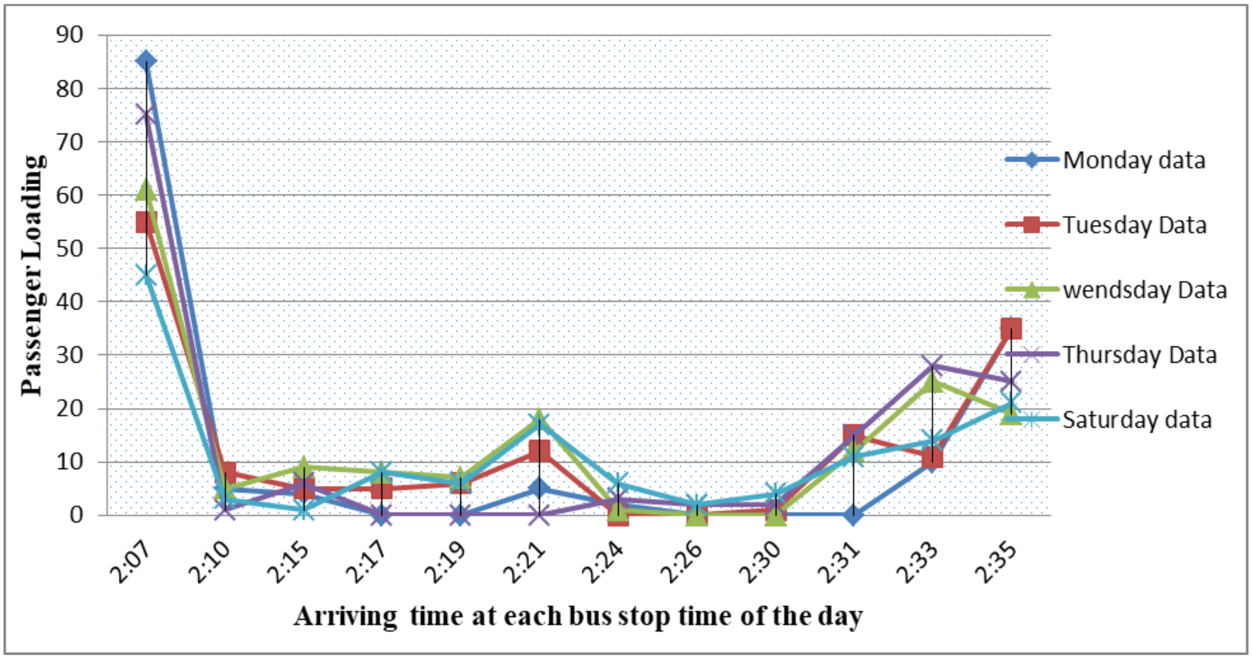

Figure 9 Passenger loading Gurara- Merkato road segment at the morning peak hour

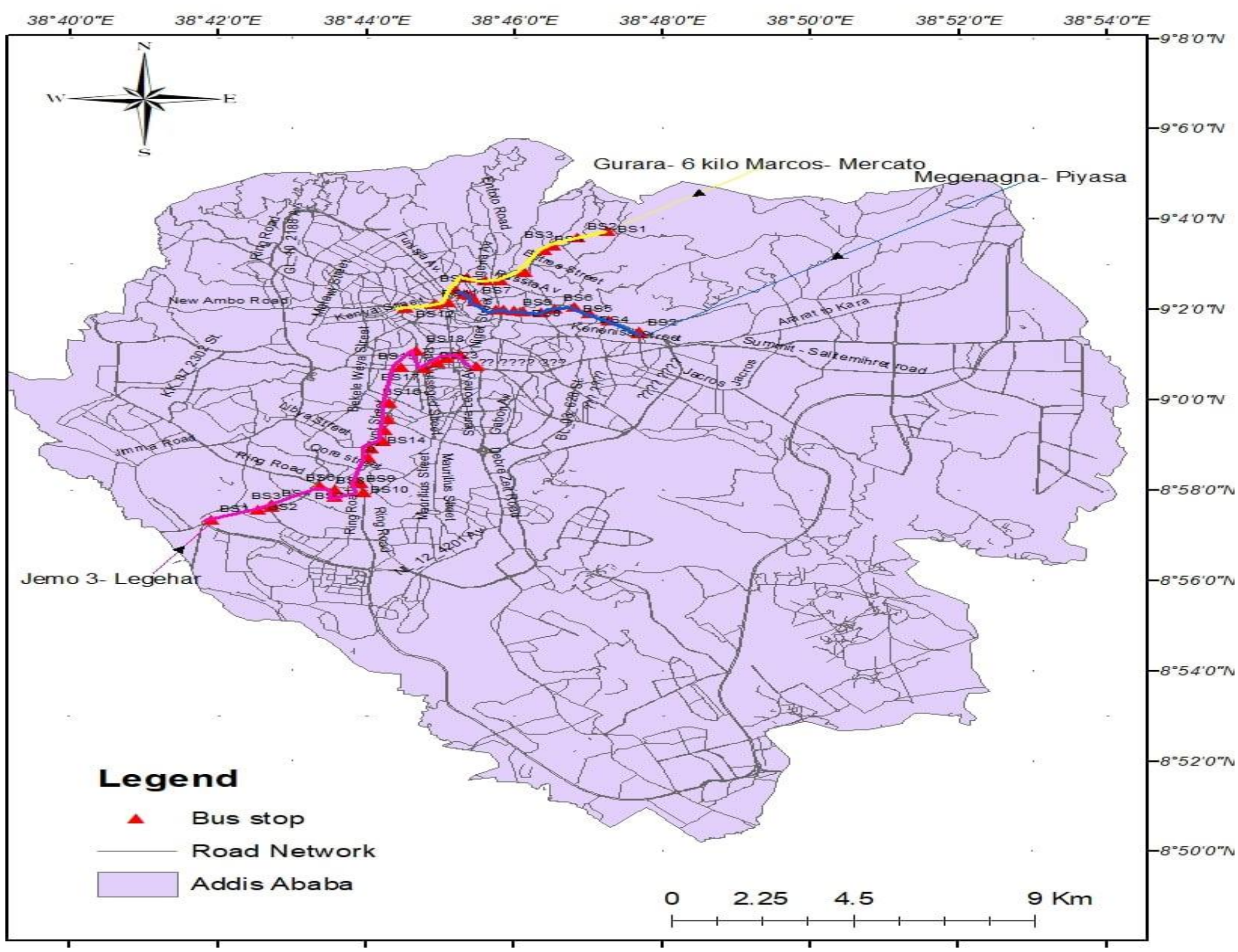

Figure 10 Existing bus stops location on the three routes

4. CONCLUSIONS

The study has evaluated ACBSE bus stop location and spacing using Passenger loading, configuration, service radius and existing bus stop location evaluation parameters. From the findings of the study, it can be concluded that both bus stop location and spacing of ACBSE, as compared to the standard, are relatively low in some of the evaluation parameters. In case of bus stop configuration, though the overall average exhibits very low, 29% of Mid-Block pullout bus stops should be changed to mid-block curb-side bus stops and mid-block bus bulb bus stops on-street that has vehicle parking which shows the existing bus stop configuration needs further improvement.

Based on the result of bus stop location with respect to the intersection evaluation, 8% of the bus stops throughout the selected routes need further modification on their location. Traffic marking of the bus stops, distance from parking area and pedestrian crosswalk were general problems throughout the road segments.

From the study finding, bus stops location and spacing depend on the combined effect of their distance with respect to the nearest intersection and bus stop, their configuration, direction and speed of travel bus, traffic volume and passenger loading of the surrounding area, appropriateness of the area for locating bus stops, service radius, topographical and security issue of the road segments.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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