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Assessment of Pedestrian Facilities Accessibility at Addis Ababa Light Rail Transit Stations in Case of East-West Corridor

Shimelis Getachew Tola

Department of Urban Infrastructure and Transport Management, Transport planning and management program, College of Urban Development and Engineering, Ethiopia Civil Service University, Addis Ababa, Ethiopia

Email address:
shimelis2015@gmail.com

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Abstract: Evaluation of pedestrian facility accessibility and service quality based on user perception and pedestrian level of service (PLOS) is critical to improving facility performance, particularly for transit station facilities with a high number of users. Addis Abeba, Ethiopia, has built a new light rail transit service and is putting it to use to address mobility issues in the city. Light rail transit station amenities were planned to serve pedestrians with potential benefits and criteria of decreased cost, safety, dependability, comfort, environmental friendliness, efficiency, and pedestrian attractiveness when realized. However, contrary to these expectations, the light rail transit station (LRS) facilities are currently characterized by long wait times, crowdedness, poor service quality, and uncomfortable traveling circumstances. This study aimed to determine the accessibility of pedestrian facilities at Addis Ababa Light Rail Transit Stations (AARLTS) in the East-West corridor based on pedestrian facilities level of service (PLOS) and pedestrian perception of the service quality of the AALRTS facilities service. The survey method was utilized, which included both closed-ended and open-ended inquiries. The Transit Capacity and Quality of Service Manual (TCQSM), 2013 standards were used to determine the PLOS of station facilities such as stairways, crosswalks, and platforms at three stations, Stadium (elevated station), Meganangna (semi-underground station), and Torhailoch (ground station), and descriptive analysis was used to identify pedestrian satisfaction and perception of the facilities services. The results have shown that the majority of the AALRTS facility levels of service fall into the PLOS-E category, except for the crosswalk facilities at Stadium stations, which fall into the PLOS-D category. This means the facilities provide a service that exceeds their designed capability. Most respondents (more than 80%) were dissatisfied with service quality parameters such as freedom to choose walking speed and pass others, available space (width), efficiency, comfortability, and sense of safety at the station. Most respondents (more than 50%) were pleased with the cleanliness of the facilities. It is possible to conclude that pedestrian facilities are not safe or convenient for pedestrians to use. The key countermeasures to overcome pedestrian facility accessibility concerns were redesigning and developing pedestrian facilities, good pedestrian flow management, and extending the facility width. As a result, stakeholders must address the issue through better design and maintenance, as well as pedestrian flow management.

Keywords: Pedestrians' Level of Service, Pedestrian's Perceptions, Service Quality, Pedestrians' Facilities, Light Rail Transit Stations

1. Introduction

This chapter discusses the study on pedestrian facility accessibility at AALRTS, focusing on service quality and the perception of pedestrians. It identifies problems and research gaps, outlines objectives, and provides a framework for understanding strengths, weaknesses, and improvement directions in planning pedestrian facilities at LRT stations.

1.1. Background of the Study

Addis Ababa is the capital and largest city of Ethiopia and it is home to 25% of urban population in the country [54]. Addis Ababa also serves as the capital city of Oromia, African union headquarter, headquarter of united nations economic commission of Africa, as well as various other continental and international organizations. It serves as the transportation hub of the nation. The population of the city is rapidly growing. As the population grew the city faces multitude stresses. Among those traffic congestions, wide gap between demand and supply of transportation system and environmental pollutions are the major problems faced the city. The light railway of Ethiopia is the first urban metro light rail built in eastern and sub-Saharan to address the congested road of Addis Ababa, to provide an alternatives public transport to the city's road-based system, to speed up passenger journey time and to provide a more environmentally friendly transport option. Since September 2015, up to 60,000-80,000 passengers can travel per hour. [15].

Addis Ababa light rail transit has 34 kilometers length run in two directions, east-west line from Ayat to Torhailoch and the south-north line from Kality to Menelik II square. Two lines share common track of 2.66 km from stadium station to St. Lideta stations. There are 39 ticket offices which are located near to the stations. The operation and maintenance managed by Chinese company.

Adoption of sustainable transportation systems is keeping from harm throughout the world, works towards to reduce energy consumption and emission of polluting gases as well as focus on reducing the social and environmental impacts during the carrying out the transportation activities. The accessibility, safety and comfort of transit service are major factors in pedestrian's choice of transportation mode. Reducing the numbers of private cars by promoting public transport (bus, LRT, etc), walking and cycling are the best methods used to achieve environmentally compatible and safe transport system. By its nature human beings wants a safe, comfortable, cleanable and access environment.

In developing countries, the practice of designing and building the sustainable environment is not adopted rather only to meet the desire and demand of current situations. Assessing and monitoring a public transit is crucial to understand urban transport systems. Thus, this research was assessing the pedestrian's infrastructures which promote sustainable transportation to ensuring the accessibility and mobility.

1.2. Statement of the Problem

Addis Abeba is the country's social, economic, and political hub, with a large influx of people arriving every day from all across the country. The movement of individuals from one location to another is growing as the population grows. As a result, the increased demand for public transportation in metropolises produces traffic congestion, pollution, and accidents, all of which have an impact on the economic, social, and political performance of societies. One of the most important issues of city's administration is how to solve the transportation problems which causes customer dissatisfaction. The government takes different measures such as introducing city buses (Anbessa, Shegar, etc) to solve those problems. Addis Ababa is urbanizing and growing rapidly. As a result, the city needs a contemporary mass transit system to accommodate the people's high transportation demand. The Light Rail Transit system for mass transportation was introduced as a result of the city's overburdened transportation activities and to alleviate the problems.

The Addis Ababa light rail eases the transportation problems, but fails to fix the traffic troubles. Due to the date the number of studies has been carried out to investigate the harmonization of light rail and principal arterials streets, the effect of light rail train line on non-motorized transport (walking), integration of LRT with others transport modes and surrounding land uses, suitability benefits of LRT, detail relationship of LRT between catchments areas and population users.

This agreed that most of the existing studies have evaluated LRT's current problems and challenges, but have not discussed network sustainability to encourage smart city construction and environmentally friendly systems. The government and transit agencies have done little to ensure that pedestrians have access to light rail transit. The effectiveness of light rail transit as a means of transportation is heavily reliant on pedestrian accessibility. The accessibility, safety, and comfort of LRT service are important criteria in pedestrian transit mode selection. As a result, this study would fill this research gap by investigating pedestrian infrastructure at LRT stations along the East-West corridor, which promotes sustainable transportation systems to ensure pedestrians' accessible, comfortable, safe, and convenient mobility from origin to destination.

1.3. Objectives of the Study

1.3.1. General Objectives

The main objective of this research is to evaluate the accessibility of pedestrian amenities at light rail transit stations along the east-west corridor.

1.3.2. Specific Objectives

The following are the study's specific objectives:

1. Analyzing pedestrian facilities level of service (PLOS) for AALRT stations
2. To assess perceived importance of rail transit system based on users' perspectives
3. To assess the user's perceptions to service quality of LRT stations facilities

1.4. Research Questions

The research will be focused on the following questions.

1. What is level of service of pedestrians' facilities (stairways, crossing, and platform) at rail stations considering facilities users only?
2. What are the variables or factors that determine the perceived importance of the rail transit system?
3. What are the attitudes of the pedestrians to service quality of LRT stations?

1.5. The Significance of the Study

This study is expected to benefit the transportation industry as well as the researcher's future research. The major projected contributions are outlined below.

1. It will increase the awareness of promoting sustainable transportation systems to improve the durability and sustainability of pedestrian's infrastructure and how they impact the transportations systems and smart city planning
2. Help to save cost and time-consuming journey of the pedestrians by recommend safe, comfortable and affordable facilities.
3. It can be serving as the basis for further study of sustainability of transportation systems
4. It will add the knowledge of build the safe, clean, attractive and accessible environment to the pedestrians.
5. Assessing the existing facilities would greatly help for future plans by revealing the hindering factors related with pedestrian's experience of using the facilities.

1.6. Scope of the Study

This study evaluated pedestrian facilities accessibility to three stations along Addis Ababa LRT's East-west line, focusing on current PLOS, user perceptions, and perceived importance of the rail transit system. The research included stairway, cross walkways, and stations platforms.

1.7. Limitations of the Study

As there are no local manuals and guidelines, the highway capacity manual [50] and the transit capacity and service quality manual [51] were the only viable ways found to assess the level of service and pedestrian flow characteristics at LRT rail stations under investigation. Using these manuals, which are used for traffic patterns in developed countries, can be considered a limitation of this study because the pedestrian body dimension (Human Ellipse), traffic composition, and behavior of pedestrians in Addis Abeba may differ from those of Western pedestrians.

There may also be some limitations to this study, such as limited access to data and data collection, sample selection and sample size, and time limits.

1.8. Research Flow Chart

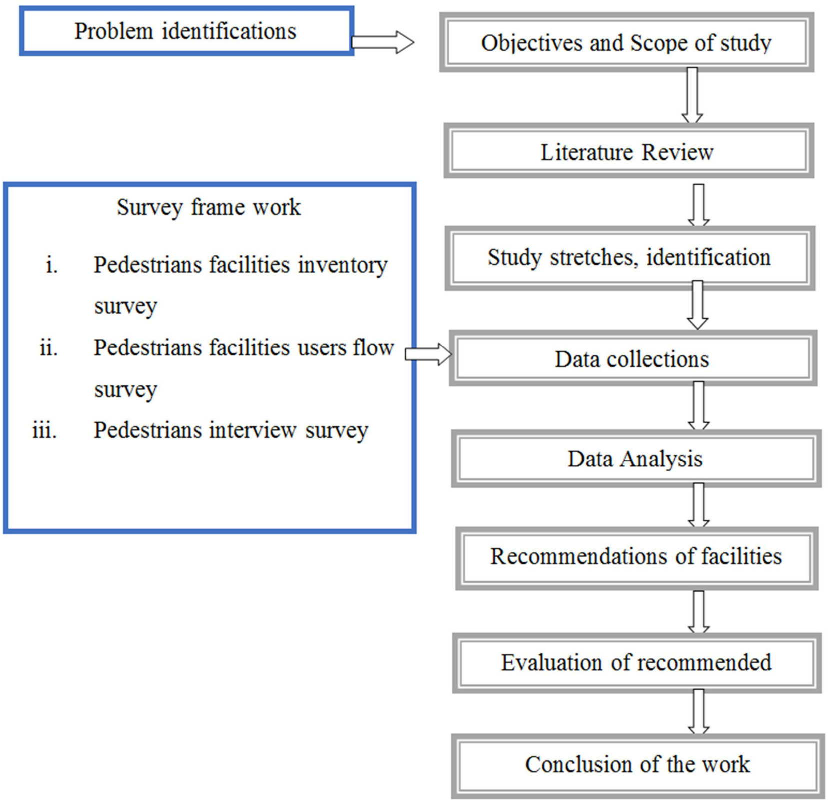


Figure 1. *Research flow chart.*

2. Literature Review

2.1. Introduction

This chapter discusses related literature on LRT stations' accessibility concepts, transit accessibility concepts, pedestrian facilities, PLOS, and quality of service, focusing on the assessment of transit accessibility at LRT stations.

2.2. Conceptual Literature Review

2.2.1. Light Rail Transit (LRT) Station

Definition

A station is a location along a railway line where trains stop to allow passengers to disembark and/or board, as well as freight to load and/or unload. Rail transit stations, unlike bus stops, are permanent structures that require significant investment and often have significant impacts on their surroundings [30, 32, 45, 56]. The light rail transit station solely serves passengers. As previously stated, an LRT station is one of the components of a light rail transit system.

Many scholars and books defined LRT station in the following ways [9, 40, 42]:-

LRT stations are high-quality public transport facilities located at high travel demand points, serving key catchment areas like commercial and business districts. They are considered shopping malls, meeting places, and urban landmarks, attracting economic activities like shops, retail, and offices. Stations are considered major hubs in a multimodal network, connecting downtown and other important places in the region. Further definitions were provided as follows:

1. A light rail station is a rapid transit system station or stop. It might be as simple as a bus stop or as elaborate as a multi-use underground or elevated transit hub [49].
2. Light rail station is point where passengers board and alight from trains, and ranges from simple platforms at ground level to complex structures above or below ground which may be accessed via stairways, escalators and elevators.
3. Stations are an important part of light rail transit systems. Stations serve as access points for light rail, which connects communities, districts, and downtowns. It is critical to locate stations in strategic locations with linkages to other means of transportation. In general, stations are designated locations on a railway line where trains can:
   a. exchange goods and passengers;
   b. control train movements;
   c. allow trains to cross from opposite directions;
   d. sort bogies;
   e. change engines and staff; and
   f. Take diesel and water for locomotives.

To maximize average operating speed, sufficient distance should be provided between stations. Stations located near each other would be inconvenient for train operations, especially in cases where stations provide critical distribution for passengers in big urban areas. Stations that are close together will slow down train operations. As a result, the minimum spacing between stations should be specified. When serving as a local service, most North American cities' conventional procedures imply that stations are normally positioned 400m apart in the core business center. Stations near the city's outskirts are often spaced at greater distances apart, ranging from 800 to 1000m.

Types of stations

Station categorization is crucial for planning and programming station sizes and amenities. categorize stations into four based on annual passenger flows, customer services, and amenities, and whether the station is staffed or un-staffed. Understanding station types is essential for effective transportation system planning.

Based on locations

1. Online station
2. Inline station
3. Offline

There are two types of stations, according to KONE: regular stations and transfer stations. If the station serves as a transfer point for two or more metro lines, the number of passengers traveling between platforms may be significantly greater than the number of people entering or exiting the station. The key to dimensioning people flow is held by the transfer connecting stations. People from the other platform arrive in significant numbers at a transfer connection station. This indicates that the people flow is more concentrated.

According to the AALRT Enterprise Standard LRT stations are categorized into three levels based on their location.

1. Elevated Stations
2. Ground stations
3. Semi-under ground stations

Also based on the station nature the AALRT Enterprise Standard classified the station into origin station, intermediate station and terminal station.

2.2.2. Light Rail Transit Accessibility Concept

Accessibility is one of those concepts that have been commonly used for a number of years, with no clear and standardized definitions being given. Different authors have different meanings for accessibility at different times. Accessibility is defined as the measure of the capacity of a location to be reached by, or to reach, different locations. Therefore, the capacity and the arrangement of transport infrastructure and services are key elements in the determination of accessibility [11, 37, 48].

Transit accessibility studies focus on how people with disabilities access and use transit services, including financial, social, and virtual disabilities. These disabilities influence the interaction between transit elements and people, and personal factors like gender, age, education, and income also influence accessibility. The study mainly focuses on the accessibility of travelers to rail stations, which can determine if railways are a viable travel alternative. Improving station accessibility may be more cost-effective than improving the train journey, as it can lower disutility and benefit current rail users.

2.3. Empirical Literature Review

2.3.1. Analyzing Pedestrian Facilities Level of Service at LRT Station

Eldakdoky, S. H, [14], investigated passenger access and flow at Egypt's Cairo metro station. The authors attempted to analyze the accessibility and convenience of passengers traveling by a simulation approach and instructions in this study. According to the report, this metro station provides a desirable degree of service in terms of ticket sales and control, with variables such as pedestrian separation influencing this conclusion. In replicating the station's architectural layout, the researcher determines that it is best not to arrange the space for buying tickets with sharp angles and that the space is built to allow for the greatest dispersion of passengers in space to avoid overcrowding [17, 28].

Christoforou, Z. [7], studied passenger distribution on platforms to reduce train delays. They proposed solutions, such as displaying departure locations on platform edges and providing guide lights behind train doors. They presented a simulation model at a Western Paris subway station and assessed its performance. Hoogendoorn, S. and Bovy, P. H. L. [22], highlighted the importance of pedestrian flow analysis in railroad infrastructure planning and design. Jiten, S. [25], investigate the effect of stairway width on pedestrian flow characteristics at six railway stations at two stations; one suburban rail transit and the other intercity railway station in India. The results show that flow rate and walking speed increase with increase in width of stairway. Further, walking speed variation pattern is analyzed in three density regimes. Speed reduces gradually with increase in density and reduction in space. At both the stations, compared with the smaller stairway, maximum flow and walking speed are observed for wider stairway. The study establishes that the average walking speed, flow and density are more influenced by width of stairway than other dimensions.

Brahmbhatt, C., Zala, L. B. and Advani, M. [5], examine on estimation of walker stream with chose parameters. Think about zone is chosen at Dakor, situated in dist. Kheda, Gujarat. For this study firstly indentifying peak hour for pedestrian flow then secondly analyzing the pedestrian space, speed, low & density in peak period after lastly, they were check benefit level for person on foot gathering as direction by roadway limit manual 2000. For information gathering period essential information is taken from video recording position during 8.10am to 12.16pm & after secondary data collected as general details & AutoCAD drawing map of Dakor town form DakorNagarpalika. Result was compared with both national & international standards of level of service & found that Level of service is “E”.

Understand the commuter flow behavior on stairways. Authors mainly focused on movement of pedestrian traffic on stairways during peak time [46]. This review is investigation utilizing key relations of speed, stream and thickness. Amid this exploration, is directed at Dadar railway station, Mumbai as a review range. Study area is fully busy during morning & evening time. Video-graphical strategy is embraced for information accumulation for development of pedestrian volume similarly; geometric dimension is also note down. Authors conclude that, 0.45 ped/m^2 is free walking speed, 0.45 ped/m^2 to 4.0 ped/m^2 is speed decrease with increased density & 4.0 ped/m^2 to 4.5 ped/m^2 is speed becomes constant of pedestrians.

2.3.2. Passengers’ Perception and Satisfaction Toward LRT

Satisfaction is an experience-based construct influenced by market expectations and performance perceptions at any given time. It is also measured or compared to previous satisfaction throughout time [27]. Customers' responses to a product or service are used to determine their level of satisfaction [6, 8, 55]. In order for a firm to be successful and profitable [47], customer satisfaction surveys are a critical intermediary objective in service operations as an evaluation of organizational performance [10, 41], Service quality, on the other hand, is measured against customer expectations. That is, if a firm's service meets the expectations of its clients, it is providing excellent service [23, 26, 33]. Customers' perceptions, expectations, contentment, and attitudes about the intended services are surveyed to determine service quality [43, 36]. Similarly, assessing the quality of service provided by any transportation system from the perspective of passengers is an important component of the system's overall health. Because passengers are the system's users, they may accurately assess whether the service satisfies their expectations [4, 12, 20, 38]. Similarly, De Oña, J, de Oña, R, Eboli, L, Mazzulla, G. [57], state that the primary goal of determining service quality (SQ) in public transportation (PT) is to boost its appeal and improve its utilization by substituting as a sustainable alternative to private vehicles. The SQ in mass transit can be measured in two ways: by service operators based on the efficiency and efficacy of that PT, and by passengers based on their perception, expectation, and attitude. These can be accomplished through the use of customer satisfaction surveys (CSS).

Passengers' attitudes regarding public transportation might be either good or negative [24, 39]. Both perspectives may be formed as a result of overall service quality or a specific service attribute. According to Marteache, N., Bichler, G., & Enriquez, J. [34], unfavorable views about safety can raise passenger tension due to crowding, and poor on-time performance of a commuter rail system might operate as a deterrent to using public transit. Passengers demand a safe atmosphere in addition to a dependable, clean, and comfortable one. An altercation aboard a train is an upsetting event that contaminates the onboard climate and influences passenger perceptions of that particular trip as well as the system as a whole. As a result, these lead riders are more anxious about their safety and may retreat to other routes. Similarly, other studies on public transportation safety perceptions discovered that situations that induce perceptions of unsafety, such as dread of crime, if repeated, make riders feel more scared [16, 8]. Similarly, Eboli, L., Mazzulla, G., & Pungillo, G. [13], discovered that comfort is a primary issue for transit users. The comfort can refer to both the physical comfort of the vehicles and the comfort of the ambient conditions at transit locations such as stations and on board. According to Vuchic, V. [56], the single most important factor of passenger comfort is seat availability. Karlsson, J., & Larsson, E. [29], also described the relationship between journey time and seat availability. They added that the trip time appears to be longer when there is no seat available or when people must stand during the journey. These negative opinions of public transit may cause people to seek alternative modes of transportation by modifying their attitudes [53, 19]. However, the positive perception of LRT is primarily due to its ability to avoid congestion (relatively high speed), comfort, parking problems during peak hours, active accessibility, and convenience for users [5, 44].

2.4. Research Gap

In context of Ethiopia, few researches were conducted on the Addis Ababa light rail transit [21, 35]. Most of it covers the spatial and statistical analysis to assess the spatial accessibility of Addis Ababa LRT in the East-West corridor. The results show that the least accessibility of LRT Stations, the population accessibility and service area coverage do not directly imply a greater number of actual users, Stations with large overlap of service area have reduced number of actual users due to the fact that the accessible population is divided between shared stations [1]. The others investigated the reliability of Addis Ababa light rail transit railway operation by estimating actual delays on Addis Ababa LRT using passenger flow. As a result, the minimum line headway capacity increased from 45.1 sec to 35.74 sec. The average speed increased from 18 to 27 kilometers per hour. Based on preliminary design papers, the peak hour headway between each 20 trains increased from 6min to 3.662min, reducing the time passengers will have to wait for the next train by 39% and assessed the performance of Addis Abeba's Light Rail Transit (LRT) system based on sustainability variables before and after the implementation of a proposed LRT system. The study results suggest that the trams have a low average speed due to the tight distance between stations, short radius curves, and low operating speed.

The past research works on spatial accessibility mainly focused on walkability distance accessibility and area coverages of Addis Ababa LRT. Pedestrian flow characteristics and level of service for different types of pedestrian facilities at Addis Ababa LRT stations were studied in detail in the current paper.

3. Research Design and Methodology

3.1. Introduction

This chapter was providing details of the study area, types of data required for the study, sampling techniques and the methods that will be used for collecting the various data along with the tools employed. The chapter was also discussed and describes techniques used to analyze the data that yields answers to the research questions and realize the objectives of the research.

3.2. Research Approach

The research method is the philosophy or general principle which guides the research. It is a tool one can use to gather and analyze data. Basically, there are two types of research i.e., qualitative and quantitative type research. In this study a combination of qualitative and quantitative forms of inquiry will be used in order to rip the advantages of both qualitative and quantitative research approach.

The steps taken to achieve the study's objectives include identifying and defining the problem through field observation, reviewing relevant literature, and developing acceptable methods for data collecting and analysis stages. Relevant information and essential concepts were gleaned from the literature and used to develop several criteria for assessing the performance and effectiveness of pedestrian facilities level of service at LRT stations. Following the development of a research question and the establishment of an objective, relevant methods to provide responses to the research questions were developed.

Passengers or users rated the service quality of AALRTS station facilities using the provided five-point Likert scale (1 = lowest scale and 5 = highest scale), while for the open-ended questionnaire, passengers listed any comments they had about the service quality of AALRTS station facilities. As a result, data collection methods were based on a poll of passengers' perceptions. After gathering the essential information, data processing was carried out using Excel software. Using descriptive approaches, the data was arranged and analyzed. Conclusions and recommendations were derived from the analysis stage data.

3.3. Research Method

Different type of study requires different research method based on nature and purpose of the research according to literatures. This study employed descriptive survey study method for investigating pedestrian facilities accessibility and pedestrian's perceptions to the facilities. The purpose of descriptive research is pointed out to determine the way things done. Thus, descriptive study employed to investigate pedestrian facilities accessibility of pedestrian level of service was used to measure pedestrian facilities quality [51].

3.4. Study Area

The pedestrian facilities levels of performance were assessed along the LRT stations of East-West (EW) corridors. The study was conducted on pedestrian facilities (crossing, stairways, and waiting (platforms)) of 3 LRT stations along the study route.

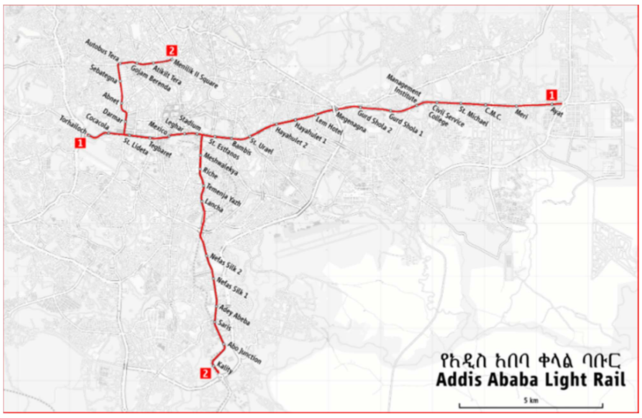


Figure 2. *AA LRT Routes.*

3.5. Research Technique

Personal observation and interviews were used to obtain the relevant primary and secondary data for the assessment of pedestrian facility accessibility using the AALRTS questionnaire. For the secondary data source, a desk study and a literature review were used.

3.5.1. Data Sources

Both primary and secondary data were used. The secondary data such as the dimensions and design standards of the facilities (crosswalks, stairways, shelters, etc.) were gathered from AALRT service. Pedestrian data are required to estimate the pedestrian flow and speed and to compute the characteristics like pedestrian density were collected with most suitable method information is by make videographs of pedestrian movements at a selected location [18]. It allows the extraction of required information at a desired time interval later. Pedestrian traffic data will be captured for 15 min before and after the arrival of train during morning and afternoon peak periods (8:00-3:30pm and 4:45-6:15 pm).

3.5.2. Questionnaire

A questionnaire is the most efficient and time-saving means of collecting data from a large number of respondents. It will be used to determine pedestrian perceptions of facility spacing, site appropriateness, design, and capacity. At rail stations, questionnaire material was provided to pedestrians. It had been distributed to random pedestrians of various ages, genders, educational backgrounds, and so forth. A blend of closed-ended and open questionnaire forms was employed, with respondents simply selecting from closed questions and providing feedback on some of the open-ended questions. Respondents were asked to rank the parameters to be evaluated on several scales of measurement.

3.5.3. Populations of the Study

This study's populations will be pedestrians or facility users at LRT stations along the East-West circuit.

3.5.4. Sampling Method

(i). Sample Size for Questionnaire Survey Respondents

The population (pedestrians or users of station facilities) is very vast or unknown in order to establish the sample size for the questionnaire survey responses. As a result, for a population that is too vast or unknown precisely, the sample size (n) is calculated using the Equation following.

$$n = \frac{z^2}{e^2} * p * (1-p) \quad (1)$$

Where: n = sample size, Z = Confidence interval (CI), e = Margin of error and p = Standard deviation (degree of variability).

Using the commonly used value of 95% CI (Z-score = 1.96) with margin of error e = 5% and a standard deviation of p = 0.5 would yield a sample size of 385 which is too small. Hence for the purpose of this study additional 5 percent was added to compensate un-returnable.

Therefore, the sample size used was 405 for this study. Hence total of 405 sample pedestrians were involved in the survey. The 405-sample size was divided equally for the three stations selected, which are 135 for single station.

(ii). Sample Size Used for Pedestrians Level of Service Analysis

The sample size is determined from the total population of 22 LRT stations. Thus, from the total number of 22 stations Purposively 3 stations were selected based on the density of pedestrian and categories of the station. In my study the stations are classified as elevated, semi-underground and ground stations. Therefore, Megenagna semi-underground station, Stadium elevated station and Torhailoch ground stations were chosen for collecting video-graphic data for the PLOS analysis.

3.6. Data Analysis and Presentations

3.6.1. Performance of Pedestrian Facilities at LRT Stations

This study aims to assess the performance of LRT station facilities (stairways, walkways, and waiting) along the study route in terms of service quality and P-LOS, primarily using TCQSM 2000 and HCM 2010, which are internationally accepted and widely used manuals for assessing the performance of transportation facilities.

3.6.2. Pedestrian Level of Service (P-LOS)

The PLOS categories are called A through F based on the average pedestrian space (AP), flow rate (VP), and volume to capacity ratios (V/C). The PLOS ranges used in this investigation are based on the [51]. The degree of service of the LRT station pedestrian amenities along the research route was calculated by considering the volume of pedestrians using the facilities in the three instances listed below;

Case-I: Pedestrian count data crossing the track using the crossing;

Case-II: Pedestrian count data circulating on the stairways on the left and right side of the facility);

Case-III: Pedestrian count data standing and circulating on the waiting on the left and right side of the facility).

Following are the general steps followed to determine the level of service (P-LOS) of pedestrian facilities at LRT stations.

STEP 1: Determination of Effective Width for facilities (WE)

Effective width for pedestrian facilities is the portion of the facilities that can be used effectively by pedestrians. The effective width at a given point along pedestrian facilities is computed as follows:

$$WE = WT - WO \quad (2)$$

Where: W_E = effective width of the facilities, W_T = total width of the facilities at a given point along pedestrian facilities, and W_O = sum of fixed object effective widths and linear feature shy distances at a given point along the facility.

STEP 2: Calculation of Pedestrian Flow Rate (VP)

Pedestrian flow rate is the number of pedestrians passing a point per unit of time, expressed as pedestrians per 15 minutes or pedestrians per minute. Point refers to a line of sight across the width of a facilities perpendicular to the pedestrian path. The peak 15-minutes count and the effective width of facilities is required to compute pedestrian unit flow rate, VP. The volume of pedestrians crossing for every 15 minutes of the peak hour is counted from the captured videography. Dividing it by the effective width (WE) of the facility gives the flow per meter. This flow value per minutes gives the flow rate in pedestrians/min/m.

$$V_p = \left(\frac{V_{15}}{15W_E}\right) \quad (3)$$

STEP 3: Calculation of Average Pedestrian Space (A_P)

Pedestrian space, which is the inverse of density, is a more practical unit for analyzing pedestrian facilities, is defined as the average area for each pedestrian on a pedestrian facility, expressed in terms of square meter per pedestrian (m2/p). The most important parameter for designing and evaluating a pedestrian facility is the area required by a pedestrian to stand comfortably or make a comfortable movement which is referred as Body Ellipse (Human Ellipse) and depends on shoulder width and body depth of a human being (and also on the kind of activity i.e. Standing or Walking). Pedestrian space cannot be directly observed in the field; but the pedestrian unit flow rate can be related to pedestrian space and speed. PLOS for the stairways was computed by considering the ascending and descending speed of pedestrians separately.

$$A_p = \left(\frac{S_P}{V_P}\right) \quad (4)$$

Where:

A_p = pedestrian space (m^2/p), S_P= ped. Speed (m/minutes), and V_P= ped. Flow per unit width (p/min/m).

STEP 4: Calculation of Volume to Capacity ratio (V/C)

For determination of PLOS, volume to capacity (V/C) ratio is one of the most important factors. The demand (peak flow rate values) and capacities of 75ped/min/m and 49ped/min/m respectively were used to compute the V/C ratios of the overpass facilities along the study route.

STEP 5: Determination of Pedestrian Level of Service (P-LOS)

PLOS categories are labeled A to F on the basis of average pedestrian space (AP), flow rate (VP) and volume to capacity ratios (V/C) as adopted from TCQSM 2000.Another case of analysis inquires whether the pedestrian facility fulfill a level of service 'C' during peak hours or not. Effective width (WE) required to keep a LOS-C (if PLOS found to be less than C from analysis) was to be computed by considering the pedestrians within the different ranges of distances in both sides. The research works will be presented after analysis of collected data by using graphs, tables, charts and figures. Moreover, the whole report will be presented using narrative report too.

3.7. Data Presentation

Using data analysis and interpretation tools the data were discussed and interpreted with the help of statistical tool including tables, charts, percentages, and presented accordingly. And presented in the form of table, and different types of chart.

4. Results and Discussions

4.1. Introduction

This chapter analyzes performance and accessibility of pedestrian facilities at AALRT stations, discussing P-LOS, service quality, user perceptions, pedestrian flow characteristics, and suggested remedial measures to improve hindering factors related to facility accessibility.

4.2. Response Rate

As shown in table 1 the response rate was 95.06%. The total number of 405 sample units was used and questionaries' distributed for all sample units but only 385 respond which accounts 95.06% of the sample size. The questionnaires were distributed to pedestrians who were at Megenagna, Stadium and Torhailoch LRT stations. Therefore 95.06% of the sample size was used for computation of analysis. Furthermore, the selected sites such as Megenagna, Stadium and Torhailoch were observed in depth for rating the service quality of AALRT stations facilities.

Table 1. *Response rate of questioner.*

S/N	Location	Questioner		Response Rate
		Distributed	Collected	
1	Meganagna	135	128	94.81%
2	Stadium	135	131	97.04%
3	Torhailoch	135	126	93.33%
Total		405	385	95.06%

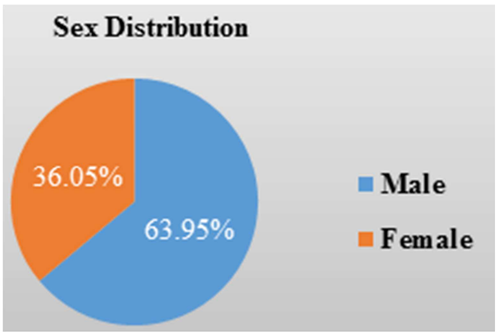
Source: Field Survey, 2021

4.3. Demographic Data

For the purpose of determining the degree of satisfaction of pedestrians with LRT facilities, variables of economic and demographic character such as gender, age, household income, and trip characteristics were included in the survey questionnaire, and the survey was done at each selected station.

4.3.1. Sex of Respondents

According to the results of the study, 36.05% of the 385 pedestrians sampled are females, while 63.95% are males.



Source: Field Survey, 2021

Figure 3. *Sex Distribution of Respondents.*

4.3.2. Age of the Respondents

The age distribution of respondents varies from 2.6% for those over 61 years, 5.5% for those 51-60 years, and 13.2% for those under 18, with 24.3% of respondents being young.

Table 2. *Age of respondents in Year.*

Ages in year	percentages
Below 18	13.2
18-24	24.3
25-30	31.7
31-40	12.3
41-50	10.4
51-60	5.5
Above 61	2.6

Source: Field Survey, 2021

4.3.3. Respondent's Occupations

Table 3. *Respondents Occupation.*

Occupation	Percentages
Student	21.5
office works	20.9
Business Employee	44.7
Unemployed	7.3
Others	5.6

Source: Field Survey, 2021

The major respondents were business employee, students and office works which accounts 44.7%, 21.5%, and 20.9% respectively.

4.3.4. Monthly Income of Respondents

The table below shows, 6.5 percent of respondents earn below 100 ETB, 25.3% respondentsearn between 1000 and 2000 ETB, 21.1% of respondents earn between 2001 and 3000, 18% of respondents earn between 3001 and 4000, 13.4% of respondents earn between 4001 and 5000 ETB, while the rest 15.7% of respondents earn above 5000 ETB.

Table 4. *Monthly incomes of Respondents.*

Income interval	Income in percentages
Below 1000	6.5
1001-2000	25.3
2001-3000	21.1
3001-4000	18
4001-5000	13.4
Above 5001	15.7

Source: Field Survey, 2021

As shown in the table 4 most respondents have low income which is below 2000 monthly income, and the middle income has significant value.

4.4. Results or Findings

Based on the research objectives the findings on assessment of pedestrian facilities accessibility at Addis Ababa light rail transit stations in case of east-west corridor is discussed as follows based on Transit Capacity and Quality of Service Manual [51] standards and Pedestrian's perceptions on service quality of AALRTS facilities as well as expert descriptions and existing physical infrastructures.

4.4.1. Analysis of Pedestrian Level of Service (P-LOS) For AALRTS Facilities

The sub-section of this chapter was provided the analysis, results, and discussions for the pedestrian level of service (P-LOS) for LRT station facilities which were purposively selected for this study which are waiting areas (plat forms), crossing and stairways.

4.4.2. Pedestrians Level of Service (P-LOS) for Crosswalk P-LOS Based on Flow Rate (V_P)

The steps for obtaining pedestrian flow rate data are as follows:

The volume of pedestrians was manually tallied every 15 minutes during the peak period from the videos (for 8 hours) on three weekdays (designated as D-1, D-2, and D-3) at each site. Manual counts of pedestrians entering and departing the facility were performed every 15 minutes from 8:00AM-12:00PM in the morning and 2:00PM-6:00PM in the afternoon.

The maximum 15-minute volume was recorded. The flow per meter is calculated by dividing it by the effective width of the facility. The flow rate in pedestrians/minutes/meter is given by this flow value per minute.

$$V_p = \frac{V_{15}}{15*W_E} \tag{5}$$

Where: V_P = ped. Flow rate (p/min/m), V15 = peak 15-min flow rate (p/15-min), and WE = effective width.

The walkways' total width (WT) was measured in the field using tape and determined to be 3.5m. The effective width (WE) was also measured in the field by excluding the 0.5m at both crosswalk borders, and it was found to be 2.50m.

Table 5. *Volume of Pedestrians during the Peak Periods for Crosswalk Users*

Stations	Days	15 Minutes Volumes	
		Morning	Afternoon
Stadium	D1	2308	2276
	D2	2223	2220
	D3	2178	2256
Torhailoch	D1	2625	2602
	D2	2502	2463
	D3	2485	2479

For the morning peak time, a sample calculation of pedestrian unit flow rate and 、LOS for crosswalk ways at Stadium Stations is shown below. Peak 15-minute volumes were 2530 on Day 1, 2012 on Day 2, and 1222 on Day 3. As a result, for analytical purposes, the highest peak 15-minute volume in the morning peak period (V15) = 2530 (from Day-1 count), the effective width of the walkways (WE) = 2.5m, and the effective width of the walkways (WE) = 2.5m.

$V_p = \frac{V_{15}}{15*W_E}$, $V_p = \frac{2308\,Pedestrians}{15\,minutes*2.5meters}$ = 61.55 pedestrians/minutes/meter ≈ 62 pedestrians/minutes/meter.

According to the TCQSM 2013 level of service criteria tables, a flow rate of 62 p/min/m is classified as a PLOS-D.

The LOS analyses for the crosswalk at stadium AALRTS fall to category of PLOS-D. This result shows that Freedom to select walking speed and pass others is restricted; high probability of conflicts for reverses or cross movements. The LOS analyses for the crosswalk at Torhailoch AALRTS fall to category of PLOS-E. This result shows that Walking speeds and passing ability are restricted for all pedestrians; forward movement is possible by shuffling; reverse or cross movements are possible only with extreme difficulty; volumes approach limit of walking capacity.

Table 6. *Pedestrian Level of Service for Walkways Based On Flow Rate.*

Stations	Flow Rates (VP) values and P-LOS	Morning	Afternoon
Stadium	Vp	62	61
	PLOS	D	D
Torhailoch	Vp	70	70
	PLOS	E	E

P-LOS Based on Average Pedestrian Space (A_P)

Body depth and shoulder breadth are the minimal spacing standards used by pedestrian facility designers. As the practical minimum for standing pedestrians, a simplified body ellipse of 0.5m x 0.6m with a total area of 0.3 m^2 is utilized as the fundamental space for a single pedestrian. In evaluating pedestrian facilities, a buffer zone of 0.75 m^2 is recommended for each pedestrian (HCM 2000).

Using equation (6), the pedestrian unit flow rate can be related to the pedestrian space and speed:

$$A_P = \frac{S_P}{V_P} \tag{6}$$

Where: AP= peds. space (m^2/p), S_P = ped. Speed (m/min), and VP = pedestrian flow per unit width (p/m/minutes).

According to TCQSM, 2013 Free-flow walking speeds have been shown to range from 45 m/min to 145 m/min. On this basis, speeds below 45m/min would constitute restricted, shuffling locomotion, and speeds greater than 145 m/min would be considered as running. A pedestrian walking speed typically used for design is 75 m/min. Therefore, based on this standard 75m/min walking speed was used for this study.

Pedestrians Speed along the walkways for the selected samples are shown on the table below.

Table 7. *Pedestrian Speed along the Crosswalk.*

Stations	Speed (m/min)
Stadium	75
Torhailoch	75

For the Stadium Cross-way, a sample calculation of average pedestrian space is shown below.

1. Speed of pedestrians on cross-walkway =75m/min
2. Flow Rate in the morning peak period =62ped/min/m
3. Flow rate in the afternoon peak period =61ped/min/m

Average pedestrians space in the morning peak period:

$$A_P = \frac{S_P}{V_P} = \frac{75/min}{62ped/min/m} = 1.21m^2/p$$

Average pedestrians space in the afternoon peak period:

$$A_P = \frac{S_P}{V_P} = \frac{75m/min}{61\text{ped/min/m}} = 1.23m^2/p$$

Table 8. *P-LOS for cross-way based on Average Pedestrian Space.*

Stations	Average pedestrian Space value and PLOS	Morning	Afternoon
Stadium	A_P	1.21	1.23
	PLOS	D	D
Torhailoch	A_P	0.66	0.66
	PLOS	E	E

P-LOS for Walkways Based on Volume to Capacity Ratio (V/C)

According to TCQS 2013, the capacity of a walkway is 82 p/m/min, corresponding to LOS "E." According to the TCQS 2013, the walkway's volume-to-capacity ratio (V/C) along the study's route was calculated by dividing the flow rate figures by 82 p/m/min.

The following is a sample calculation of the volume-to-capacity ratio (V/C) for the Stadium Station walkway during the morning peak time.

1. Flow Rate = 62 ped/min/m during the morning peak time
2. Capacity of pedestrians walkway = 82 p/m/min

$$\text{Volume to Capacity Ratio (V/C)} = \frac{\text{Flow rate}}{\text{Capacity}} = \frac{62\text{ ped/min/m}}{82\text{ ped/m/min}} = 0.76\text{(PLOS Category D)}$$

Table 9. *PLOS Based on Volume to Capacity (V/C) Ratios (walkway).*

Stations	Volume to Capacity (V/C) Ratios and PLOS	Morning	Afternoon
Stadium	V/C	0.76	0.74
	PLOS	D	D
	V/C	0.85	0.85
Torhailoch	PLOS	E	E

To classify the PLOS of the crosswalk facilities at the selected LRT stations, three parameters were considered: flow rate (VP), pedestrian space (AP), and volume-to-capacity (V/C) ratios. With a PLOS-D for stadium AALRTS and a PLOS-E for Torhailoch AALRTS, the results reveal that the facilities can accommodate both users and non-users. It demonstrates that all walkers' walking speeds and passing ability are limited; forward movement is only achievable by shuffling; backward or cross movements are only conceivable with severe effort; and volumes approach the limit of walking capacity.

4.4.3. Pedestrians Level of Service (P-LOS) for Stairways

PLOS Based on Flow Rate (V_P)

The steps for obtaining pedestrian flow rate data are as follows:

i. The volume of pedestrians was manually tallied every 15 minutes throughout the peak period for three weekdays (designated as D-1, D-2, and D-3) at each site for eight hours. Manual counts of pedestrians entering and departing the facility were performed every 15 minutes from 8:00AM-12:00PM in the morning and 2:00PM-6:00PM in the afternoon.

ii. The maximum 15-minute volume was recorded. The flow per meter is calculated by dividing it by the effective width of the facility. The flow rate in pedestrians/minutes/meter is given by this flow value per minute.

$$V_p = \frac{V_{15}}{15 * W_E}$$

Where VP represents the ped. flow rate (p/min/m), V15 represents the peak 15-minute flow rate (p/15-min), and WE represents the effective width.

The total width (WT) of the stairs was measured in the field using tape from the face of the railing to the face of the handrail and was found to be 4m. The effective width (WE) was measured in the field as well, but without the curb extensions at the bottom of the handrails (which pedestrians avoid stepping on), and it was determined to be 2.5m. Moving pedestrians avoid the curb and do not lean against the handrails. As a result, this unutilized area was discounted.

Table 10. *Volume of Pedestrians during the Peak Periods for Stairways Users.*

Stations	Days	15 Minutes Volumes	
		Morning	Afternoon
Meganagna	D1	1650	1602
	D2	1130	1247
	D3	750	956
Stadium	D1	1720	1645
	D2	1252	1023
	D3	978	1012

For the morning peak time, a sample calculation of pedestrian unit flow rate and LOS for walkways at Maganegna Stations is shown below. The highest 15-minute volumes were 1650 on Day 1, 1247 on Day 2, and 956 on Day 3. As a result, the highest peak 15-minute volume in the morning peak time (V15) = 1650 (from Day-1 count), the effective width of the stairways (WE) = 2.5m, $V_p = \frac{V_{15}}{15 * W_E}$, $V_p = \frac{1650\ Pedestrians}{15\ minutes * 2.5 meters}$ = 44 pedestrians/minutes/meter.

According to the TCQSM 2013 level of service criteria tables, a flow rate of 44 p/min/m is rated as a PLOS-E. The LOS analyses for all the walkways for selected stations fall to category of PLOS-E. The result shows that walking speeds and passing ability are restricted for all pedestrians; forward movement is possible by shuffling; reverse or cross movements are possible only with extreme difficulty; volumes approach limit of walking capacity.

Table 11. *Pedestrian Level of Service for stairways Based On Flow Rate.*

Stations	Flow Rates (VP) values and P-LOS	Morning	Afternoon
Meganagna	Vp	44	43
	PLOS	E	E
Stadium	Vp	46	44
	PLOS	E	E

P-LOS Based on Average Pedestrian Space (A_P)

Body depth and shoulder breadth are the minimal spacing standards used by pedestrian facility designers. As the practical minimum for standing pedestrians, a simplified body ellipse of 0.5m x 0.6m with a total area of 0.3 m2 is utilized as the fundamental space for a single pedestrian. In evaluating pedestrian facilities, a buffer zone of 0.75 m2 has been used for each pedestrian (HCM2000).

Using equation 4.7, the pedestrian unit flow rate can be related to the pedestrian space and speed:

$$A_P = \frac{S_P}{V_P}$$

Where: AP= peds. space (m^2/p), S_P = ped. Speed (m/min), and VP = pedestrian flow per unit width (p/m/minutes).

Pedestrians Speed along the stairways for the selected samples are shown on the table below.

Table 12. *Pedestrian Speed along the Stairways.*

Stations	Speed (m/min)	
	Stair Ascending	Stair Descending
Meganagna	30	31
Stadium	29	30

A sample computation of average pedestrian space for the Meganagna stairway is shown below.

1. Speed of pedestrians on (Ascending in Stairway) =30m/min
2. Speed of pedestrians on (descending in Stairway) =31m/min
3. Flow Rate in the morning peak period =44 ped/min/m
4. Flow rate in the afternoon peak period =43 ped/min/m

Average pedestrians space in the morning peak period (Stairway ascending):

$$A_P = \frac{S_P}{V_P} = \frac{30\text{m/min}}{44\ \text{ped/min/m}} = 0.68\ \text{m/min}$$

Average pedestrians space in the morning peak period (Stairway descending):

$$A_P = \frac{S_P}{V_P} = \frac{31m/min}{44\ \text{ped/min/m}} = 0.7\text{m/min}$$

Table 13. *Pedestrian Level of Service for stairways based on Average Pedestrian Space.*

Stations	Average pedestrian Space value and PLOS	Stairway ascending		Stairway descending	
		Morning	Afternoon	Morning	Afternoon
Meganagna	A_P	0.68	0.56	0.7	0.62
	PLOS	E	E	E	E
Stadium	A_P	0.67	0.69	0.52	0.45
	PLOS	E	E	E	E

To classify the P-LOS of the stairway facilities at the selected LRT stations, two factors were considered: flow rate (VP) and pedestrian space (AP). The results demonstrate that the facilities can handle PLOS-E users. It demonstrates that all pedestrians' speeds have decreased. Intermittent stoppages are likely, and reversal flows cause major disputes.

4.4.4. Determining Pedestrians Level of Service (PLOS) For Platforms

The procedures to determine the PLOS for queuing areas based on Average Pedestrian Area (m^2 /P) are described as follows.

1. calculate the effective area of the platform
2. Determine the maximum number of peoples stay in the waiting areas for 15minutes.
3. Calculate Average Pedestrian Area (m^2 /P) by dividing the effective area to the number of pedestrians

Calculating areas for platform for selected stations.

1. The Torhailoch platform has a clear width of 2.5m and a length of 60m. The effective area is 150m^2.
2. The Stadium platform has a clear width of 3.5m and a length of 60m. The effective area is 210m^2
3. The Meganagna platform has a clear width of 5.5m and a length of 60m. The effective area is 330m^2

Table 14. *Volume of Pedestrians during the Peak Periods for platforms Users.*

Stations	Days	15 Minutes Volumes	
		Morning	Afternoon
Torhailoch	D1	748	712
	D2	553	421
	D3	536	435
Stadium	D1	1001	963
	D2	853	952
	D3	840	752
Meganagna	D1	1650	1235
	D2	1247	1014
	D3	978	1012

For the morning peak time, a sample calculation of Average Pedestrian Area (m^2 /P) and LOS for queue area at Maganegna Stations is shown below. The highest 15-minute volumes were 1650 on Day 1, 1247 on Day 2, and 978 on Day 3. As a result, the maximum peak 15-minute volume in the morning peak time (V15) = 1650 (from Day-1 count), and the effective area = 330m2.

Average Pedestrian Area (m^2 /P) = 330m^2/1650pedestrians =0.2m^2/p (category E PLOS)

Table 15. *PLOS for platform based on Average Pedestrian area.*

Stations	Average Pedestrian Area (m^2 /P),	Morning	Afternoon
Meganagna	M	0.2	0.27
	PLOS	E	E
Stadium	M	0.21	0.22
	PLOS	E	E
Torhailoch	M	0.2	0.21
	PLOS	E	E

Determining PLOS based on the Average Inter-Person Spacing (m).

Average Inter-Person Spacing (m) = total length of queening area/number of pedestrians.

For the morning peak period, a sample calculation of Average Inter-Person Spacing (m) and LOS for queuing area at Maganegna Stations is shown below. The highest 15-minute volumes were 1650 on Day 1, 1247 on Day 2, and 978 on Day 3. As a result, for the purposes of study, the maximum peak 15-minute volume in the morning peak period (V15) = 1650 (from the Day-1 count), the length of 60m,

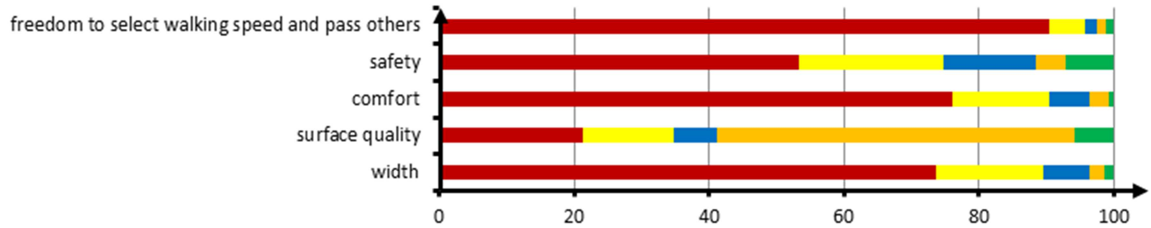
1. Average Inter-Person Spacing (m) =60m/1650pedestrians =0.036m/ped< 0.6 (catagory E PLOS).
2. Average Inter-Person Spacing (m) at stadium =60m/1001pedestrians =0.05m/ped < 0.6 (catagory E PLOS).
3. Average Inter-Person Spacing (m) at Torhailoch =60m/748pedestrians =0.08m/ped < 0.6 (catagory E PLOS)

Two parameters which include Average Pedestrian Area (m^2 /P) and Average Pedestrian Area (m^2 /P) were considered to classify the P-LOS of the queening facilities at the selected LRT stations. The result shows that Standing in physical contact with others is unavoidable; circulation within the queue is not possible; queuing at this density can only be sustained for short period.

4.5. Service Quality of AALRTS Facilities According to Pedestrians Perceptions

4.5.1. Satisfaction Level of Pedestrians to Facilities at LRT Stations

To assess pedestrians' perceptions and attitudes toward the service quality of facilities at AALRTS stations, the survey questionnaire included five service quality parameters for crosswalks and six service quality parameters for stairways and platforms (waiting areas)[2]. The existing LRT station facilities satisfaction was graded on a scale of 1 (low) to 5 (very high). Figure 4 depicts the findings on the level of satisfaction with crosswalk facilities at AALRTS.



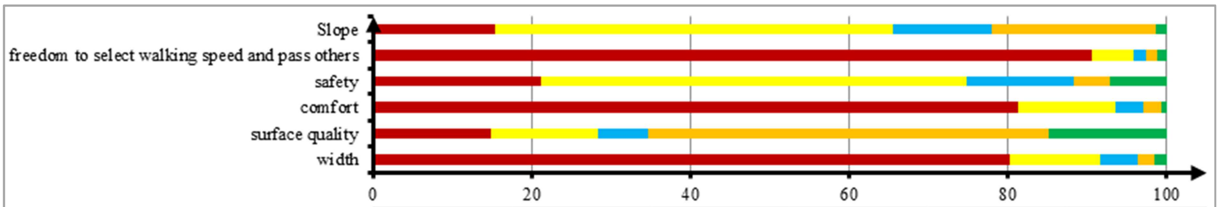
	width	surface quality	comfort	safety	freedom to select walking speed and pass others
Very Dissatisfied	73.70	21.32	76.11	53.33	90.50
Dissatisfied	15.93	13.52	14.30	21.44	5.27
Neither	6.67	6.30	5.89	13.56	1.65
Satisfied	2.22	52.94	2.96	4.44	1.34
Very Satisfied	1.48	5.93	0.74	7.22	1.24

Very Dissatisfied Dissatisfied Neither Satisfied Very Satisfied

Figure 4. *Satisfaction levels of pedestrians to crosswalk facilities.*

The survey results showed that 90.5%, 76.11%, 73.7%, and 53.33% of respondents were Very Dissatisfied with service quality parameters such as freedom to choose walking speed and pass others, comfortability, width of crosswalk, and sense of safety while crossing at Stadium and Torhailoch LRT stations, respectively. While the surface quality of crosswalk parameter of service quality at the station the pedestrians were satisfied with 52.94%.

The findings on satisfaction level of stairways facilities at Meganagna and Stadium AALRTS were shown in Figure 4.3 below.



	width	surface quality	comfort	safety	freedom to select walking speed and pass others	Slope
Very Dissatisfied	80.25	14.82	81.27	21.18	90.50	15.32
Dissatisfied	11.38	13.52	12.30	53.60	5.27	50.12
Neither	4.67	6.30	3.55	13.56	1.65	12.50
Satisfied	2.22	50.44	2.14	4.44	1.34	20.68
Very Satisfied	1.48	14.93	0.74	7.22	1.24	1.38

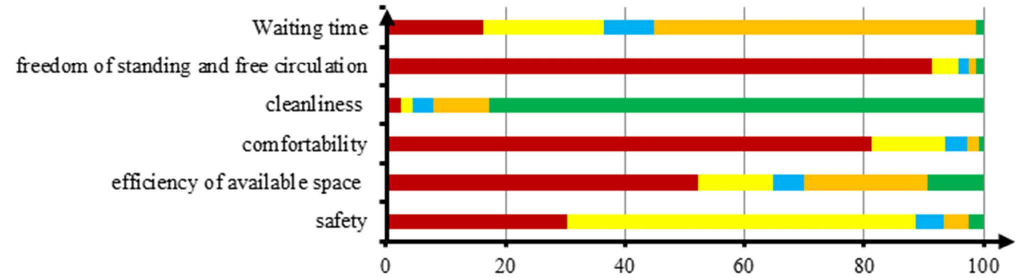
Very Dissatisfied Dissatisfied Neither Satisfied Very Satisfied

Figure 5. *Satisfaction levels of pedestrians to stairway facilities.*

The analysis of the data revealed that the freedom to choose walking speed and pass others was the highest (90.50%) in terms of 'Very Dissatisfied' and as compared to other satisfaction measurements (as shown in Figure 5). The highest result (14.93%) was for the surface quality, which was rated as very satisfied. Apparently, three criteria received more than 80.0% of the 'Very unhappy' rating. These were the flexibility to choose walking speed and pass others (90.50%), comfort ability (81.27%), and stairway width (80.25%). The stairs slope was also rated as "dissatisfied" (50.12%) in terms of satisfaction.

The findings on satisfaction level of waiting areas (platforms) facilities at the selected AALRTS stations were shown in Figure 4.4 below.

The analysis of the data revealed that the freedom to choose walking speed and pass others was the highest (91.20%) in terms of 'Very Dissatisfied' and as compared to other satisfaction measurements, as shown in Figure 6. below. The surface quality (cleanliness) was ranked as very satisfied which was the highest performance (82.68%). 58.15% of pedestrians were dissatisfied with the safety at the waiting areas of AALRTS. As shown in the figure there were three factors, which were rated more than 50.0% of 'Very dissatisfied'. These factors were freedom to select walking speed and pass others (91.20%), comfort ability (82.27%) and efficiency of available space of platforms (52.20%).53.81% of pedestrians were satisfied with the waiting time at AALRTS.

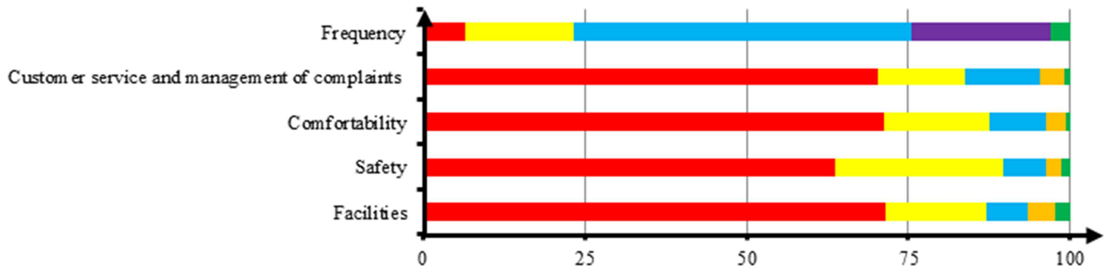


	safety	efficiency of available space	comfortability	cleanliness	freedom of standing and free circulation	Waiting time
Very Dissatisfied	30.42	52.20	81.27	2.54	91.20	16.32
Dissatisfied	58.15	12.52	12.30	1.87	4.57	20.27
Neither	4.67	5.30	3.55	3.47	1.65	8.22
Satisfied	4.28	20.47	2.14	9.44	1.34	53.81
Very Satisfied	2.48	9.51	0.74	82.68	1.24	1.38

Figure 6. *Satisfaction levels of pedestrians to platform facilities.*

4.5.2. Current Satisfaction on Rail Transit System

Figure 7 depicts a measurement of rail users' current satisfaction with the urban rail transit system. This evaluation was considered to investigate the level of satisfaction with the current light rail transport system based on rail transit users' perceptions and experiences. The five analyzed qualities of contemporary rail transit performance are: (1) facilities at rail transit stations; (2) safety at stations; (3) comfort ability at stations; (4) customer service and complaint management; and (5) rail frequency (number of trains arriving in one hour). Current rail satisfaction was rated on a scale of 1 (very poor) to 5 (very good).



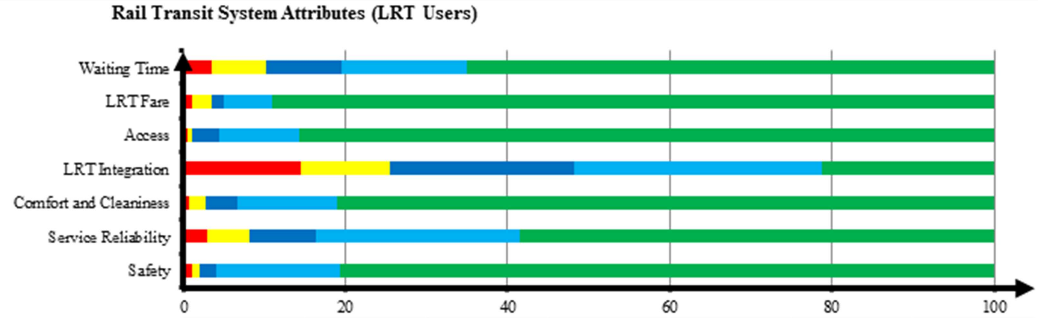
	Facilities	Safety	Comfortability	Customer service and management of complaints	Frequency
Very poor	71.5	63.70	71.11	70.25	6.5
Poor	15.46	25.93	16.30	13.48	16.75
Fair	6.5	6.67	8.89	11.52	52.25
Good	4.34	2.22	2.96	3.75	21.5
Very good	2.2	1.48	0.74	1	3

Figure 7. *Satisfaction measurements of AALRT users.*

As depicted in Figure 7, the analysis of the data revealed that the light rail transit users ranked facilities at rail transit stations (71.5%), Comfort ability at station (71.11%) and Customer service and management of complaints (70.25%) as the higher in terms of 'Very poor' as compared to other current satisfaction measurement. The rail frequency (number of train arrive in one hour) was ranked as the lowest (6.5%) in terms of "very poor" satisfaction measurement.

4.5.3. Important Factors Influencing LRT Use

Throughout the study, regular rail users were asked to rank the main light rail transit system qualities that they value when traveling by light rail transit system. Seven rail transit system characteristics were studied [3]. (1) Safety against crimes on at station, (2) Service frequency and reliability of rail transit system (LRT come on schedule, punctuality), (3) Comfort and cleanliness at station (train crowding during peak hours, air conditioning, level of noise, cleanliness), (4) Better integration of rail transit system, (5) Good access to rail transit station, (6) Rail transit ticket fare, and (7) Waiting time in station for ra These factors were measured with a score range from 1 “Not important” to 5 “Very important”. The findings on important level of light rail transit system attributes were depicted in Figure 8 below.



	Safety	Service Reliability	Comfort and Cleaniness	LRT Integration	Access	LRT Fare	Waiting Time
Not Important	1	3	0.74	14.5	0.5	1	3.5
Slightly Importatnt	1	5.07	1.96	11	0.65	2.5	6.74
Moderately Important	2	8.3	3.89	22.76	3.23	1.5	9.26
Important	15.3	25.11	12.3	30.5	10	6	15.5
Very Important	80.7	58.52	81.11	21.24	85.62	89	65

■Not Important ■Slightly Importatnt ■Moderately Important ■Important ■Very Important

Figure 8. *Perceived importance of rail transit system.*

According to LRT users, four variables rated more than 80.0% of the 'Very important' rating. LRT pricing (89%), accessibility (85.62%), comfort and cleanliness (81.11%), and safety (80.7) were the criteria. One element received fewer than 50% of the "very important" rating from rail users. LRT Integration (21.24%) is the greatest factor (14.5%) in terms of "Not Important" importance measurement.

4.6. Results Discussion

4.6.1. Consistence of the Sample Characters

For this research, out of three stations one station was ground station (Torhailoch), one station was Semi-underground station (Meganagna) and the other one is elevated station (Stadium).The three selected pedestrians' facilities which are stairways, crosswalks and platforms are the facilities which make the stations accessible to the users.

Among the 385 pedestrians sampled for this study, 36.05% are females, while 63.95% are males. In terms of age, the majority of respondents (31.7%) were between the ages of 25 and 30, with 24.3% being between the ages of 18 and 24. Furthermore, the majority of the pedestrians had a family income of less than 2000 ETB, which is approximately 40.0$ USD per month or less than $ 6 per day, showing that the majority of them were low income passengers, as defined by world poverty lines and indicators.

4.6.2. Pedestrians Level of Service (PLOS) for AALRTS Facilities Based on TCQSM (2013)

The finding related to the PLOS of AALRTS facilities were fall in the category of PLOS-D and PLOS-E. Accordingly, PLOS of crosswalk for elevated station (Stadium) was fall to the category of PLOS-D, which shows pedestrians freedom to select walking speed and pass others is restricted; high probability of conflicts for reverse or cross movements. In addition, the PLOS of crosswalk at the other station (Torhailoch) was became PLOS-E, which shows pedestrians walking speeds are severely restricted; frequent, unavoidable contact with others; reverses or cross movements are virtually impossible; flow is sporadic and unstable. In this facilities number of pedestrians flow on it were highly crowded at Torhailoch station than the stadium station because of both users and non-users of the LRT cross the road by using the crosswalk on the station.

The finding related to PLOS of stairways at both stations (Sadium and Magenagna) were found as a category of PLOS-E. These results show that Speeds of all pedestrians reduced. Intermittent stoppages likely to occur. Reverse flows cause serious conflicts. In addition, the PLOS for platforms were PLOS-E, which indicate Standing in physical contact with others is unavoidable; circulation within the queue is not possible; queuing at this density can only be sustained for short period without serious discomfort.

4.6.3. Pedestrians Perception Toward the Service Qualities of AALRTS Facilities

According to the findings about the service quality of LRTS facilities, the majority of respondents (more than 80%) were unsatisfied with service quality indicators such as freedom to choose walking speed and pass others, efficiency of available space (width), comfort ability, and sense of safety at station. The majority of responders (more than 50%) were pleased with the cleanliness of the facilities. The cleanness could refer to both the physical cleanliness of the facilities and the comfort associated with ambient states at transit locations such as stations and on board, with the station cleanness being evaluated as good performance in the AALRTS scenario.

4.6.4. Pedestrians Perception Toward the Service Qualities of AALRT

According to the Findings related to LRT service quality, the majority of respondents (more than 50%) were satisfied by service quality parameters such as LRT fare and dissatisfied with parameters such as facilities at rail transit stations (71.5%), Comfort ability at station (71.11%), and Customer service and complaint management (70.25%). In addition the pedestrians rank the importance of AALRT service quality parameters such LRT fare (89%), accessibility (85.62%), comfort and cleanliness (81.11%) and safety (80.7) as very important.

5. Conclusion and Recommendation

5.1. Conclusion

The study was conducted to assess the accessibility of AALRTS facilities in terms of PLOS and service quality. Quality of service describes how well a station facilities or service operates from the pedestrians' perspective. Level of service (LOS) is quantitative stratification of a performance measure or measures that represent the facilities quality of service. The LOS concept facilities the presentation of results, through the use of a familiar A (best) to F (worst) scale. In transit transportation the station facilities designed to PLOS of C and D level of service for peak pedestrians flows.

The following is a summary of the study's findings organized by the study's specific objectives.

According to the study findings, the majority of the PLOS of AALRTS facilities were PLOS of E category, with the exception of the crosswalk facilities at the stadium station (elevated station), which were PLOS of D type since only LRT users used the crosswalk. To classify the PLOS of the crosswalk facilities at the selected LRT stations, three parameters were considered: flow rate (VP), pedestrian space (AP), and volume-to-capacity (V/C) ratios. During the busiest periods of the day, the AALRTS crossing facilities can accommodate all users and non-users with a PLOS-D and E for the Stadium and Torhailoch stations, respectively.

To classify the P-LOS of the stairway facilities at the selected LRT stations, two factors were considered: flow rate (VP) and pedestrian space (AP). During the peak periods of the day, the AALRTS stairway facilities can accommodate all users and non-users with a PLOS-E for Stadium and Meganagna stations. To classify the P-LOS of the queening facilities at the selected LRT stations, two metrics were considered: Average Pedestrian Area (m2 /P) and Average Pedestrian Area (m2 /P). During peak parts of the day, the AALRTS queening facilities can accommodate all users with a PLOS-E for three selected stations.

According to the study's findings, the majority of respondents (more than 80%) were unsatisfied with service quality indicators such as freedom to choose walking speed and pass others, efficiency of available space (width), comfort ability, and sense of safety at station. The majority of responders (more than 50%) were pleased with the cleanliness of the facilities.

According to the findings of LRT service quality, the majority of respondents (more than 50%) were satisfied by service quality factors such as LRT fare and dissatisfied with parameters such as facilities at rail transit stations (71.5%), Comfort ability at station (71.11%) and Customer service and management of complaints (70.25%). In addition the pedestrians rank the importance of AALRT service quality parameters such LRT fare (89%), accessibility (85.62%), comfort and cleanliness (81.11%) and safety (80.7) as very important.

Generally, the pedestrians' facilities accessibility of the AALRT stations is very poor based the thesis finding of PLOS which were fall to the category of 'E' which were the worst category of level of service and the pedestrians perspective towards the quality of service of facilities which most of the pedestrians (averagely greater than 85%) were dissatisfied with the AALRTS facilities services. The majority of the available area and/or width of the facilities do not meet acceptable criteria. The designs of the AALRTS facilities are inaccessible and do not meet the needs of pedestrians, as there is no smooth transition between sidewalks and the facilities.

5.2. Recommendations

The study suggests that some service quality can be enhanced in short-term planning and improved in long-term planning, thereby enhancing user accessibility and accessibility of facilities.

Note that in this case, the short term refers to improvement efforts that can be completed in one year, whilst the long term refers to improvement actions that can be completed in more than two years.

The short-term improvements to AARTS facilities include ensuring pedestrian safety by reducing waiting times, increasing train frequency, and implementing techniques to decrease crowdedness and waiting times. These improvements can be achieved through various approaches.

1. Increase the number of double trains in line with minimizing waiting time in order to improve the facilities' level of service.
2. Defining the number of passengers per train to reduce waiting times and increase the number of trains if they are overcrowded.

Additionally, concentrate on improving the coverage of station shelters and increasing the number of station seats.

Long-term, i.e. more than two-year, improvement. The following are the important areas for improving the accessibility of AARTS facilities.

Crossing locations and pedestrian routes to the station should be free of traffic accidents and safe for passengers entering and exiting the station. As a result, strictly working on crossing areas to stations or ticketing places in ways that promote pedestrian safety and security. Redesign and maintaining the facilities at LRTS in order to accommodate the high pedestrians demands and increases additional vertical and horizontal circulations at the LRT stations.

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