



ADDIS ABABA INSTITUTE OF TECHNOLOGY
School of Civil and Environmental Engineering

**Effects of Light Rail Transit System on Pedestrians
and Public Transport Users' Mobility**

(Case study- Addis Ababa Light Rail Transit Corridor along
East-West Line from Ayat to Megenagna)

A thesis submitted to the School of Graduate Studies of Addis Ababa Institute of
Technology University in candidacy for the Degree of Masters of Science in
Civil Engineering (**Road and Transport** Engineering Stream)

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ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)
School of Civil and Environmental Engineering
(Under Road and Transport Engineering Stream)

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Declaration

I, Elizabeth Azmeraw, declare that “Effects of Light Rail Transit System on Pedestrians and Public Transport Users' Mobility” a case study on Addis Ababa Light Rail Transit Corridor along East-West Line from Ayat to Megenagna is my original work, has not been presented for award of any degree or diploma in this or other universities. All sources of materials used for this thesis work have been fully acknowledged.

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Abstract

The introduction of Light Rail Transit system in Addis Ababa's existing road corridors has an advantage of reducing the demand for vehicles but it will induce additional delays to pedestrians and passengers mobility due to intervals of LRT crosswalks distance.

The major purpose of this research was to analyze the effects of introducing LRT system in urban transport design on pedestrians and public transport users' travel distance and time to cross crossways of LRT. The study had two objectives; quantifying walking parameters (walking distance and time) to crossways and testing the effect of LRT system on these parameters when walking is used as a primary mode and/or an access mode to public transport.

The LRT crossway user survey was conducted by randomly distributing questionnaires to a sample of 98 pedestrians and passengers at different places who cross through LRT crossways. Collected crossway user survey includes; access mode choices, trip origins destinations (O-D), number of cross trip per day and type of LRT crossways. Geometric data of crossways, Video surveys, pedestrian and traffic count was also conducted to analyze waiting time and crossway coverage rate (crossway areas).

Walking Distance and Time were analyzed for both scenarios i.e. before and after LRT construction. A statistical comparison was then conducted by paired t-test and p-value to determine the significance of the effect on mobility parameters. It is found that the introduction of LRT would increase walking distance and time to sampled pedestrians by 580.2m and 9min in a round trip. The increase distance and time in total O-D trips per day would be 752.2 m/day and 11.4 min/day. The paired t-test test statistic 9.759 greater than 1.663 the critical value and p-value 2.78×10^{-16} less than 0.05 the significant level, there has been increase in distance due to LRT constructed or introduced. Overall additional average walking distance to total O-D trips per day is 752.2 m/day: the additional median walking distance is 568.5 m, with 25% of trips less than 321.5 m and 75% of walking trips less than 919.5 m.

Mean and Standard deviation of walking distance were calculated to determine which station posed the longest travel distance to users. The longest travel distance to a station crossway was observed at station East West two (EW2) with a mean distance of 809.7m in a round trip and 1127.6m/day in total O-D trips per day. While the shortest travel distance was at station East West six (EW6) with a mean distance of 108.6m in round trip and/or total O-D trips per day. It was found that a grand mean of 394.3m and 6.1 min and 485.6m and 7.3 min of additional travel distance and time was induced on users to access each LRT crossings in a round trip and total O-D trips per day respectively. Overall additional grand mean walking distance to access/reach on LRT crossways of EW1 to EW8 crossways in total O-D trips per day is 485.6 m/day: the additional median walking distance is 395.84 m, with 25% of trips less than 262 m and 75% of walking trips less than 785 m. Walking distance to different mode choices was also quantified using mean and standard deviation. Accordingly, walk trip mode choice would be more affected by LRT system.

It is finally concluded that introducing LRT affects both pedestrians and public transport users' mobility by creating walk distance increment, time delay and mode choice delay. It is recommended that affordable overpass bridges, pedestrian refuge area and integrate other transit locations with LRT crossways can potentially reduce the impact.

Keywords: Light Rail Transit, O-D trip, Walk distance, Walk time, Paired t-test, Mode choice

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Acronyms

A.A.....	Addis Ababa
AACRA.....	Addis Ababa City Roads Authority
AALRT.....	Addis Ababa Light Rail Transit
CBD.....	Central Business District
CK.....	Center Mileage
DIMTS.....	Delhi Integrated Multi-modal Transit System
DDA.....	Disability Discrimination Act
ERC.....	Ethiopia Railway Corporation
EW.....	East West
FDRE.....	Federal Democratic Republic of Ethiopia
GTP.....	Growth and Transformation Plan
LRT.....	Light Rail Transit
LRV.....	Light Rail Vehicles
NS.....	North South
OD.....	Origin Destination
PT.....	Public Transport
SD.....	Standard Deviation
TCRP.....	Transit Cooperative Research Program
UATP.....	African Association of Public Transport
UITP.....	International Association of Public Transport
Vs.....	Versus

1. Introduction

1.1 Research Project Description

Addis Ababa, the administrative and financial capital of Ethiopia, is experiencing continued growth and change which is the location of the head office of African Union. Economically the city is transforming from a predominantly administrative and service center into an industrial and financial sector. The population of Addis Ababa is estimated to be over 3.4 million, all being urban residents and taking up 2.4% of the total population of Ethiopia. The population density reaches 5,607.96 persons/km² (CREC, 2009). The urban area is 537 km² (DIMTS, 2014). So it is rapidly growing into a major urban area and lack of adequate transport and traffic management system have created pedestrian mobility effect, acute traffic congestion and increased accident rates. The level of air and noise pollution is also becoming critical. The movement of people and goods into and out of the city is restricted due to the deteriorating traffic condition and walk distance; hence having a direct negative impact on the economic performance of the city and the nation as a whole.

Mobility and safety is a basic human need, everyone travels for different access. Public transport has a key role in ensuring accessibility to activities and services. There are many influences on the use of public transport including spatial access, cost, physical accessibility, information and attitudes which all contribute to people's ability and motivation to use public transport. Railway has been the effective means of land transport for freight and passenger. Currently the developing countries are realizing the importance of the railway industry and have been investing in the infrastructure. It is also believed that a railway system well integrated with other modes of transport is environmentally friendly, economically feasible and can be a growth engine for development in economy. LRT system is an alternative transportation mode and has been cited as a way to help influence development by promoting more desirable and sustainable land uses near the LRT lines. It is also generally less expensive to construct and operate than other kinds of rail transit systems. LRT is an attractive option because of its ability to be located in a variety of settings, from tracks on an exclusive right-of-way to shared lanes with vehicles in

an urban street. To effectively solve the problem of urban transportation, esp. that of the downtown area, the government of Ethiopia decided to build a light rail in the city of Addis Ababa. With the above background that the FDRE Government in its Growth & Transformation Plan (GTP) is engaged in the implementation of a 475 million dollar project for AALRT. It also intends to cover over 2,300 km of railway in eight corridors connecting the potential development areas of Ethiopia. Ethiopian Light rail project will be among the 7 out of the 54 countries in Africa using this mode of transportation (CREC, 2009). The objective of constructing LRT at A.A roads is to propose a “quick win” solution, easy to implement, and that could run with and without the LRT system being operational.

The Phase 1 of the LRT system comprises an East – West Line starting from Ayat and ending at Torhailoch. The total length is 16.998 km; there are 22 stations, among which 6 are elevated (5 on common track section), 2 underground and 15 grounds. The maximum station interval in this line is 1.260km while the minimum is 0.435km, with the average of 0.798km. Another North-South Line starts from Menelik II Square and ends at Kaliti. The total length is 16.689 km. There are 22 stations, among which 8 are elevated (including 5 common stations at the common line), 1 underground and 13 ground. The maximum and minimum intervals between stations are 1.972km and 0.435km respectively. The average station interval is 0.773km. The total length of Phase 1 will be 31.025 km. The two lines share common tracks between Meskel Square and Lideta along RasMekonen Street and Chad Street, on a distance of approximately 2.662 km, which has the currently highest passenger number (CREC, 2012). Existing Addis Ababa City transport service for the public transport system comprises 750 Anbessa bus service with 100 seat capacity, 10500 privately owned mini bus taxis with 12 seat capacity, 439 midi buses (Higer) with 25 seat capacity, 4000 Saloon taxis with 4 seat capacity and non – motorized transport (walking) 44% (DIMTS, 2014).

The provision of this transit system will be a huge addition to the public transport but it will not be efficient unless it is supported by integrated transport and traffic management strategies. Road ways should be used efficiently and harmonically by the different modes of transport, namely train, vehicles and pedestrian; this harmony will help in order to reduce travel time, congestion

and accidents. Policies need to be drafted in such a way that preferred mode of transport system is favored, address the safety and pollution issues efficiently. This research focuses on spatial access as understanding influences of the LRT on walking distance to cross by walk and use other public transport facilities. Potential influences on the characteristics and variability of walk distance as an access mode to public transport include trip purpose, demographics, built environment, local geography and public transport supply. Since the AALRT system is safe guarded with fences so, additional delay on travel time and increase in walking distance may be created on pedestrians.

1.2 Research Problem Statement

LRT has both positive and negative effects on mobility, but in this research analyze the negative effects of the introduction of LRT system. The introduction of LRT system in existing road corridors has the advantage of reducing the demand for vehicles, increase safety of train users, decrease pollution of air, waiting time, travel cost and time of train users but it will induce additional delays on vehicles, pedestrians and other public transport users due to interval on crossway and at grade crossings and increase mobility. Priority given to LRV will also cause additional delays. If delays are unacceptable, transport and traffic management strategies are required to improve the situation and pedestrian crossing with acceptable distance.

The LRT system is at grade adjacent to the road therefore it creates difficulties on:-

- Crossing through the LRT route for different access. The distance pedestrian walk to cross and access other public transport modes is larger and crossing occupation time is higher than the usual. So it is low affordability for a pedestrian who was traveled short distance before introducing LRT system at A.A roads from one's origin.
- High levels of road accidents may occur while pedestrians try to cross without using crossways or jump on fences because of being impatient to cross through the long intervals of crossways and creating a sense of insecurity on elders, kids and disables (wheelchair users and blind persons).
- Increase the waiting and crossing time of pedestrians due to the crossways capacity and ramp gradient.

Considering all the aforementioned factors an assessment of the effect of LRT line on Non – motorized transport (walking) and other public transport users' is required, and transport management measures have to be developed for the shortcomings encountered during evaluation.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of this study is to evaluate the effects of light rail transit on pedestrians and public transport users' mobility to cross through Addis Ababa LRT system.

1.3.2 Specific Objectives

- The main objective of this study can be broken down into number of specific objectives to analyze pedestrian mobility at LRT line consists of a process
 - Identify factors affecting pedestrian mobility due to LRT
 - Analyze factors affecting pedestrian mobility by quantifying walking parameters (walking distance and time) to crossways
 - Testing the effect of LRT system on these parameters when walking is used as a primary mode and/or an access mode to public transport.
 - Select recommendations that address pedestrian mobility to establish corrective transport management strategies.

1.4 Research method

The method to be employed to achieve the objectives of the research includes:

Literature Review: is the study of different research works including reading documents, specifications, publications and journals on pedestrian walking distance and Addis Ababa LRT profile.

Data: The methodology of the thesis includes study area survey, pedestrian questionnaires, geometric survey, pedestrian trip, pedestrians' questionnaire, video survey and pedestrian and vehicle count data.

Analysis and interpretation of results: This involves interpretation of walk distances and time before and after LRT was introduced. Analysis of field observation with spot places of

pedestrians number and pedestrian behavior while crossing, comparison of pedestrian perception on LRT, geometry of crosswalk facilities interval, gradient and capacity, walk trips distance and time of O-D, return trips and mode choice trips, pedestrians characteristics and interaction with vehicle, other pedestrian characteristics, waiting time of pedestrians and pedestrian and vehicles flow number was carried out using appropriate descriptive and statistical tools.

1.5 Scope and Limitation of the Study

The study addresses the effect of LRT on pedestrians and public transport users' mobility. Scope of this study is limited to assessment of selected E-W line route of Addis Ababa Light Rail Transit corridor to assess' pedestrian movement across surface crossings along Ayat to Megenagna sections. The analysis is made based on data collected from questionnaire, design documents of the AALRT, field survey, video survey and field pedestrian and traffic count.

During the data collection process, there was construction going on around the study areas and all lines were fenced except at some locations. There were an almost 2 m opening that are not fenced and serve as crossing facilities until the train starts its operation. Those areas were in front of Saint Mikael, Gurd Shola Ethiopia Commercial Bank and Civil Service College. Pedestrian were cross through these facilities that had no fences. Some answered the questionnaire depending on crossing facilities that had no fences. By asking of their origin destination, crossing facility and distance trying to know the estimated distance and station crossway that will used by pedestrians using the ERC LRT road network plan and profile drawings. The other limitation does not know of their home address. Some respondents mentioned their distance from their home wrongly; this makes difficulties to estimate walking distance from their O-D. Another limitation of the study is that all computations were performed manually due to inaccessibility of simulation programming software that could have furnished better modeling for pedestrians like PTV VISWALK, a soft-ware tool specially designed for pedestrian simulation.

1.6 Structure of Final Report

The study is structured in seven chapters; the first chapter is a general introduction describing the research project description, research problem statement, objectives of the study and scope and limitation of the study. A review of relevant literature is presented in Chapter 2 and the methodology used for determining additional delays caused by light rail transit crossways, including descriptions of the scenarios that were conducted for the study described at Chapter 3. Analysis and results are discussed in Chapter 4. At the end of the section depending on the results described findings and discussions in Chapter 5, conclusions and recommendations in detailed at Chapter 6 and proposed for future studies at Chapter 7.

2. Literature review

2.1 Introduction

This section provides mobility for walk and access public transport and classification of LRT. Also provides understanding how far passengers and pedestrians walk to cross the LRT and to access public transport by a review of possible influences on walking distances and provides mode choice factors. Pedestrians cross the road an average of two to three times on every walking trip and may also need to cross railways. Their perceptions of the walking experience largely focus on difficulties crossing roads and railways. Any problems with walking can cause delays and create a sense of insecurity.

2.2 Mobility

Walking mode continues to play an important role, both in its own right, and as a feeder mode to public transport. The number of daily trips in Addis Ababa urban area is constantly increasing, with commuting to work being the main reason for travel, followed by traveling to school/university. Walking is the most widely used transport mode in the city of Addis Ababa, taking the modal split of 44 % (UITP and UATP, 2010). But also motorized travel is increasing in the city and impacts on pedestrian mobility. Most researchers conducted that transport demand tends towards private vehicles makes congestion. The increase number of urban population at Addis Ababa increases the usage of low capacity vehicles. These account for the congested roads and streets of Addis Ababa and creating mobility problems. The heavy reliance of urban transport on minibuses and the rise of private automobiles increase the rate of road accidents in the city (DIMTS, 2014). Much of the growth in overall trip-making in recent years is a growth in motorized trip-making, much of which derives from a transfer from walking (TRL593 Report, 2004).

Walkers may not use the road network, as they may walk through parks and open space or use pedestrian-only links which reduce their walk distance. Alternatively they may walk longer than the shortest road network distance, depending on the facilities for crossing roads, and their ability and confidence. Walkers may also choose a longer route than the shortest road distance because the longer route is more attractive or avoids negative elements.

Therefore, the Addis Ababa mobility facilities are not well settled for pedestrians to flow freely without any interruption by vehicles and long distance crossings exist. Many researches identify that foreign pedestrian walk through parks to get to stations but in Addis Ababa there are no parks that can serve as a mobility access.

2.3 Public transport

Public transport has a key role in ensuring accessibility to activities and services. There are many influences on the use of public transport including spatial access, cost, physical accessibility, information and attitudes which all contribute to people's ability and motivation to use public transport (Daniels and Mulley, 2011). Accessibility planning to improve social inclusion in the UK focuses on improving access by public transport (Daniels and Mulley, 2010a).

The strategic land use and transport plans for Sydney (Australia) include a broad accessibility target of increasing the proportion of the population with access within 30 minutes by public transport to one of a set of centers which is large enough to provide a range of activities and services (Daniels and Mulley, 2010a).

2.3.1 Mass transit systems

In urban areas there are five main passenger transport modes available: walking, cycle, motorcycle, private car, and some form of public transport. Walking and cycling are for short distance journeys. If motorcycle activity is recognized as catering for a relatively small proportion of trips, then the main competition between modes in urban areas lies between the private car and some form of public transport. Passengers need availabilities of public transport facilities for different access like work, school, church etc. High capacity transport modes such as bus and light rail are required to satisfy the need of high density movements of passengers. These mass transit systems are more economical, energy efficient and use less space than private cars. Urban transport systems are classified as private and mass transit (public) transport.

Private transport: transport by walking, private cars, cycles and motor cycles.

Bus transport: are the most accessibility transport modes for passengers. They can integrate with other transport facilities and can transport large numbers of people with a little road space.

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The cost for bus transport is minimum and acceptable compared with other transport systems like taxi.

Bus stops should be located at appropriate intervals along the bus route at which passengers' board and alight. Some shelter (with seating) may be provided, but many stops are fully exposed to the weather. For disabled and elderly people, and people with pushchairs or luggage, this can create problems, especially as many entrances are narrow, as well as increasing the wait time for the bus at the stop.

A number of simple guiding principles can be laid down governing the location of bus stops.

1. They should be located at/near places of pedestrian concentration. In particular they should be close to any designated homes for elderly people.
2. They should be positioned where they will not cause a safety hazard and where disruption to other traffic will be minimized.
3. Bus stops should be located preferably where bus bays can be provided. However, in urban areas it will not always be possible to provide the standard dimensions because of lack of space etc.

Therefore, Addis Ababa Public Transport System includes the bus service provided by Anbessa Bus Corporation, the Mini-Bus service provided by a large number of private operators, and the saloon taxi service. The mode share of existing public transport system is provided in the table given below:-

Table 2.1 Mode share of various types of buses in A.A (DIMTS, 2014)

PT- Mode	Seating Capacity	Fleet Size	Passenger Carried	Share
Mini Bus Taxi	12	10500	1.6 million	73 %
Midi Bus (Higer)	25	439	180,000	8 %
Anbessa Bus	100	750	420,000	19 %
Total			2.2 million	100 %

It is observed from the above table that, Mini Bus taxis are the preferred public transport due to high supply of taxis existed than other modes in Addis Ababa followed by Anbessa buses (19%).

Light rail transit (LRT) transport: according to the Transportation Research Board's Committee on Light Rail Transit, LRT is defined as "a metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights of way at ground level, on aerial structures, in subways or, occasionally, in streets, and to board and discharge passengers at track or car-floor level". It is the most common mode of semi rapid transit and is a form of urban rail public transportation that generally has a lower capacity and lower speed than heavy rail and metro systems, but higher capacity and higher speed than traditional street-running tram systems. LRT operating mostly in private rights-of-way separated from other traffic but sometimes, mixed with other traffic in city streets on edge sides or along center of the road. LRT are modern, high quality and environmentally-acceptable modes of transport. LRT systems are introduced into high degree of segregation and priority over other traffic. This can be achieved either through construction of purpose-built track, fences and bridges or through the use of redundant railway lines in combination with preferential traffic management and control.

Rapid transit (Metro): is a type of high-capacity public transport generally found in urban areas. Unlike buses, trams or light rail, rapid transit systems operate on an exclusive right-of-way which is usually grade separated in tunnels or elevated railways. It has the highest performance of capacity, speed, and reliability than other modes. It requires very high investment, but it is essential in large cities. Metro is an underground railway system in a city.

2.3.2 Classification of Light Rail Transit Systems

Light rail systems can be found in a variety of land use contexts, from suburbs to high-density central business district areas, and they can operate in a range of right-of-way types. Because of the wide variations in operating characteristics among LRT systems, researchers have attempted to create classification schemes for comparison purposes. Operating speeds and alignment types are two characteristics of LRT systems that can be used for classification (Chandler, 2004).

2.3.2.1. Speed-based classification

According to Transit Cooperative Research Program (TCRP) Report 17, the use of average speed is acceptable to show the diversity of LRT systems. Average speed on systems that use primarily one type of right-of-way could be a good way to differentiate among systems that use different types. Since higher speeds can be obtained with a greater degree of exclusivity. However, this classification does not fully account for the use of multiple alignment types and speed changes from block to block.

2.3.2.2. Alignment-based classification

According to TCRP Report 17, the use of alignment types as the basis for classification would be the most appropriate method to categorize systems for planning and operations purposes. LRT alignments are typically categorized into three right-of-way types for planning purposes. These classifications are also used for operations and safety. The alignment classification system recommended by TCRP 17 includes three basic alignment classes:

- I. Type a (Exclusive): Exclusive alignments use full grade separation of both motor vehicle and pedestrian crossing facilities. Exclusive alignments eliminate grade crossings and operating conflicts, and maximize safety and operating speeds.
- II. Type b (Semi-exclusive): Semi-exclusive alignments keep the LRT apart from road vehicles and pedestrians, except where road vehicles and pedestrians intersect at an at-grade crossing. This means that it is with grade crossings as well as segments of separate right-of-way protected between crossings by fencing, barriers, curbs, etc.
- III. Type c (Non-exclusive): Non-exclusive alignments allow for mixed flow operation or a shared right-of-way with motor vehicles or pedestrians, resulting in higher levels of operating conflicts and lower-speed operations. From these three classes, TCRP 17 further defines nine types of alignments, which are listed in Table 2.2.

Table 2.2 Classification of LRT alignments [TCRP Report 17]

Class	Category	Description of access control
Exclusive:	Type a	Fully grade-separated or at-grade without crossings
Semi-Exclusive:	Type b.1	Separate right-of-way
	Type b.2	Shared right-of-way protected by 6-inch high curbs and fences
	Type b.3	Shared right-of-way protected by 6-inch high curbs
	Type b.4	Shared right-of-way protected by mountable curbs, striping, and/or lane designation
	Type b.5	LRT/Pedestrian mall adjacent to a parallel roadway
Non-Exclusive:	Type c.1	Mixed traffic operation
	Type c.2	Transit-only mall
	Type c.3	LRT/Pedestrian mall

Therefore, Addis Ababa Light Rail Transit system is a semi-exclusive (type b) of Light Rail Transit alignment based on alignment-based classification system with category (type b.2) shared right of way protected by high curbs and fences.

2.4 Pedestrian and public transport users' mode choice

The choice of transport mode is probably one of the most important classic models in transport planning and policy making. Rail modes can provide a more efficient mode of transport (in terms of resources consumed, including space), but there is also a trend to increase travel by road. Given the decision to walk to public transport, demographic characteristics such as age, gender, income and labour force status and trip characteristics such as trip purpose, time of day and week, fare and ticket type and trip duration are not significant in explaining walk distance to each mode of public transport. The mode of the public transport trip is the most important determinant of walking distance, reflecting the different supply and spacing of each mode in which there may be many more bus stops than train stations. The differences between train and bus users suggest that accessibility initiatives for public transport may not be the same for each mode. Factors influencing mode choices classified into three groups (Ortuzer and Willumsen, 2001):-

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- 1) Characteristics of the trip maker: Car availability / car ownership, Possession of a driving license, Household structure (age, number of employed, couples with children, singles, etc), Income, Need for car for something else (at work, take children to school, etc)
- 2) Characteristics of the journey: Mode (Public Transport, Private), Trip purpose / frequent or rare (ex. work trips are often easier to undertake by public transport than other trips), Time of day (late trips are difficult to accommodate by public transport)
- 3) Characteristics of the transport facility
 - a) Quantitative factors: - Relative travel time; in-vehicle, waiting and walking time by mode, Relative monetary costs (fare, fuel, parking, toll/road pricing), Availability and cost of parking
 - b) Qualitative factors: - Comfort and convenience, Reliability and regularity, Protection and security

A joint research by International Association of Public Transport (UITP) and African Association of Public Transport (UATP) has estimated modal share for the city of Addis Ababa. According to the transport studies by UITP and UATP (2010), walking takes a modal share of about 44% and is followed by minibus (34%).

Table 2.3 Mode split in Addis Ababa (UITP and UATP (2010))

Mode of Transport	Modal share
City Bus	7 %
Mini Bus	34 %
Walking	44 %
Private Taxi	6 %
Private Car	9 %
Total	100 %

Therefore, it is observed from the above table that walking is the preferred mode choice option among the users followed by mini bus and private car respectively.

2.5 Effects of LRT on public transport users mobility

In delivering public transport accessibility goals and targets, service planning makes assumptions about walk distance to access public transport. Guidelines often use $\frac{1}{4}$ mile or 400 m, or multiples such as $\frac{1}{2}$ mile or 800 m, as key distances in network and service planning. Walk distance is important because walk is the primary access mode for trips from home to public transport and because walking distance has a significant impact on public transport use. In Sydney, walking is the access mode for almost 90% of bus trips from home and for about half of train trips from home, people will walk further than 400 m to access public transport, once they have decided to walk, people walk further from home to access train than to access bus and average walk distance to public transport demonstrated significant differences in relation to demographic and trip-type variables (Daniels and Mulley, 2011).

In Sydney, Australia, people walk further to train than to bus, the distributions of walk distances are different for each mode and the trip and demographic characteristics of train and bus users are different. Many regions around the United States are considering developing light rail transit (LRT) systems as an alternative transportation mode. LRT is an attractive option because of its ability to be located in a variety of settings, from tracks on an exclusive right-of-way to shared lanes with cars and trucks in an urban street. There is a great possibility for vehicles to experience additional delays when there is interference by LRT operations so pedestrians faced difficulty with the bus schedules and delays, such as in the case of at-grade crossings or due to priority being given to LRT vehicles at signalized intersections at the expense of conflicting turning movements.

Therefore, in Addis Ababa LRT system oriented at the center of the road with high curbs and fences so pedestrians travel long distance to bus than train because bus users can reach on bus stops after they cross through LRT crossways.

2.6 Influences on walking distances and times

Walking Speed varies between 0.9 to 2.4 m/sec the design value is ~ 1.2 m/sec and used to calculate safe pedestrians crossing time. However, it is approximated as 0.5 m/sec for disabled people and 1.0 m/sec for elderly (Rouphail and Allen, 1998). The acceptable distances for elderly or disabled people are 50-150 m.

Table 2.4 Recommended walking distances (DDA, 2005)

Impairment group	Recommended distance limit without a rest (m)
Wheelchair users	150
Visually impaired	150
Stick users	50
Ambulatory without walking aid	100

Ramp gradients (5-8%, preferably with handrails, and flat rest platforms every 10m) most guidelines specify 5 percent (1 in 20) as the preferred gradient and 8 percent (1 in 12) as the absolute maximum gradient.

In Ethiopia there are no walking distance guidelines provided to access public transports. In Canada the walking distance guidelines range from 300 m to 900 m for all surface transport modes. In U.S. the walking distance guidelines specify between 400 m – 800 m (O'Sullivan and Morrall, 1996).

Transport planning research has focused on mode choice, not on access to different modes, and there is a less well-established literature on how far pedestrians walk and the factors that influence their route choice (Agrawal et al., 2008). The impact of socio-demographic factors has mostly been studied in the context of being a differentiating factor in choice of travel behavior. Corpuz et al., (2005) found that in Sydney, females walk more than males, that older and younger age groups walk more, and that people with low car ownership walk more. The many elements of the built environment from density, diversity and design to micro-level details such as ambience and aesthetics have an influence on walking. Cervero et al., (2009) cited to assert that the characteristics of the built environment including permeability, footpaths, lighting, security, density, and mixed land use can influence walking both as a transport mode, and as an access mode to public transport.

The distance a person will walk and the mode of transport use are strongly affected by the walking environment. The tolerable walking distance for a given situation is related to such factors as trip purpose, available time, and walking environment. Improvements to the designed environment to reduce negative psychological factors may be as important as reducing pedestrian walking distances and times. O'Sullivan and Morrall (1996) research strongly indicates that people walk farther to reach an LRT station than a bus stop. For the city of Calgary the average walking distance to suburban stations is 649 m with a 75th-percentile distance of 840 m at CBD stations the average walking distance is 326 m and the 75th-percentile distance is 419m. A study in Central Edinburgh, Canada, found that 50 percent of pedestrians would walk more if walking conditions were improved. Walking routes to LRT stations should be as direct as possible.

Therefore, previous researches suggests that walk distance and time to public transport may be influenced by the purpose of the overall trip, by demographic factors, particularly age and gender, and by the location of the access trip in terms of built environment and natural environment, although the impacts are variable. It is difficult to disentangle the effect of the built environment on walk access to public transport because of the interdependencies between access distances and supply of services. Overall, it appears that built and natural environment factors determine the ease of walking but the supply of public transport, including type of mode, may be more of a factor in determining how far people walk to public transport, once the decision to walk to public transport has been made. The pedestrians walk long distance to access train than bus.

2.7 Transit users' walking distance

There has been relatively little research done on how far transit users will walk to the station, and whether walkability influences their walking distance. Daniels and Mulley (2011) analysis of influences on walking distance to public transport was conducted in three stages. Firstly, walking distance was described in terms of its central tendency and shape. Secondly, the relationship between walking distance to public transport and possible explanatory variables was analyzed. Finally, the potential causal relationship between walking distance to public transport and the characteristics of the walk trip, the characteristics of the walker, and characteristics of public transport was investigated. Analysis of the Sydney Household Travel Survey data people walk

further from home to access train than to access bus. Daniels and Mulley (2011) analysis result on average walking distance to public transport is 573 m, with 25% of trips less than 235 m and 75% of walking trips less than 824 m. There have been two notable studies conducted in North America. O'Sullivan and Morrall, (1996) study done in Calgary showed that 75 percent of sample walked 840 m or less to a suburban LRT station, and the distance was shorter in the CBD, at 419 m. Agrawal et al.(2008) conducted surveyed transit users at five transit stations in the Bay Area and in Portland, Oregon. Although it varied by station, they found that 75 percent of travelers walked maximum (network) distances between 1110 m and 1609 m. A majority of the survey respondents 64% chose the shortest route was their first priority and 28% respondents safety was their second priority (Agrawal et al., 2008).

The inadequacy of the Addis Ababa road infrastructure is reflected in the poor performance of the city bus. It indicates long waiting and travel times, walking distance, overcrowding in some past research. The average waiting times of bus is 30 to 45 minutes and average travel time of 48.5 minutes. 71 % of Addis Ababa residents live in range of less than 500 m walking distance to bus stop, 16 % between 500-1000m and the remaining 13% lives between 1000 – 2500m as per one research study done in past (DIMTS,2014). Therefore on average, citizens spend at least 1.5 hours for waiting and travel time in road environment they will cover more than 8km per trip by walking. Thus, the road authority should promote walking mode and to construct more footpaths. Also walking has many health benefits such obesity, lowers disease rickets etc.

Therefore, other researches show that walk to different transit places for different access had a long distance between their origin destination to transit facilities of train and bus.

2.8 Summary

Therefore, the Addis Ababa mobility facilities are not well settled for pedestrians to flow freely without any interruption by vehicles and long interval LRT crossings. Many researches identify that foreign pedestrian walk through parks to get stations but in Addis Ababa there are no parks that can serve as a mobility access. The Addis Ababa Public Transport System includes the bus service provided by Anbessa Bus Corporation, the Mini-Bus service provided by a large number of private operators, and the saloon taxi service. Addis Ababa Light Rail Transit system is a

semi-exclusive (type b) of Light Rail Transit alignment based on alignment-based classification system with category shared right of way protected by high curbs and fences (type b.2).

In Addis walking is the preferred mode choice option among the users with 44% share followed by mini bus and private car respectively. The Addis Ababa LRT system is oriented at the center of the road with high curbs and fences so pedestrians are forced to travel long distance.

Previous researches suggests that walk distance and time to public transport may be influenced by the purpose of the overall trip, by demographic factors, particularly age and gender, and by the location of the access trip in terms of built environment and natural environment, although the impacts are variable. It is difficult to disentangle the effect of the built environment on walk access to public transport because of the interdependencies between access distances and supply of services. Overall, it appears that built and natural environment factors determine the ease of walking but the supply of public transport, including type of mode, may be more of a factor in determining how far people walk to public transport, once the decision to walk to public transport has been made. The pedestrians walk long distance to access train than bus.

Therefore, walk to different transit places for different access had a long distance between their origin destination to transit facilities of train and bus. At CBD areas the walk distance to transits are shorter compared with other areas.

3. Research Methodology

3.1 Introduction

There are three different station types on AALRT system. These are ground surface station, elevated stations, and underground stations 1 and 2. The study focuses on analyzing the additional walk distance and time at ground surface LRT crossing facilities on pedestrians and public transport users from origin destination survey. So the study is on-ground surface stations labeled EW1 to EW8. The overall pedestrian mobility analysis covers the LRT alignment along the E-W line (Ayat-Megenagna) with crossings at station locations that the train and pedestrian share the ground surface stations.

3.2 Data Collection and Sample Selection

3.2.1 Study area

The research covers the LRT alignment that goes from station CK14+559.100 (Megenagna roundabout) to CK22+482.000 (Ayat roundabout) i.e. E-W line of the LRT. The length of the selected section is 7.9Km or it is approximately 8 Km along the East West side of the LRT line. The study area was selected due to the presence of long intervals between crossways, availability of data and continuity of ground surface stations compared with other sections of the LRT.

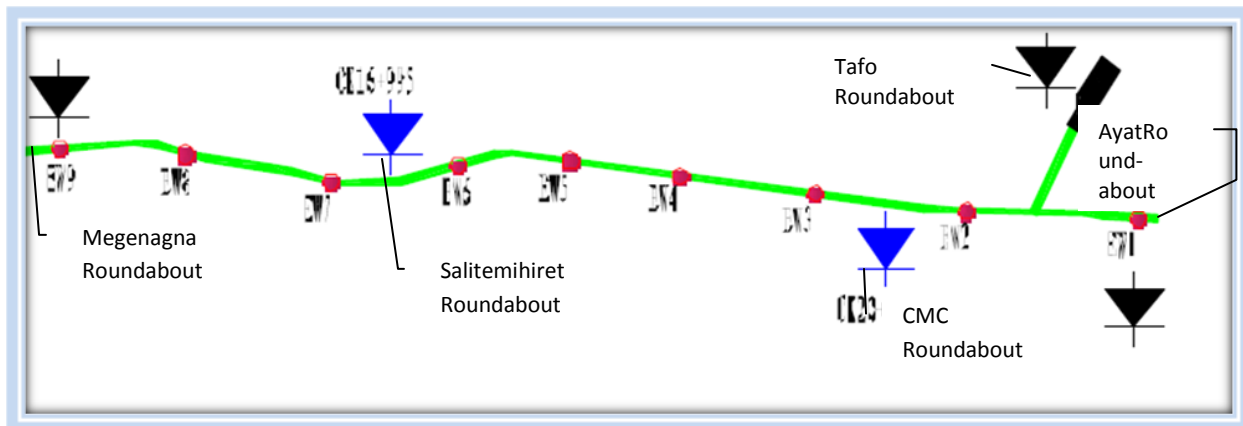


Figure 3.1 A case study on E-W LRT line from Ayat to Megenagna (CREC, 2012)

Table 3.1 LRT stations along East-West line (CREC, 2012)

No	Station Name	Center Mileage	Station type	Location
1	EW1	22+300.000	Ground surface station	Ayat before Zone2
2	EW2	21+040.000	Ground surface station	Front of Meri central hotel
3	EW3	19+948.000	Ground surface station	After CMC roundabout
4	EW4	19+085.000	Ground surface station	Before Saint Michael church
5	EW5	18+225.000	Ground surface station	Southeast of Ethiopia Institute of Civil Engineering Service
6	EW6	17+500.000	Ground surface station	South gate of Ethiopia Institute of Management
7	EW7	16+530.000	Ground surface station	South east of Ethiopia Telecom Company
8	EW8	15+444.000	Ground surface station	North of Ethiopia Geology Survey Bureau
9	EW9	14+615.000	Semi-underground island station	East of Megenagna loop interchange

3.2.2 Sample size

There is no evidence about the number of LRT crossway users and deviation (δ) is unknown. Therefore, to find the sample size needed to determine a confidence interval about a proportion used sample size for proportions. The minimum sample size needed for interval estimate of a population proportion is calculated by (Bluman, 2009).

$$n = p \hat{q} \left(\frac{Z_{\alpha/2}}{E} \right)^2 \dots\dots\dots (3.1)$$

Where n= Sample size, $p \hat{=}$ sample proportion who are affected by LRT, $q \hat{=}$ sample proportion who are not affected by LRT, $Z_{\alpha/2}$ = z value, α = significance level, E = margin of error or maximum error of the estimate.

To determine the sample size need to estimate with 95% confidence, the proportion of people who are affected by LRT and wish to be accurate within 10% of the true proportion. If some

approximation of sample proportion (\hat{p}) is known (e.g. from a previous study) that value can be used in the formula. Since there is no prior knowledge of sample proportion, statisticians assign the values $\hat{p} = 0.5$ and $\hat{q} = 0.5$ (Bluman, 2009).

Take 95% confidence interval

CI=95%, E=10%, $\hat{p}=50\%$,

$\alpha = 1 - CI = 1 - 95\% = 1 - 0.95 = 0.05$ and $Z_{\alpha/2} =$

$Z_{\alpha/2} = Z_{0.05/2} = Z_{0.025} = 1.96$ from table 3.2 below

Table 3.2 Value of $Z_{\alpha/2}$ to different confidence

Confidence	$Z_{\alpha/2}$
90%	1.645
95%	1.960
99%	2.576
99.9%	3.291

$$\hat{p} = \frac{X}{n}, \hat{q} = \frac{n-X}{n}, \hat{q} = 1 - \hat{p} \dots \dots \dots (3.2)$$

Where X - number of sample units that possess the characteristics of interest.

When \hat{p} and \hat{q} are given in decimals or fractions, $\hat{p} + \hat{q} = 1$. When \hat{p} and \hat{q} are given in percentages, $\hat{p} + \hat{q} = 100\%$. It follows, then, that $\hat{q} = 1 - \hat{p}$, or $\hat{p} = 1 - \hat{q}$, when \hat{p} and \hat{q} are in decimal or fraction form (Bluman, 2009).

$$\hat{q} = 1 - \hat{p} = 1 - 0.5 = 0.5$$

$$\hat{q} = 50\%$$

$$n = (0.5)(0.5) \left(\frac{1.96}{0.1} \right)^2 = 96.04 \text{ this is the minimum sample size}$$

So can take approximately 98 persons to have a full number on the survey questionnaire

This is the minimum recommended size of the survey. If create a sample of this many people and get responses from everyone, it will more likely to get a correct answer.

3.2.3 Data Classification

The data required for this research contains both qualitative and quantitative data on the data collection and analysis process.

- (i) Site investigation (visual observation)
 - Spot crossways within pedestrians flow
 - Pedestrians behavior
- (ii) Perception of pedestrians (questionnaires)
 - Number of travelers with capacity of the crossway
 - LRT effect on disabilities
 - Pedestrian walking habit
- (iii) Geometry (direct measurement survey and ERC document)
 - LRT Stations and Crosswalk facilities (crossway interval, length, width& height)
 - Ramp gradient
- (iv) Demographic and other pedestrian characteristics (questionnaires)
 - Type of crosswalk used
 - Mode of access
 - Reported additional walk times
- (v) Pedestrian trip (questionnaires and ERC AutoCAD road network)
 - O-D trip, return trip, round trip and total O-D trips/day
- (vi) Waiting time (video survey)
 - Pedestrians waiting time while crossing
 - Pedestrian movement and interaction with vehicles
- (vii) Pedestrian and Traffic data (count)
 - Pedestrians volume
 - Vehicles volume and existence of on-street parking

3.2.4 Collected data

Most data available for this thesis were collected from primary data through questionnaires, field survey and secondary sources through documents. Random sampling procedure was used to obtain the above mentioned data through questionnaires.

1. Questionnaires explanatory variables

To collect the data questionnaires are prepared for pedestrians and public transport users when they walk for different access at work places or business centers, schools and public transport stations (bus, taxi, midi bus (higer bus) and service stop stations). (Appendix A: Questionnaire)

Data from the questionnaire 98 sampled persons respond on their O-D, the estimation of walk distance and time from their origin (home) to destination, type of LRT crosswalk used and number of cross trips per day was collected. Walk trips, distances and times were gathered from the questionnaire.

A range of potential explanatory variables are collected as part of the questionnaire at public transport stop stations, schools, work or business places and church area. These were provided for each walking trip.

Through the questionnaire, the following data are gathered:

- General demographic characteristics- sex, age, labor force status, day and time of walk trip and purpose of the trip.
- Pedestrian trips characteristics: Origin Destination of the trip, location of the crosswalk used, number of crossing per day, mode of transport, stop station of public transport, distance and time taken from ones origin to the crosswalk before and after LRT introduction.
- Pedestrians' perception on capacity of crosswalk compared with number of pedestrians, difficulties of disabilities while crossing and walking habit after LRT introduction.

The dataset used is summarized in Table 3.3

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Table 3.3 Potential explanatory variables from E-W (Ayat – Megenagna), public transport stop stations travel survey and work/school or business centers travel survey use crossways

Type of variable	Variables and categories
Trip characteristics – walk trip from home	<ul style="list-style-type: none"> • Distance of walk trip (calculated from origin and destination using LRT plan and profile AutoCAD road network distance between O-D survey) • Destination of walk trip and walk time • Distance before and after LRT constructing: bus, taxi, midi (higer) bus or service or other places • Day of week of walk trip and number of crossing LRT cross facility: weekday, weekend • Time of day of walk trip by cross LRT: am peak, inter peak, pm peak, evening • Location of the crosswalk, location of bus, midi (higer) bus, taxi, service stop stations
Trip characteristics – public transport trip after walk trip	<ul style="list-style-type: none"> • Purpose of trip: work, education, social/recreational, shopping, personal business, church/mosque • Duration of trip (mins) • Type of public transport used: bus, midi (higer) bus, taxi, service
Demographic characteristics	<ul style="list-style-type: none"> • Age: under 19 years, 19-29 years, 30-49 years, 50-64 years, 65 years and over • Sex: male, female • Labor force status: full-time work, part-time work, economically inactive, student
Pedestrians' perception	<ul style="list-style-type: none"> • Social image of neighborhoods, walking habit after LRT constructed, travel demand and crossing facility, Physical disabilities restricting walking

map. Walk distance measured on the CAD using O-D data and bus stop location from LRT crosswalk estimated on the field.

4. Video survey

Sample pedestrians waiting time conducted on 7 groups of pedestrians who cross in groups through LRT crossway within 15 minutes. The survey was conducted for 1:30 hours cross trips from road to LRT North-South flow direction at EW7 station on Monday March 28, 2015. Because on Monday there is high traffic and pedestrian flows existed to work and education.

The video survey conducted and used to:-

- Estimate/determine the waiting time of pedestrians to cross the road and LRT
- Record pedestrian movements and their interaction with vehicles and LRT
- Documents flows/walking patterns and interaction, as a base for several kinds of analysis such as crossing difficulty
- Study delay and behavior patterns (e.g. reluctance of an elderly to cross a road and LRT)

The waiting time of pedestrians to cross the two roads and LRT line at crossing facilities was recorded through video surveys.

Table 3.5 Video survey waiting time data on 7 group cross trips

Time (am peak)	North to South total waiting time of pedestrians (sec)	
	Road sidewalk to LRT station	LRT station to road sidewalk
7:30-7:45	160	248
7:45-8:00	149	239
8:00-8:15	163	251
8:15-8:30	159	279
8:30-8:45	162	280
8:45-9:00	150	267

5. Pedestrian and Traffic volumes

Counting techniques of pedestrian and traffic conducted at LRT station of EW4 crosswalk around Mikael church during peak hours. Count survey was conducted on working days for 2 hours of am peak and pm peak.

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On Friday March 25, 2015:- Pedestrian and Vehicle volumes at the morning time am peak from 7:00 – 9:00am and at the evening time pm peak from 5:00 – 7:00pm

Time (am peak)	Pedestrians		Vehicles		Time pm peak	Pedestrians		Vehicles	
	South	North	East	West		South	North	East	West
7:00 – 7:15	247	362	158	405	5:00 – 5:15	219	208	308	247
7:15 – 7:30	374	430	216	650	5:15 – 5:30	298	258	341	235
7:30 – 7:45	483	550	302	647	5:30 – 5:45	339	309	338	223
7:45 – 8:00	515	549	280	423	5:45 – 6:00	290	355	381	236
8:00 – 8:15	429	525	240	650	6:00 – 6:15	362	398	431	224
8:15 – 8:30	300	331	215	526	6:15 – 6:30	242	227	393	246
8:30 – 8:45	261	345	190	485	6:30 – 6:45	201	243	376	257
8:45 – 9:00	229	276	189	427	6:45 – 7:00	223	283	401	245
Total	2838	3368	1790	4213	Total	2174	2281	2969	1913

Table 3.6 Pedestrian and Traffic volumes at am peak and pm peak (Friday March 25, 2015)

3.3 Data Analysis

i. Field observation analysis

The analysis method used for the site investigation was by comparison of flow rate of pedestrian crossing users with type of crossway by visual survey. This helps to know the spot crossways that had high flow of pedestrians. Also observed the pedestrian behavior while crossing LRT through crossing facilities and interpret the pedestrians' different characteristics (illegal activities) while crossing LRT. These illegal activities are jumping on fences, cross through at-grade crossings of vehicles, cross through restricted crossings and not respect of signals.

ii. Pedestrian perception analysis

The pedestrians' perception on the effect of LRT collected through questionnaire was analyzed by comparison of response of travelers. The comparison of perception was within sufficiency of width of the LRT crosswalk, LRT difficulty for disabilities, feeling toward added walking distance or walking habit after LRT constructed and LRT effect on social image of neighborhoods.

iii. Geometry analysis

Analyze the pedestrian LRT crossing facilities by considering the geometry effects of LRT. This consideration includes geometry of crossing facilities at LRT stations like intervals of the

crosswalk, ramp gradient, capacity of crosswalk area and no existence of refuge space between the road and LRT that serve as waiting place until vehicles and trains passed. The average pedestrian crossing interval by the performance of pedestrian crossing facilities along a route was evaluated based on the average distance a pedestrian travel to get a crossing.

iv. Questionnaire analysis

Number of pedestrians that use EW1 – EW8 stations, total crossing trips per day and access mode choice of pedestrians' frequency was analyzed. Also analyze pedestrians' different demographic characteristics, frequency perception of additional walking time and statistical mean test of perception of additional walk time trips to each crosswalk.

v. Pedestrian trip analysis

Walk trips, Walk distances and Walk times were analyzed by conducting (before - after) analysis on walking distances and times. Walking distance and time to each road crossway (before) and LRT crossway (after) was also analyzed by taking walk distance and time to access each LRT crosswalk. This helps to know which station posed the longest and shortest travel distance and time to users. Questionnaire perception Vs Pedestrian trip analysis of additional walk times to each crossway was analyzed using the CAD measurements. The walk distance to access different modes choices tested by statistical analysis of mean and standard deviation walk distance. Also analyze walking distance to transit bus stops from LRT crossways through estimating the distance of the bus transits from the LRT crossways.

Statistical test

The travel distance was tested by statistical analysis of mean and standard deviation; and a paired t-test and p-value was conducted to check the effect on walk distance before and after LRT construction. To illustrate the influence of Addis Ababa LRT on accessibility and mobility on pedestrians and public transport users by conducting travel distances to crossways. The larger the travel distance is the larger the influence of the crossway on accessibility and mobility. To enumerate this chose quantitative measurements as follows:-

1) Mean and Standard deviation test:

$$\bar{d} = \frac{1}{n} \sum_{i=1}^n d_i \dots\dots\dots (3.3)$$

$$\bar{d}_{..} = \frac{1}{k} \sum_{j=1}^k \bar{d}_j \dots\dots\dots (3.4)$$

$$SD = \sqrt{\frac{\sum_{i=1}^n (d_i - \bar{d})^2}{n - 1}} \dots\dots\dots (3.5)$$

Where d_i the distance from i 's origin (home) to crossway and destination to crossway by walk and \bar{d} is the mean distance for pedestrians; \bar{d}_j is the j 's crossways mean distance and $\bar{d}_{..}$ is the grand mean; n is the number of pedestrians that use the crossway and k is the number of the crossways; SD is standard deviation of the pedestrian distance. The median (MD) is the halfway point in a data set or the midpoint of the data array. All crossway of LRT line are oriented at long distance. The longest distance is between EW1 and EW2 at a value of 1,260 m and the shortest distance is between EW5 and EW6 with 725 m.

2) Paired t-test and P-value

$$t = \frac{\bar{d}_d}{\frac{s_d}{\sqrt{n}}} \dots\dots\dots (3.6)$$

Where t = test statistic, \bar{d}_d = mean of differences = after – before = $\bar{d}_1 - \bar{d}_2$, s_d = standard deviation of differences and n = sample size.

vi. Video Survey analysis

The waiting time of pedestrian on crossing facilities were analyzed by taking the pedestrian flow from North to South direction. Average waiting time was calculated from video survey data. The average waiting time was determined from pedestrians waiting time who cross from North to South direction for 1:30 hrs within 7 groups of pedestrians who crosses in 15 minutes. The video survey data was also used to know pedestrian characteristics and interaction with vehicles by observing difficulty and feel insecurity on pedestrian while cross through LRT and road crossway.

vii. Pedestrian and traffic analysis

Volume of pedestrians and vehicles were analyzed by ped/min and veh/hr/lane. This helps to know the flow number of pedestrians and vehicles, to compare pedestrians within capacity (coverage rate) of the LRT crosswalk and safety of pedestrians with number of vehicles. Also to analyze whether congestion and on-street parking observed or not and had impact on pedestrians free movement.

3.4 Summary of Research Design

The research design includes the flow chart that shows the process of the research.

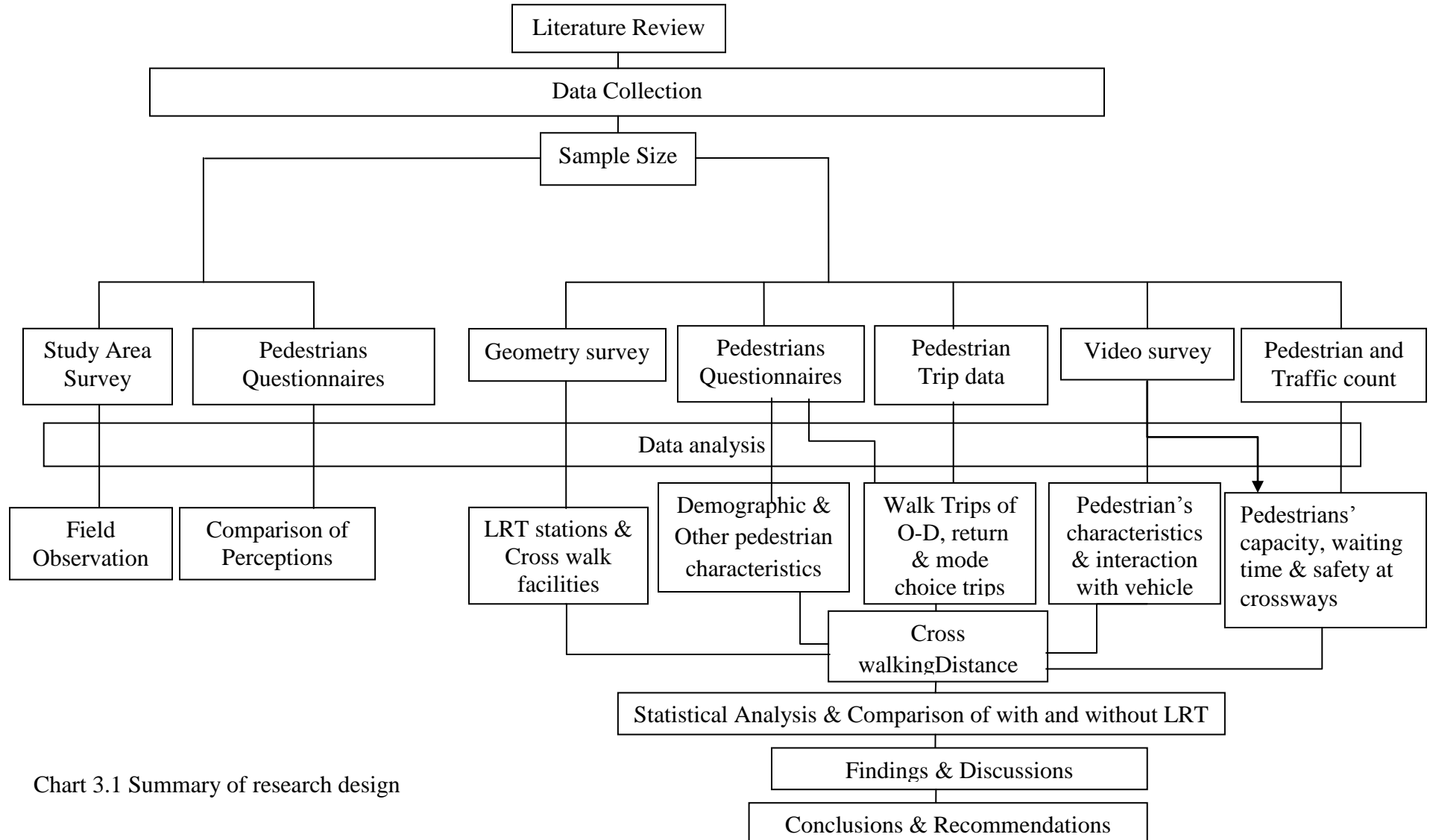


Chart 3.1 Summary of research design

4. Analysis and Results

4.1 Field observation

4.1.1 Spot crossways within pedestrians flow

The spot crossways that had been observed depend on number of pedestrians that used the LRT stations as crossing facilities. Stations crossways with the highest pedestrians flow observed on the visual survey are EW2, EW4 and EW7 compared with the other stations. On this 3 crossways observed that pedestrians push each other while crossing at peak hours than other 5 crossways. EW2 station is located around Meri and it is market and school area so high flows of pedestrians exist (especially on market day Wednesday and Saturday). EW4 station is located around Mikael church with many residential places so high flow of pedestrian from and to the church and home exist. EW7 station is located around Gurd Shola with many residential places so high flows of pedestrians exist from and to home.

4.1.2 Pedestrian behavior

Site survey also revealed different behavior of pedestrians while crossing the LRT line:

- Jumped on the fences to cross the LRT
- Some run to pass the vehicles on the road and reached to LRT crosswalk
- Some pedestrians cross through at-grade crossings of vehicles. It is designed for vehicles not for pedestrians.

Onsite visits the pedestrians' flows on the road and LRT crossings were in groups. But some users were run individually to cross the road with vehicles high speed so accidents may occur on the road environment pedestrians with vehicles.

4.2 Comparison of pedestrian perception

4.2.1 Number of travelers within the capacity of the crossway

On the questionnaire respondents answered that the capacity of the crosswalk; by comparing number of users within the width of the crosswalk during their trip.76%of respondents answered that the width of the cross walk is not enough for their free movement given high number of pedestrians while 24% responded that the width is enough.

4.2.2 LRT effect on disabilities

Most respondents answered that 80% of disabilities had faced difficulties while crossing through LRT crossways while only 13% responded that the LRT had no effect on disabilities while crossing through LRT crossways and 7% respond that they had not seen any disables when crossings LRT. These difficulties on disabilities are crossing through stairs and high gradients (on wheelchair users). Difficulties to cross LRT are due to crosswalks like ramps and stairs. The ramps used to access train but to cross the LRT crosswalk there exist stairs so wheelchair users couldn't cross LRT crosswalk. Also ramps have high gradient so it may accelerate or decelerate them and there is the height difference on the crosswalk and creates difficulties to cross by wheelchair as seen on the figure 4.1 below.



Figure 4.1 Wheelchair users difficulties to cross through the LRT line

4.2.3 Feeling toward LRT crosswalks

The pedestrians that used the LRT crossing facilities showed many different characteristics (illegal activities like jump on fences and cross through at-grade crossings of vehicles) and their walking habit changed because of the existence of long distance interval of the crosswalk from their origin and destination for different access. These observations collected from the questionnaire. Due to the construction of LRT system many pedestrians change their walking habit while walking to different destinations through crossways. On the questionnaire 40% pedestrians answered on the positive response cross by being of patience while 60% answered

with negative responses like anger, impatient and sadness. Pedestrians have no choice except to change their walking habit because the LRT is fully fenced and long distance crosswalks exist. The movement of people and goods into and out of the area is restricted due to the deteriorating traffic condition and increased walk distances so pedestrians change their walking habit; hence having a direct negative impact on the economic performance of the area.



Figure 4.2 Pedestrians illegal activities like jumped on fences

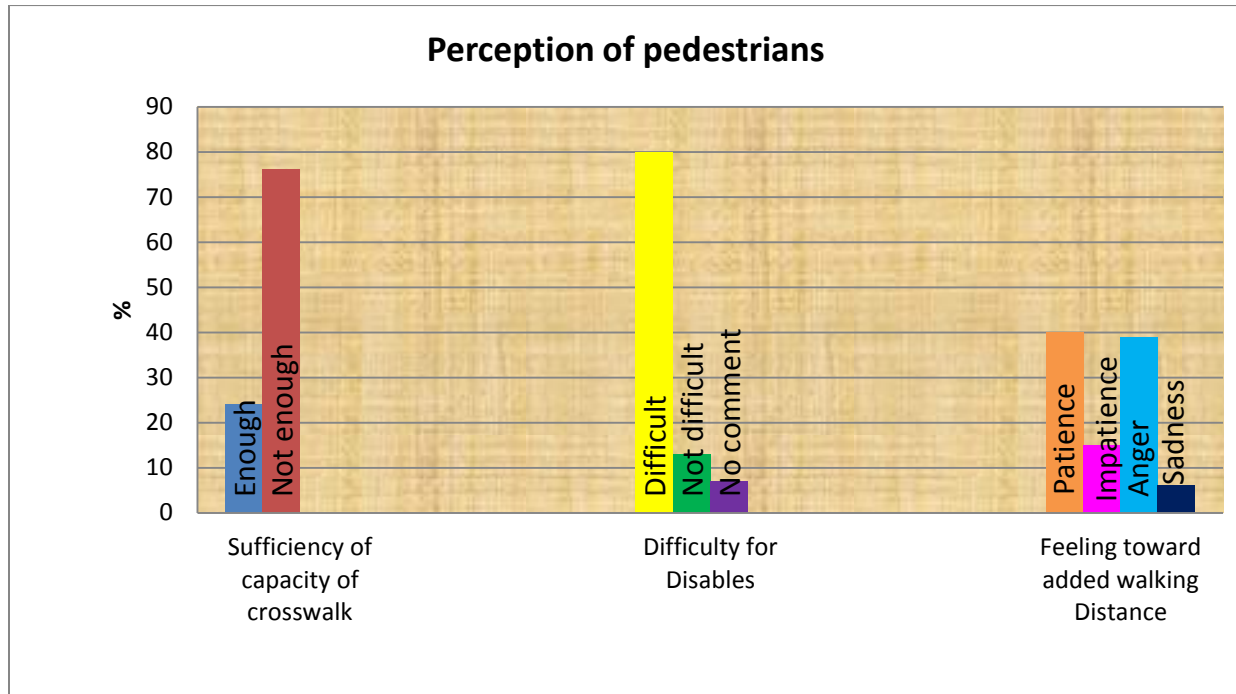


Chart 4.1 Summarize perceptions of pedestrians on LRT effect

4.3 LRT stations and crosswalk facilities

Analysis of pedestrian crossing locations by taking the geometry effects of LRT system. Analyzing crossing facilities of LRT crosswalks; intervals of the crosswalk, ramp gradient, crosswalk area with capacity of users and no existence of refuge area between the road and LRT that serve as waiting area.

According to the schematic design of the AALRT pedestrian crossing are provided at LRT station locations. Those stations had a long distance interval between them and fenced along the whole LRT alignment except at pedestrian crosswalks and at-grade vehicular crossings. Because the station left and right side will serve as pedestrian and passenger crossing facility and at-grade vehicular crossing serve for vehicles. So it made the pedestrians and public transport users to walk for long distance for access.

Table 4.1 Pedestrian crossing location facilities along the East-West route (Ayat- Megenagna)

Crossing stations	Location	Interval Distance (m)
EW1	22+300	
EW2	21+040	1260
EW3	19+948	1092
EW4	19+085	863
EW5	18+225	860
EW6	17+500	725
EW7	16+530	970
EW8	15+444	1056
EW9	14+615	829
Average distance between stations (m)		956.88
Maximum distance to crossing facility(m) $= \frac{\text{Average Distance}}{2}$		478.44

The above analysis shows that a maximum distance to be covered by a pedestrian to find a crossing is half of the average crossing interval. This is 478.44 m for East-West routes on Ayat-Megenagna stretch.

Pedestrians conflict at station while crossing the pathway where pathways are oriented in such a way that pedestrians tend to cross both tracks at the same time. As LRVs approach from both directions, there is an evident safety concern for crossing pedestrians. According to CREC stations preliminary design one-way and two-way walking stairs preferred minimum width is 1.8 m and 2.4 m respectively and length 2.8 m. Also the clear width of station platform is 2.5m and length is 60m. Ground stations are two-way walking stairs so preferred minimum width of 2.4 m and length of 2.8 m, this are the standards applied for evaluation. From the geometric condition survey, the geometry configurations of crosswalk areas to each station have different width and length. The direct measurement average width is 2.5 m and the average length is 2.8 m therefore giving the total area of 7 m². It is also observed that the width of the crosswalk were same as the width of the platform on the stairs and ramps. The pedestrian flow density on the crosswalk is 0.5 m²/ pedestrian (CREC, 2009). Therefore take 0.5 m²/ pedestrian as pedestrian buffer zone space and calculating the number of persons in each side gives 14 person capacities of the crosswalk that serve as waiting area until vehicles and/or trains pass. Therefore, there is lack of

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refuge space between the railway and roadway for pedestrian to wait. So there is a pedestrian's safety concern.

The gradient of ramps dedicated to the disabled is 1:12 on the ground stations (source: CREC, 2009). In percent gives LRT ramps for disabled persons have 8.33% of gradient for ground stations. On survey of ramps they had high slope on table 4.2 below so wheelchair users face difficulties to cross without any support of others. This may expose to crash on the disabled users by accelerate or decelerate them. But the ramps constructed used as to access trains, to cross the LRT it creates difficulties on wheelchair users' disabilities. This is because there is no crossing surface for wheelchair users on the crosswalk at most stations. The crossings are stairs after pass through ramps.

Table 4.2 Summary of site measured crosswalk geometries

Station	Crosswalk (m)					Ramp gradient (%)		
	Width (m)	Length (m)	Area (m ²)	Capacity (person)	Remark	Height & Length (m)	Slope (%)	Remark
EW1	2.30	1.90	4.37	9	Less than min. length & width	H=0.30, L=3.4	8.8	Greater than 8 %
EW2	2.50	2.60	6.5	13	Less than min. length	H=1.70, L=27	15.9	Greater than 8 %
EW3	2.80	3.00	8.4	17	Good	Normal (no ramp)		Safe
EW4	2.00	4.00	8.0	16	Less than min. width	H=1.05, L=8.20	12.8	Greater than 8 %
EW5	2.80	2.40	6.72	14	Less than min. length	H=0.35, L=2.30	15	Greater than 8 %
EW6	2.70	3.00	8.1	17	Good	H=0.35, L=2.35	15	Greater than 8 %
EW7	1.90	2.80	5.32	11	Less than min. width	H=1.20, L=8.50	14	Greater than 8 %
EW8	2.50	2.80	7.0	14	Good	H=0.80, L=6.50	12	Greater than 8 %
Avg.	2.5	2.81	6.8	13.9			13.4	

Note that:-

Crosswalk remarks: Indicates if the measured length and width less than the recommended standard minimum width (2.4m) and length (2.8m) on the CREC design, it should be reconstructed to have a good capacity of pedestrians.

Ramp remarks: Indicates if the measured ramp gradient greater than the design standard (8%) on CREC, the ramp should be reconstructed to lesser slopes.

This geometry survey result showed that crosswalk facilities are not enough for pedestrians as waiting place and to cross freely. It is also observed that pedestrians push each other while crossing on the crosswalks at peak hours.

4.4 Pedestrians questionnaire analysis

The origin-destination data of pedestrians and passengers are collected with respect to the station crossway. Questionnaire results: show that the total number of station crossway users and crossing trips per day for the 98 respondents.

Table 4.3 Number of pedestrians that uses EW1 - EW8 stations and total crossing trips/day

Stations	No. of crossway users at each crossways/day (pedestrians/day)	No. of trip crossing/person/day (cross trips/pedestrian//day)
EW1	12	18
EW2	32	88
EW3	5	7
EW4	12	19
EW5	4	4
EW6	8	18
EW7	27	40
EW8	17	32
Total	117	226

A total of 98 persons were sampled and got 117 LRT crosswalk users in a day trip from EW1-EW8 station crosswalks. One person may cross two crossways in a trip per day. 98 persons were the sampled respondents who used the LRT crossways and 117 were the total record number of pedestrians who used each 8 crossway in a day trip from 98 sampled pedestrians. A total of 226 cross walking trips per day were found from these 98 respondents from home to different access. These 226 trips per day use any of the 8 crossing facilities as shown in the table 4.3 above. On

the questionnaire walk trips to bus stops were responded by identifying the location of the bus stop in terms of streets or building names.

Access mode choice of pedestrians also recorded and determined by fraction of sample with mode available.

Table 4.4 Mode choice of pedestrians

Mode choice	Frequency	Percent (%)
Walking	21	22
Taxi	43	44
Midi bus (Higer bus)	10	10
Bus (Anbessa bus)	16	16
Service	8	8
Total	98	100

4.4.1 Perception of walking distance or time

On the questionnaire recorded that 94% pedestrians had faced additional distance or time due to LRT constructed while 6 % had no addition of distance or time on their trip.

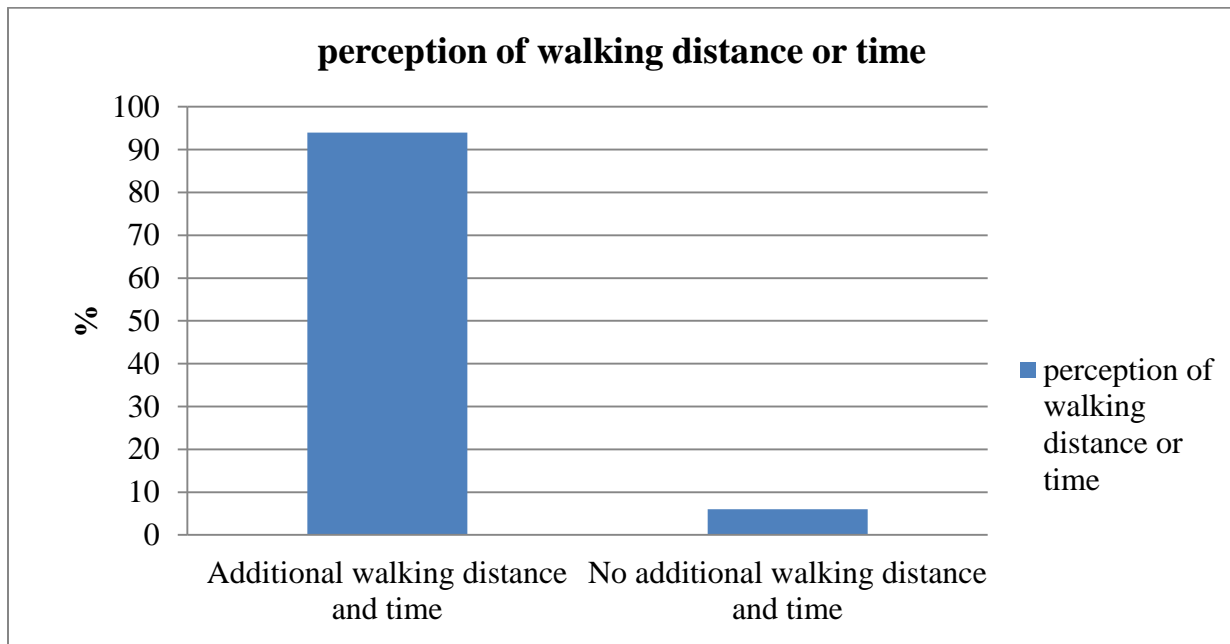


Chart 4.2 Pedestrians perception on effects of LRT of walking distance or time

All walk, taxi, bus, midi bus (higer) and service transport users were affected by LRT except 2 service transport users and 4 walk users. As seen on the result, taxi users take the highest modal

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share with walkers coming second. Therefore, these pedestrians were much more affected by LRT because they cross the LRT an average of two times per day.

Most of the travelers on the survey who walked were between the ages 19 and 65: the uppermost walkers were between 19-29 ages. At all stations home was the most frequent origin or destination. At the market area and other stations work was the primary origin or destination, whereas school was the second most frequent origin or destination. On the site visits males are often more in road environment compared to females. 58 percent of the pedestrians on the survey questionnaire were males and 42 percent were females and 57 percent were between 19-29 years old and 23 percent were 30-49 years old. 74 percent of the trips were home-to-work trips and 62 percent were made at least 6 times per week. Summarized demographic characteristics are shown in Table 4.5 below.

Table 4.5 Demographic characteristics of pedestrians

Demographic characteristics		Pedestrians Response		Demographic characteristics		Pedestrians Response	
		NO	%			NO	%
Sex	Male	57	58	Labor force status	Full time work	59	60
	Female	41	42		Half time work	23	24
	Total	98	100		Student	9	9
Age	<19	12	12		No work	5	5
	19-29	56	57		Pension	2	2
	30-49	22	23		Total	98	100
	50-65	4	4	Purpose of trip	Work	77	74
	>65	4	4		Education	9	8
	Total	98	100		Church/Mosque	7	7
Day of trip	Monday - Friday	34	35		Social	5	5
	Monday - Saturday	26	26		Recreation	3	3
	Monday - Sunday	38	39	Market	2	2	
	Total	98	100	Training	1	1	
				Total	104	100	

4.4.2 Pedestrian perception of additional walk time trips to access each crosswalk and O-D

The LRT may reduce the waiting time, travel cost and time on train users but on pedestrians and other public transport users (bus, midi bus (higer), taxi and service) it increase the walking distance and time due to long crosswalks interval. Analysis of the responses of 98 respondents on their 117 crosswalk users and 226 trips/day gives the perception on average additional walk times due to the construction of LRT. These are the additional walk time trip to each crossway as shown in the table below:

Table 4.6 Questionnaire pedestrian perception on average additional walk times to access each LRT crossway

Trip type	Mean time to access each station crosswalk (min)								
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8	Total mean
O-D	9.38	8.17	5.2	5.45	4.25	4.25	7.06	4.38	6.02
Return	9.38	8.17	5.2	5.45	4.25	4.25	7.06	4.38	6.02
Round	18.75	16.34	10.4	10.91	8.5	7.25	14.1	8.75	12.03
Total trips/day	26.5	40.56	15.4	13.86	11	9.75	19.7	20.94	19.71

The above table results showed that the additional walk times in mean and grand mean time to access each station crosswalk on the questionnaire analysis increased because of the introduction of LRT system. Every pedestrian who cross through LRT crossway must walk additional 6 min in O-D trip and/or in Return trip, 12 min in Round trip and 20 min/day in total O-D trips per day to reach to each crosswalk from ones origin. The additional walk times to each station crossway from EW1 to EW8 occurred because of LRT introduction and the maximum walking times exist on station EW2 and the minimum on EW6 according to the responses of mean walk time in total trips per day.

These are the additional walk times to different O-D trips as shown in the table below:

Table 4.7 Questionnaire pedestrian perceptions on average additional walk times on O-D trips

Trip type	Time (min)
O-D trip	7.87
Return trip	7.87
Round trip	15.74
Total O-D trips/day (m/day)	28.91

This table showed that the additional walk times of the 98 sampled pedestrians to different O-D trips. Depend on their response sum the total additional walk times and divide with 98

pedestrians. The result gives every pedestrian who cross through LRT crossway must walk additional 8 min in O-D trip and/or in Return trip, 16 min in Round trip and 29 min/day in total O-D trips per day to reach to destinations from ones origin. Therefore depending on the above table's questionnaire pedestrian perception results the average additional walking time tripson98 sampled pedestrians in total O-D trips per day. These were the average additional walking times need with29 min/day to destination trips and 20 min/day to access each crosswalk from ones origin in total O-D trips per day.

4.5 Walk trips, Walk distances and Walk times

Analysis of walking distance from home to destination, LRT crossways and to public transport is a significant issue for this research. The method of distance estimation in the questionnaire was based on each trip origin (home) and destination being coded with O-D coordinate and road network distance calculated using ERC road network plan and profile AutoCAD drawing. (Appendix D: ERC road network plan and profile AutoCAD drawing and road network distance).

4.5.1 Walking distance and time before and after LRT construction

- **Walk Distances**

Mean walking distances were determined by different variables along with number of crossing LRT cross facility trips per day and O-D trips distance (in O-D trip, Return trip, Round trip and total O-D trips per day).

The trip distance of pedestrians and public transport users before the introduction of LRT system is shown below: (Appendix B: Trip distance before and after LRT introduction of 98 sampled walkers).

Table 4.8 Trip distance before the introduction of LRT

Distance (m) before LRT introduction	Trip type			
	O-D	Return	Round	Total trips/day
Statistic value				
Mean	351.79	351.79	703.58	939.23
Standard deviation	228.16	228.16	456.33	909.64

The table above showed that the mean and standard deviation distance of pedestrians and public transport users' before the introduction of LRT system at A.A roads. The pedestrians were cross

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through crossings of the road at different locations. The results show that the walk distance before LRT constructed were 352 m in O-D trip and/or Return trip, 703.6 m in Round trip and 939.2 m/day in total O-D trips that performed in a day.

Trip distance of pedestrians and public transport users' after the introduction of LRT system is shown below:

Table 4.9 Trip distance after the introduction of LRT

Distance (m) after LRT introduction	Trip type			
	O-D	Return	Round	Total trips/day
Statistic value				
Mean	623.88	659.91	1283.79	1691.40
Standard deviation	423.41	438.67	807.73	1420.29

The table above showed that the mean and standard deviation distance of pedestrians and public transport users' after the introduction of LRT system at A.A roads. The results show that the walking distance after LRT construction were 624 m in O-D trip, 660 m in Return trip, 1283.8 m in Round trip and 1691.4 m/day in total O-D trips that performed in a day or total trips per day per person.

The additional walk distance of pedestrians and public transport users' is the difference before and after the introduction of LRT system at A.A existing roads from Ayat to Megenagna section. The table below shows the difference in walking distance that was incurred due to the construction of LRT.

Table 4.10 Trip distance difference of after-before the introduction of LRT

Trip type	Mean (m)				Standard deviation (m)		
	Before	After	Difference	% increase	Before	After	Difference
O-D trip	351.79	623.88	272.09	77	228.16	423.41	294.35
Return	351.79	659.91	308.12	88	228.16	438.67	287.48
Round	703.58	1283.8	580.21	82	456.33	807.73	501.88
Total trip/day	939.23	1691.4	752.16	80	909.64	1420.3	763.03

The results show that there is additional walk distance because of LRT construction. An average of 272.1 m in O-D trip, 308.12 m in Return trip, 580.2 m in Round trip and 752.2 m/day was added to the walking distance of pedestrians because of the LRT construction. This almost increased by an average of 82%.

The chart below shows the increase in walking distance as a further illustration.

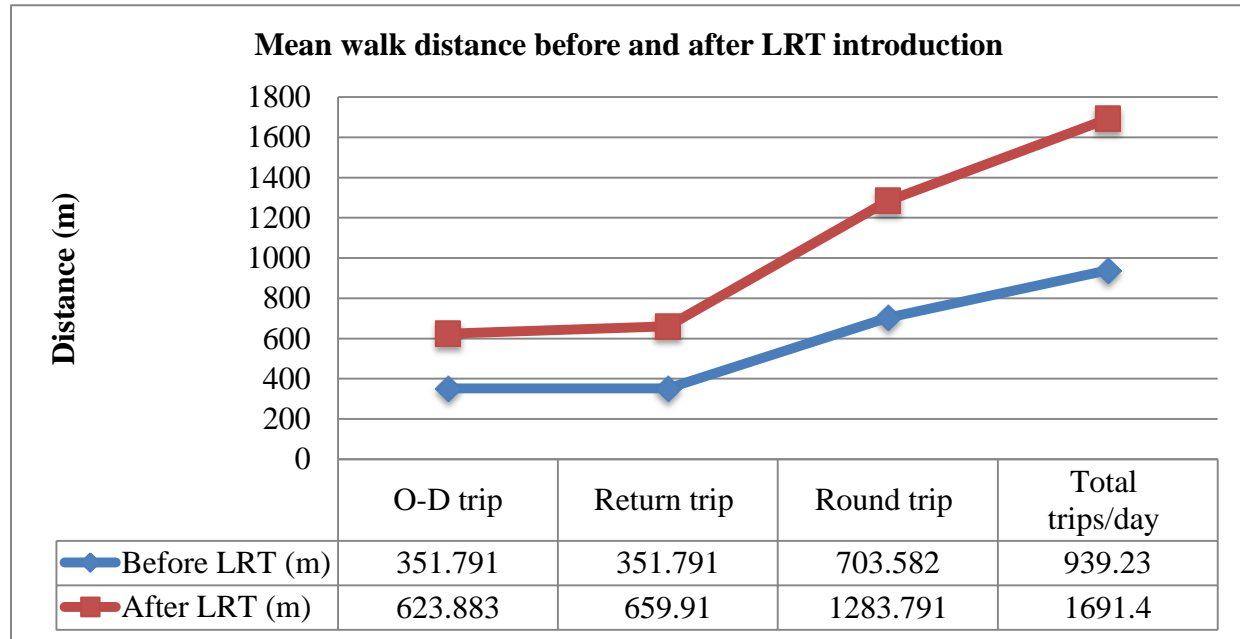


Chart 4.3 Mean walk distance before and after LRT introduction

This chart elaborates the difference before and after LRT construction. Walking distance after LRT construction approximately doubled. Therefore the introduction of LRT would increase walking distance to sampled pedestrians in total O-D trips per day by an average of 752.2 m/day. The additional median walking distance is 568.5 m, with 25% of trips less than 321.5 m and 75% of walking trips less than 919.5 m.

- **Walking time**

By using design walk speed of pedestrians, an estimate walking time of 98 sampled persons was calculated. Walking speed varies between 0.9 to 2.4 m/sec, the design value being~ 1.2 m/sec. However, it can be as low as 0.5 m/sec for disabled and 1.0 m/sec for elderly people. In this analysis, the walking speeds used were 1.2m/sec for age <65, 1.0 m/sec for age > 65 years and 0.5 m/sec for disabled people.

The walking trip time of pedestrians and public transport users before the introduction of LRT system is shown in table 4.11 below;

Table 4.11 Mean trip time before the introduction of LRT

Trip type	Time (min)
O-D trip	5
Return trip	5
Round trip	10
Total O-D trips/day (m/day)	12.8

The table above showed that the mean time of pedestrians and public transport users' before the introduction of LRT system at A.A roads. The results show that the walk time before LRT constructed were 5 min in O-D trip and/or Return trip, 10 min in Round trip and 13 min/day in total O-D trips that performed in a day or total trips per day per person.

The walking trip time after the construction of LRT is shown below:

Table 4.12 Walking time after the introduction of LRT

Trip type	Time (min)
O-D trip	9
Return trip	9.5
Round trip	18.5
Total O-D trips/day (m/day)	23.6

This showed that the mean walk time of pedestrians and public transport users after the introduction of LRT system at A.A roads. The results show that the walking time after LRT construction were 9 min in O-D trip, 9.5 min in Return trip, 18.5 min in Round trip and 23.6 min/day in total O-D trips that performed in a day or total trips per day per person.

The additional walk time of pedestrians and public transport users' is the difference before and after the introduction of LRT system. The table below shows the difference in walking time that was incurred due to the construction of LRT.

Table 4.13 Trip time difference before and after the introduction of LRT

Trip type	Mean walk time (min)			
	Before LRT	After LRT	Difference	% difference
O-D	5	9	4	80
Return	5	9.5	4.5	90
Round	10	18.5	8.5	85
Total trips/day	12.8	23.6	10.8	84

The results show that the additional walk time because of LRT construction is 4 min in OD trip, 4.5 min in Return trip, 8.5 min in Round trip and 10.8 min/day in total trips that are performed in a day per person.

The chart below shows the increase in walking time as a further illustration.

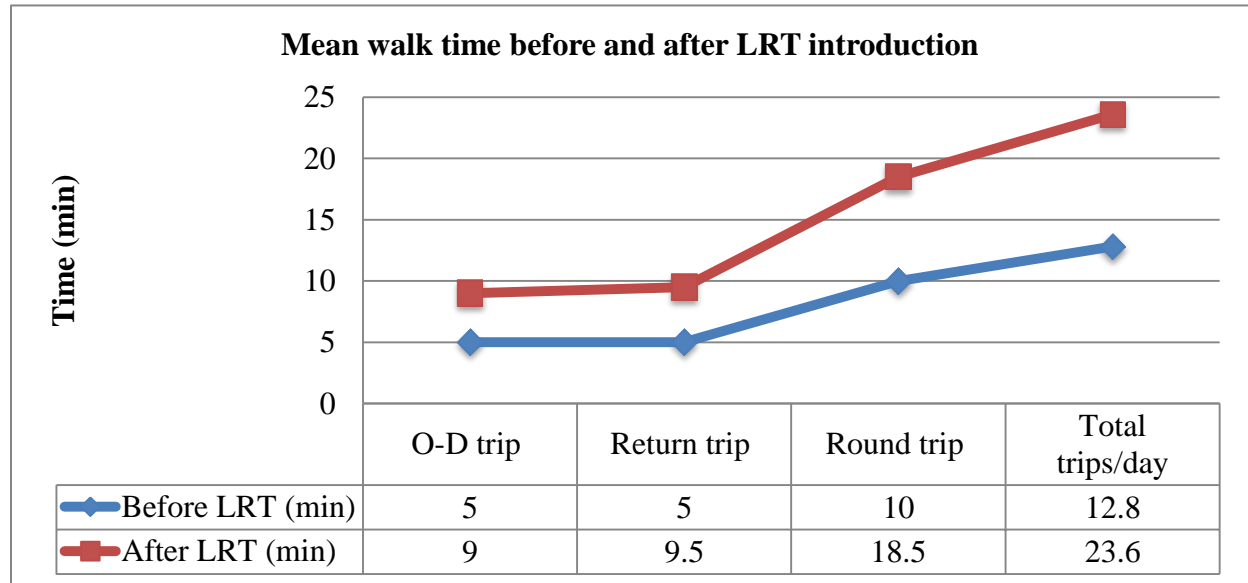


Chart 4.4 Mean walk time before and after LRT introduction

The above distances and times are the increased mean distances and times after the construction of LRT. Pedestrians and passengers travel long distances and times as a result of introducing LRT system at A.A existing roads on EW line (Ayat-Megenagna). Table below provides a summary of the results of the walking distance and time analysis.

Table 4.14 Summarized walking distances and times in total O-D trips per day

Walking distance in total O-D trips/day (meter/day)			
Characteristic	Before	After	Difference
Mean distance	939.2	1691.4	752.2
Female mean	852.2	1513.2	660.9
Male mean	1001.7	1819.6	817.9
Median	732.5	1323.5	568.5
Mean time	13 min/day	24 min/day	11 min/day

This needs statistical test to interpret if the distance is significant or non-significant. A paired t-test and p-value test are performed to demonstrate the significance of the distance.

• **Paired t-test**

Paired t-test is used to analyzing the differences between groups. If there is no difference between groups, the mean of the differences should be zero. Paired t-test is used in this research to test whether LRT has effect or not on pedestrians and public transport users' mobility. (Appendix B: Distance trip before and after LRT introduction of 98 sampled walkers)

Table 4.15 Hypothesis testing two sample groups: paired t-test

Distance sample of 98 pedestrians (m)			
No.	Before	After	Differences
1	1202	1426	224
2	733	1563	830.5
3	2404	2852	448
.
.
98	273	535	262
Mean (\bar{d})	939.23	1691.4	$\bar{d}_d = 752.16$
SD (s)	909.64	1420.29	$s_d = 763$

The null hypothesis is that there is no difference in walk distance between the two groups (before LRT and after LRT). i.e. $H_0: \bar{d}_d \leq 0$

Group 1- mean after = \bar{d}_1

Group 2- mean before = \bar{d}_2

\bar{d}_d = mean of differences = after – before = $\bar{d}_1 - \bar{d}_2$

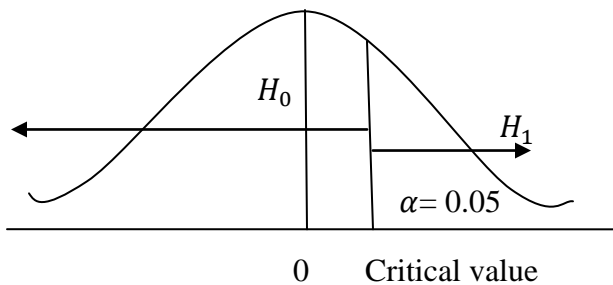
s_d = standard deviation of differences

H_0 = null hypothesis, H_1 = alternative hypothesis, n = sample size, CI = confidence interval,

α = significance level, d_f = degrees of freedom

n = 98, $\bar{d}_d = 752.16$, $s_d = 763$, wish to be 95% confident, CI = 95% or $\alpha = 0.05$

The distance is increased therefore it is a one tailed t-test, to the right side of the curve.



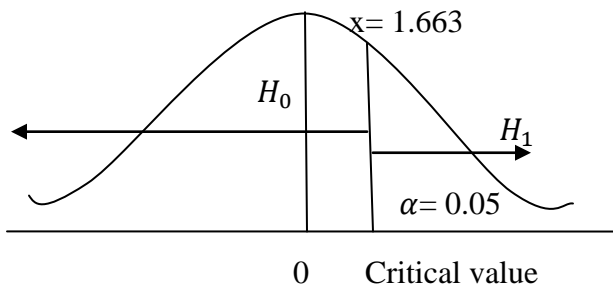
$$H_0: \bar{d}_d \leq 0$$

$$H_1: \bar{d}_d > 0$$

$$d_f = n-1 = 98-1 = 97$$

The percentage points $t_{\alpha,v}$ of the t-distribution table as shown in appendix C can be interpolated to give the critical value:

d_f	$t_{0.05}$	
60 -----	1.671	}
97 -----	x	
120 -----	1.658	
		the critical value is positive
		$x = 1.663$

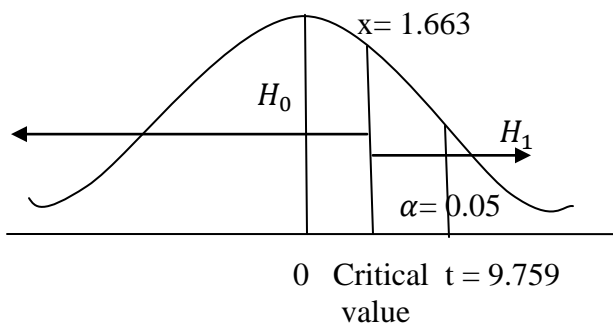


The t-test statistics can then be calculated by:

$$t = \frac{\bar{d}_d}{\frac{S_d}{\sqrt{n}}}$$

The result of the t-test then gives:

$$t = \frac{752.16}{\frac{763}{\sqrt{98}}} = 9.759 \text{ test statistic}$$



The larger the t value than the critical value; the more confident the real difference between the two mean values. Since the test statistic is greater than the critical value, ($9.759 > 1.663$) the null hypothesis H_0 can be resoundingly rejected at 95% level of confidence and accept the alternative hypothesis H_1 . It can be concluded that there has been significant increase in distance due to LRT construction.

- **P-value test**

Also by finding the p-value can justify the difference by using Microsoft Excel;

Select more function (Σ) and t-test on the excel window. Put the values of first dataset as before and second dataset as after LRT construction distances. It is increasing distance therefore specifies the number of distribution tails to return as a one-tailed distribution (1) and kind of t-test as paired (1) on excel. Then the p-value gives $2.78309E-16$.

$P\text{-value} = 2.78309 \times 10^{-16} < 0.05$. The p-value is low ($0.00 < 0.05$) therefore rejecting the null hypothesis (H_0) and accepting the alternative hypothesis (H_1). There is a significant difference between the distances of trips in before Vs after walk distance of LRT introduction at the 5% (0.05) significant level. The overall average walking distance after LRT is almost 1.7 km/day, which is approximately twice the walking distance traveled before LRT. It is 752.2 m longer than the average walking distance per day before LRT.

4.5.2 Walking distance and time to access each crosswalk before and after LRT introduction

- **Walking distance to access each crosswalk**

The trip distance of pedestrians and public transport users to access each crosswalk before the introduction of LRT system is shown below. These specific crossing points were the collector roads used to access the main asphalt road.

Table 4.16 Mean walk distance to crosswalk before LRT construction

Trip type	Mean distance at each road crosswalk (m)								
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8	Total mean
O-D	340.9	351.1	247.4	328.7	232	152.1	260.4	281.97	274.31
Return	340.9	351.1	247.4	328.7	232	152.1	260.4	281.97	274.31
Round	681.8	702.2	494.8	657.3	464	304.1	520.8	563.9	548.62
Total trip/day	844.9	995.8	601.4	942.6	464	304.1	596	887.2	587.44

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Table 4.17 Standard deviation distance to crosswalk before LRT construction

Trip type	Standard deviation at each road crosswalk (m)							
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8
O-D	134.2	160	45.5	436.9	54.9	195.4	112.4	183.9
Return	134.2	160	45.5	436.9	54.9	195.4	112.4	183.9
Round	268.5	320	91.04	873.8	109.8	390.8	224.7	367.7
Total trip/day	465.7	560.8	274.4	1794.6	109.8	390.8	285.6	1145.3

The tables above showed that the mean and standard deviation distance of pedestrians and public transport users' to access each crosswalk before the introduction of LRT system at A.A roads. The pedestrians were cross through crossings of the road at different locations. The results show that the walk distance to each crosswalk before LRT constructed were 274.3 m in O-D trip and/or Return trip, 548.6 m in Round trip and 587.4 m/day in total O-D trips that performed in a day.

The walking distance to each road crossway determined before LRT introduction and the maximum walking distance exist around EW2 crossway with distance of 995.8 m/day and the minimum exist around EW6 with 304.1 m/day in total O-D trips per day per person who was cross through road crossings before LRT depending on collector roads to access main road crossings.

The chart below shows the walking distance to access each crosswalk before LRT construction as a further illustration.

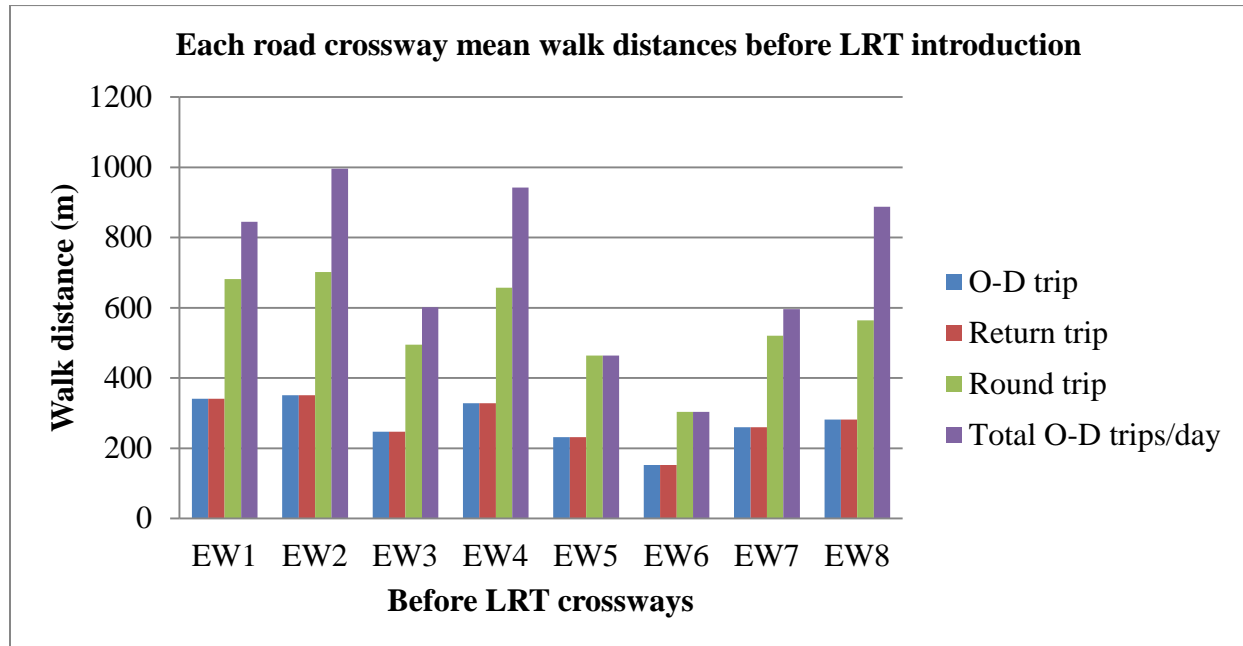


Chart 4.5 Mean walk distance before LRT introduction cross through road crossings

The chart illustrates that around EW2 road crosswalks the walk distance was the maximum traveled distance by pedestrians compared with other road crosswalks before LRT introduction. Follow with around EW4 and EW8 road crosswalks walk distance trips per day. The shortest travel distance was around EW6 crosswalk.

Trip distance of pedestrians and public transport users to access each LRT station crosswalks after the introduction of LRT system is shown below:

Table 4.18 Mean distance taken to station crosswalk after LRT construction

Trip type	Mean distance at each station (m)								
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8	Total mean
O-D	634.7	744	398.9	494.7	323	152.1	465.2	412.1	486.32
Return	607.9	767.9	452	518.4	382.5	260.7	525.7	417.5	491.55
Round	1242.6	1511.9	850.9	1013.1	705.5	412.7	990.7	829.6	944.63
Total trip/day	1565.8	2123.5	1008.5	1327.2	705.5	412.7	1123.5	1260.5	1190.9

Table 4.19 Standard deviation distance taken to station crosswalk after LRT construction

Trip type	Standard deviation at each station (m)								
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8	Total mean
O-D	276.3	431.9	169.6	512.8	155.3	195.4	283.3	254.6	
Return	297.7	420.6	184.2	478.8	133.5	352.7	316.9	261.1	
Round	532.6	835.5	106.6	958.5	40.8	567.9	510.1	411.4	
Total trip/day	984.6	1370.4	332.8	1869.2	40.8	567.9	641.7	1318.3	

This showed that the mean and standard deviation distance of pedestrians and public transport users' to each LRT crosswalk after the introduction of LRT system at A.A roads. The results show that the walking distance to each crosswalk after LRT construction were 486.3 m in O-D trip, 491.6 m in Return trip, 944.6 m in Round trip and 1191 m/day in total O-D trips that performed in a day or total trips per day per person.

The walking distance to access each LRT crossway determined after LRT introduction and gives walk distances from origin to LRT crossway trips. The longest traveled distance exist at LRT crossway of EW2 with mean distance of 744 m in O-D trip and 768 m in Return trip, 1512 m in Round trip and 2123.5 m/day in total O-D trips per day per person.

The chart shows the walking distance to each crosswalk after LRT construction as a further illustration.

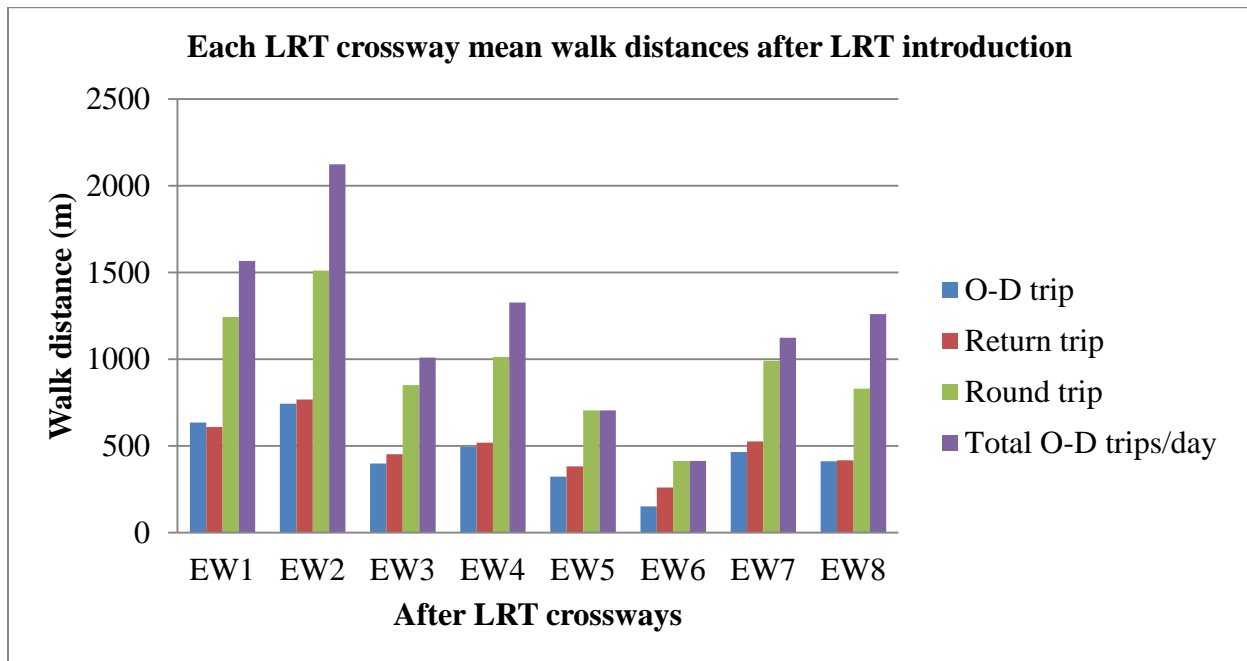


Chart 4.6 Mean walk distance after LRT introduction to each LRT crossways

Observed from the chart EW2 is the longest traveled distance than other LRT station crossways after LRT introduction. Follow with at EW1 and EW4 LRT crossways walk distances trips per day. The shortest travel distance is at EW6.

The additional walk distance of pedestrians and public transport users' is the difference distance before and after the introduction of LRT system to each crosswalk from ones origin.

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The table 4.20 below shows the difference or increase in walking distance to each crosswalk that was incurred due to the construction of LRT.

Table 4.20 Difference mean trip distance to access each station crosswalk

Station	Trip type	Mean crossing distance (m)			
		Before	After	Difference	% difference
EW1	O-D	340.9	634.7	293.8	86
	Return	340.9	607.9	267.04	78
	Round	681.8	1242.6	560.88	82
	Total trip/day	844.9	1565.8	720.92	85
EW2	O-D	351.1	744	392.9	113
	Return	351.1	767.9	416.8	119
	Round	702.2	1511.9	809.7	115
	Total trip/day	995.8	2123.5	1127.6	113
EW3	O-D	247.4	398.9	151.5	61
	Return	247.4	452	204.6	83
	Round	494.8	850.9	356.1	72
	Total trip/day	601.4	1008.5	407.1	68
EW4	O-D	328.7	494.7	166	51
	Return	328.7	518.4	189.75	58
	Round	657.3	1013.1	355.75	54
	Total trip/day	942.6	1327.2	384.58	41
EW5	O-D	232	323	91	39
	Return	232	382.5	150.5	65
	Round	464	705.5	241.5	52
	Total trip/day	464	705.5	241.5	52
EW6	O-D	152.1	152.1	0	0
	Return	152.1	260.7	108.6	71
	Round	304.1	412.7	108.6	36
	Total trip/day	304.1	412.7	108.6	36
EW7	O-D	260.4	465.2	194.1	75
	Return	260.4	525.5	262.3	102
	Round	520.8	990.7	456.4	88
	Total trip/day	596	1123.5	528.7	89
EW8	O-D	281.97	412.1	130.1	46
	Return	281.97	417.5	135.5	48
	Round	563.9	829.6	265.7	47
	Total trip/day	887.2	1260.5	365.7	41
Total crosswalk mean differences	O-D	177.43			
	Return	216.88			
	Round	394.32			
	Total trip/day	485.59			

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Table 4.21 Difference standard deviation trip distance to each station crosswalk

Station	Trip type	Standard deviation crossing distance (m)		
		Before	After	Difference
EW1	O-D	134.2	276.3	175.2
	Return	134.2	297.7	194.14
	Round	268.5	532.6	300.95
	Total trip/day	465.7	984.6	539.43
EW2	O-D	160	431.9	326.6
	Return	160	420.6	314
	Round	320	835.5	617.8
	Total trip/day	560.8	1370.4	939.4
EW3	O-D	45.5	169.6	138.33
	Return	45.5	184.2	219.08
	Round	91.04	106.6	142.37
	Total trip/day	274.4	332.8	142.8
EW4	O-D	436.9	512.8	212.09
	Return	436.9	478.8	177.96
	Round	873.8	958.5	295.67
	Total trip/day	1794.6	1869.2	290.76
EW5	O-D	54.9	155.3	11.02
	Return	54.9	133.5	14.17
	Round	109.8	40.8	95.74
	Total trip/day	109.8	40.8	95.74
EW6	O-D	195.4	195.4	0
	Return	195.4	352.7	184.97
	Round	390.8	567.9	184.97
	Total trip/day	390.8	567.9	184.97
EW7	O-D	112.4	283.3	222.9
	Return	112.4	316.9	218.1
	Round	224.7	510.1	337.2
	Total trip/day	285.6	641.7	360.2
EW8	O-D	183.9	254.6	181.9
	Return	183.9	261.1	180.2
	Round	367.7	411.4	185.4
	Total trip/day	1145.3	1318.3	303.7

The results show that there is additional walk distance to access each crosswalk because of LRT construction. An average of 177.43 min O-D trip, 216.88 m in Return trip, 394.32 m in Round trip and 485.59 m/day was added to the walking distance of pedestrians to access each LRT crosswalk because of the LRT construction. Access to each crosswalks increased by an average of 68%.

The result with the difference between before and after LRT to each crosswalk gives different mean walk distances. The longest additional traveled distance exist at LRT crossway to access each crosswalk is at EW2 with mean distance of 393 m in O-D trip, 416.8 m in Return trip, 809.7 m in Round trip and 1127.6 m/day in total O-D trips per day per person. The overall additional grand mean walking distance to each crosswalk is 485.6 m/day in total O-D trips per day to reach on LRT crossway stations per day. The additional median walking distance is 395.84 m, with 25% of trips less than 262 m and 75% of walking trips less than 785 m to arrive at LRT crossway stations. The shorter acceptable limit distances for elderly or disabled people without a rest are 50-150 m. But the result shows that all stations mean distance of O-D trips are greater than 150. The chart below shows the increase in walking distance to each crosswalk as a further illustration.

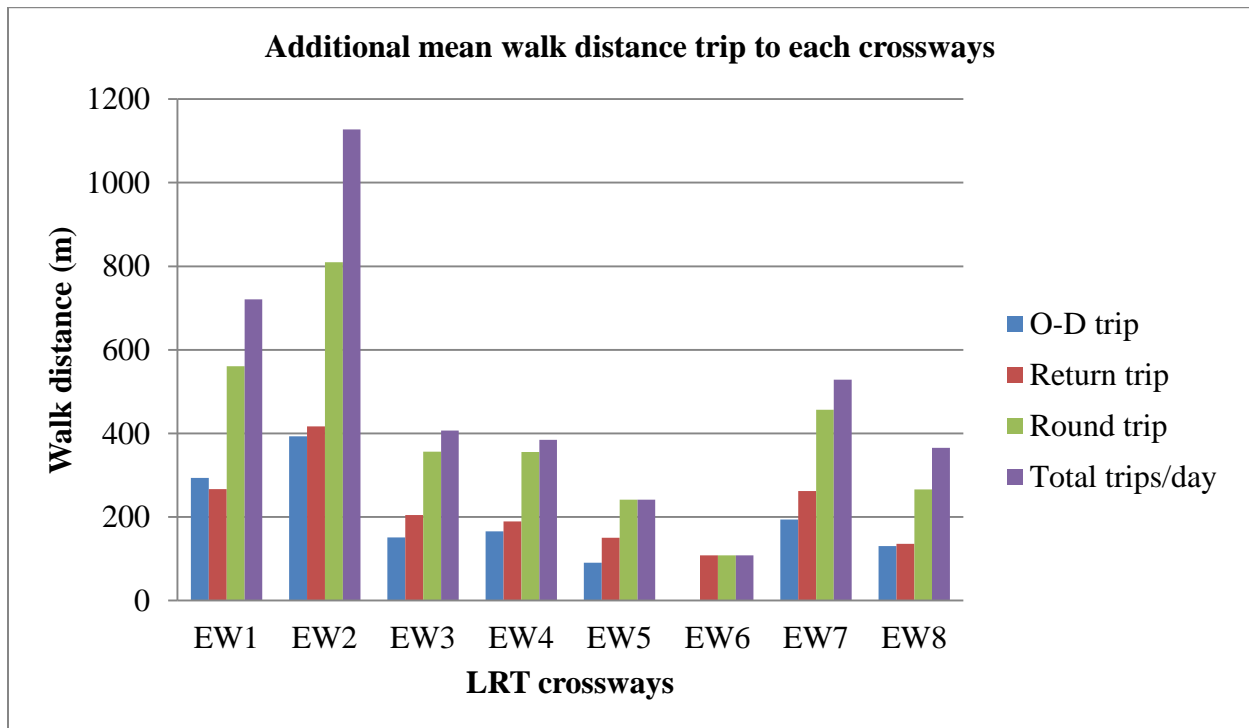


Chart 4.7 Additional mean walk distance to each LRT crossway

Observed from the above chart comparing to all 8 stations along EW LRT line walk to access EW2 crossway is the longest additional traveled distance. Also all crossways add walk distance on all pedestrians and public transport users. So the larger additional mean exist on EW2. It indicates a large influence on mobility follow with EW1 and EW7 crossways in walk distance trips per day. The shortest additional traveled distance is at EW6.

• **Walking time to access each crosswalk**

On the questionnaire analysis found that all pedestrians had faced addition of 12min in Round trip and addition of ~20min in total O-D trips per day because of introducing LRT line. But calculation need by engineering way so by using previous design walk speed of pedestrians according to their age, an estimate walking time of 98 sampled persons was calculated.

The walking trip time of pedestrians and public transport users before the introduction of LRT system to access each crosswalk is shown in table below;

Table 4.22 Mean trip time to each crosswalk before the introduction of LRT

Trip type	Mean time at each road crosswalk (min)								
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8	Total mean
O-D	5.14	4.92	3.44	4.8	3.22	2.11	3.7	3.92	3.91
Return	5.14	4.92	3.44	4.8	3.22	2.11	3.7	3.92	3.91
Round	10.28	9.84	6.88	9.6	6.44	4.23	7.32	7.84	7.8
Total trip/day	12.55	13.92	8.35	13.5	6.44	4.23	8.4	12.3	10

The table above showed that the mean walk time of pedestrians and public transport users' to access each road crosswalk before the introduction of LRT system at A.A roads. The results show that the walk time to access each crosswalk before LRT constructed were 4 min in O-D trip and/or Return trip, 8 min in Round trip and 10 min/day in total O-D trips that performed in a day or total trips per day per person to crosswalk.

The longest travel time need to access crosswalk before introducing LRT in total O-D trips per day was existed at road crosswalk of around EW2 with mean time of 14 min in total O-D trips per day per person. The chart below shows the walking time to each crosswalk before LRT construction as a further illustration.

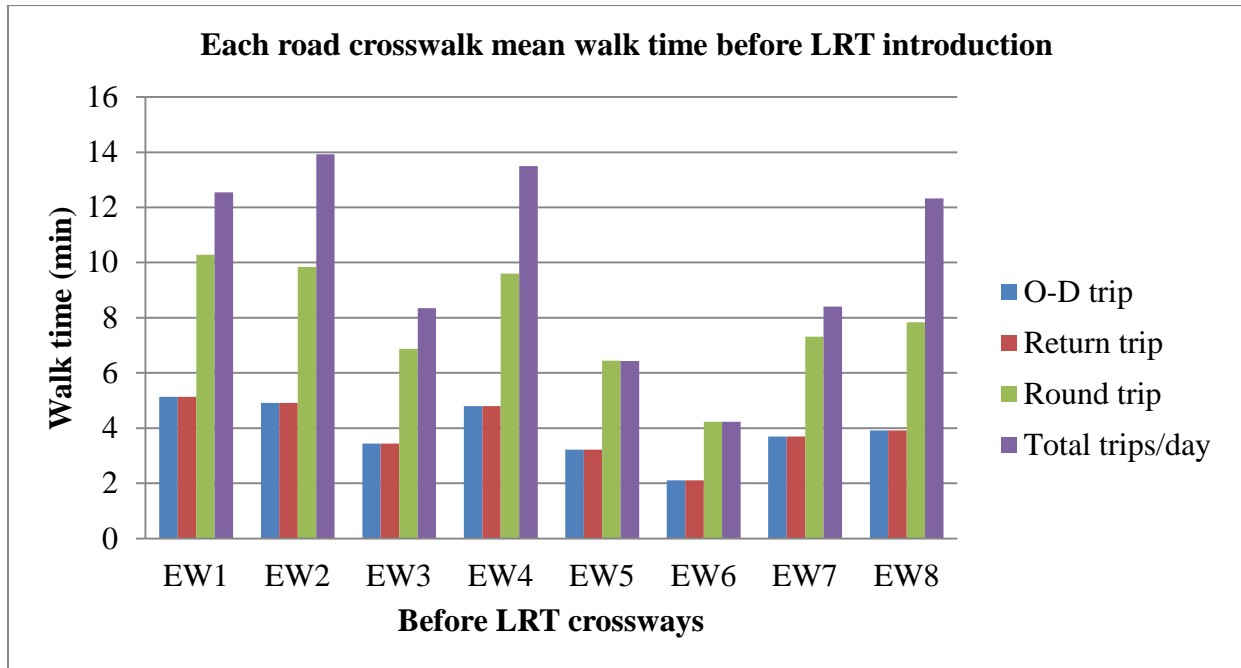


Chart 4.8 Mean walk time before LRT introduction to each road crossways

Observed from the above chart around EW2 road crossways was the longest time need to access the crosswalk compared with other road crossways before LRT introduction. Follow with around EW4 and EW1 road crossways walk time. The shortest travel time was at EW6.

The walking trip time to access each crosswalk after the construction of LRT is shown below:

Table 4.23 Time taken to access crosswalk after the introduction of LRT

Trip type	Mean time at each LRT station (min)								
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8	Total mean
O-D	9.22	10.41	5.54	7.3	4.49	2.11	6.6	5.72	6.42
Return	9.37	10.74	6.28	7.6	5.31	3.62	7.4	5.8	7.02
Round	18.59	21.15	11.82	14.9	9.8	5.73	14.03	11.52	13.44
Total trip/day	23.08	29.64	14.01	19.3	9.8	5.73	15.64	17.51	16.84

This showed that the mean walk time of pedestrians and public transport users after the introduction of LRT system at A.A roads. The results show that the walking time after LRT construction were 6.42 min in O-D trip, 7.02 min in Return trip, 13.44 min in Round trip and 16.84 min/day in total O-D trips that performed in a day or total trips per day per person.

This indicates that the mean time of pedestrians and public transport users' after the introduction of LRT system of each station crossway users from their origin to the LRT cross location. This

gives different mean walk times from different origins to LRT crossway trips. The longest travel time existed at LRT crossway of EW2 with mean time of 10.41 min in O-D trip, 10.74 min in Return trip, 21.2 min in Round trip and 29.64 min in total O-D trips per day per person. The above table would summarize by after mean walk time chart to understand the difference between crossways time.

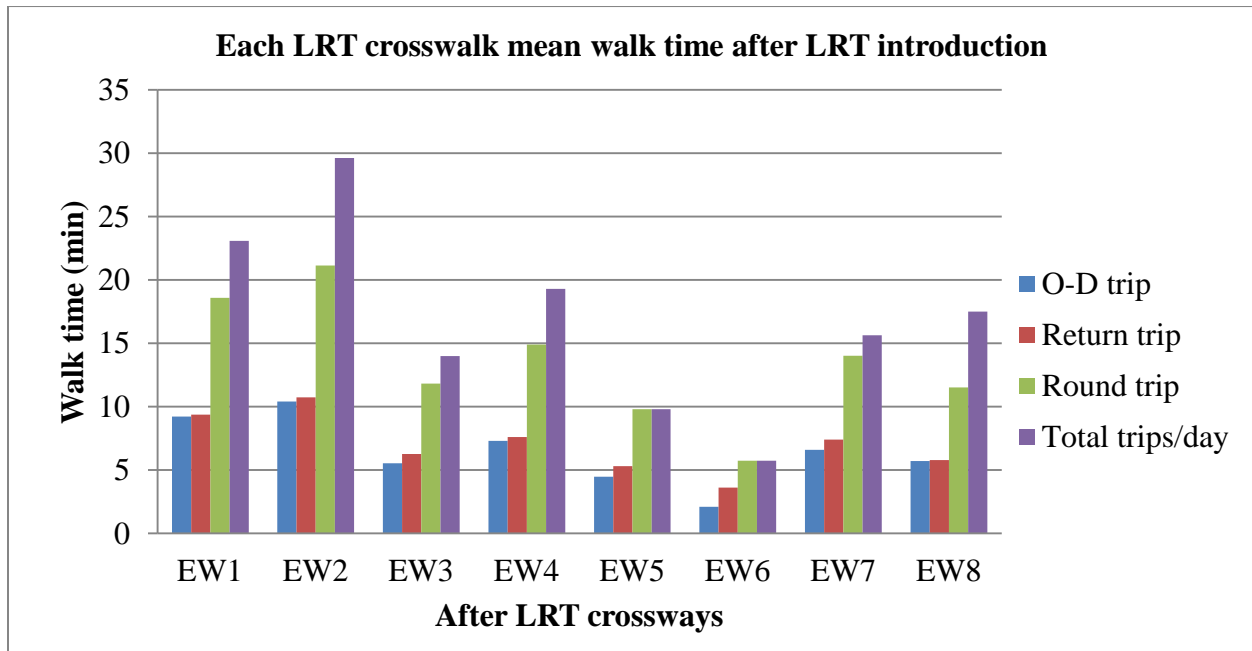


Chart 4.9 Mean walk time after LRT introduction to each LRT crossways

As seen on the chart EW2 crossway had the longest travel time compared with other station crossways after LRT introduction. Follow second with at EW1 and third at EW4 crossways walk time. The shortest travel time is at EW6.

The additional walk time of pedestrians and public transport users' to access each crosswalk is the difference before and after the introduction of LRT system to crosswalk shown below:

Table 4.24 Time trip difference to each crosswalk before and after the introduction of LRT

Trip type	Mean time at each LRT station (min)								
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8	Total mean
O-D	4.08	5.5	2.1	2.5	1.26	0	2.8	1.81	2.51
Return	4.23	5.82	2.84	2.83	2.1	1.51	3.73	1.77	3.1
Round	8.31	11.31	4.95	5.34	3.35	1.51	6.52	3.69	5.62
Total trip/day	10.53	15.5	5.65	5.74	3.35	1.51	7.52	5.08	7

The results show that the additional walk time to each crosswalk because of LRT construction is 2.51 min in O-D trip, 3.1 min in Return trip, 5.62 min in Round trip and 7 min/day in total trips that are performed in a day per person.

The longest additional travel time also existed at LRT crossway of EW2 with mean time of 5.5 min in O-D trip and 5.82 min in Return trip, 11.31 min in Round trip and 15.5 min in total O-D trips per day per person.

The chart below shows the increase in walking time to access each crosswalk as a further illustration.

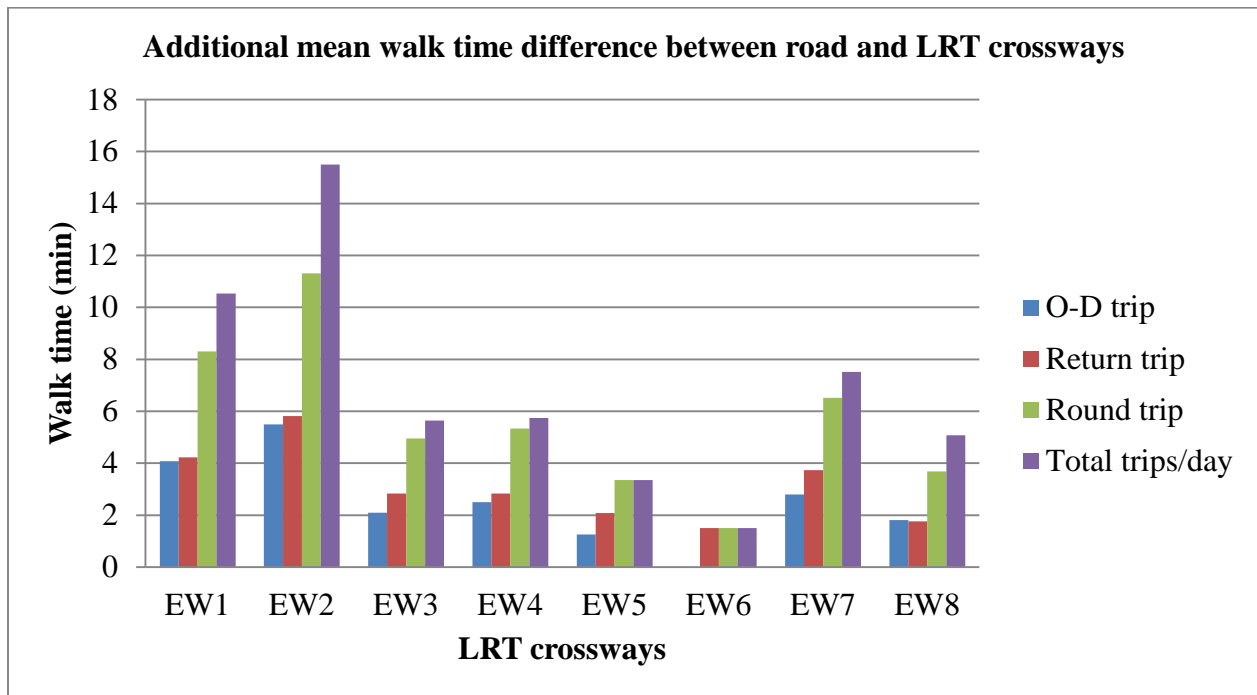


Chart 4.10 Additional mean walk time before and after LRT introduction to each LRT crossway

Also observed from the chart walk to access EW2 LRT crossway is the longest travel time. All crossways add additional trip time from previous trip times without LRT line introduction. Therefore additional time at EW2 indicates that had large influence on mobility and accessibility follow EW1 and EW7 crossways. The shortest additional travel time to access crosswalk exist at EW6.

The LRT line is limited until Ayat therefore other public transport users who went to after end of LRT line there mode choice is dependent on other public transport rather than train. For example a person went to Tafo, Summit, 49 mazorria, Arabsa, 6kilo and 4kilo etc may not use train

because the LRT line is limited to Menilik II square to Ayat. On these areas there is no LRT constructed. If LRT line extended on other areas the mode split may change to train.

4.5.3 Comparison between pedestrian perception Vs pedestrian trip

Pedestrian perception towards walk distance and time has been captured by questionnaire analysis while the objective distances was measured using engineering road network through AutoCAD analysis and calculate the walking time using design walk speeds. The difference between the subjective and objective response on additional walk times are compared in the section below.

On section 4.4.2 the questionnaire analysis result showed that pedestrians faced an average addition of 12 min in round trips to each crosswalk and 20min in total O-D trips per day to each crosswalk because of the LRT line. Whereas the CAD analysis using design walk speeds resulted in additional average walk time of 5.6 min in round trip and 7 min in total O-D trips per day to each crosswalk because of the LRT line.

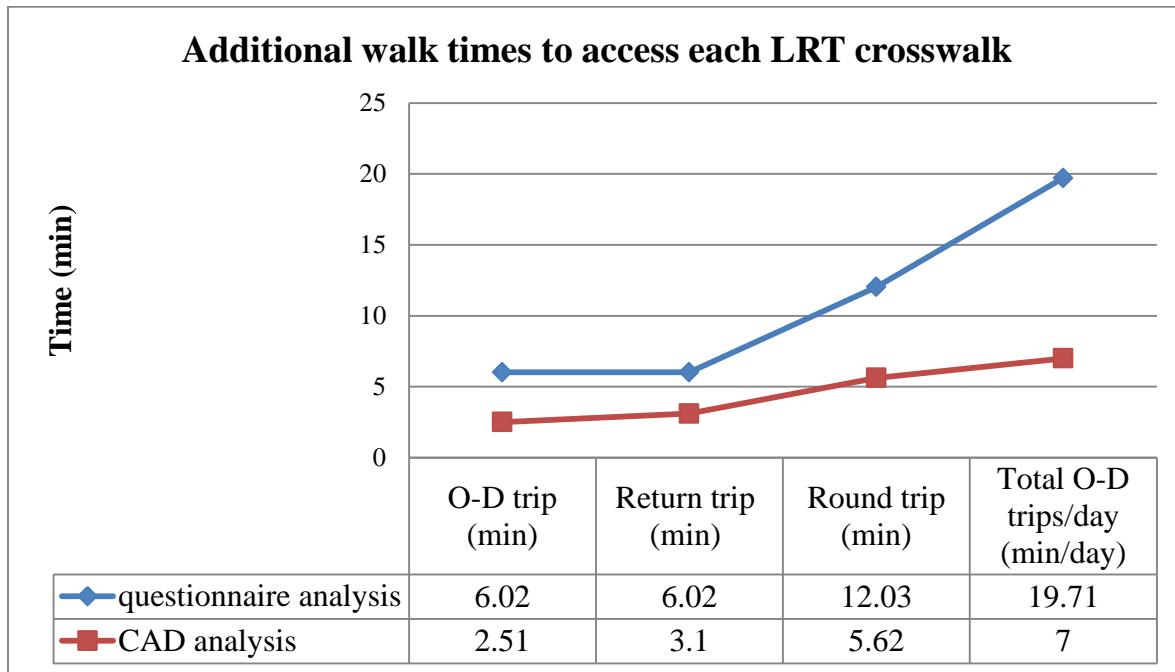


Chart 4.11 Additional total mean walk times to access each LRT crosswalk

The questionnaire analysis result from ones origin to destination shows that pedestrians faced an average addition of 16 min in round trips and 29 min in total O-D trips per day because of the LRT line. Whereas CAD analysis from ones origin to destination using design walk speeds

resulted in additional average walk time of 8.5 min in round trips and 11 min in total O-D trips per day because of the LRT line.

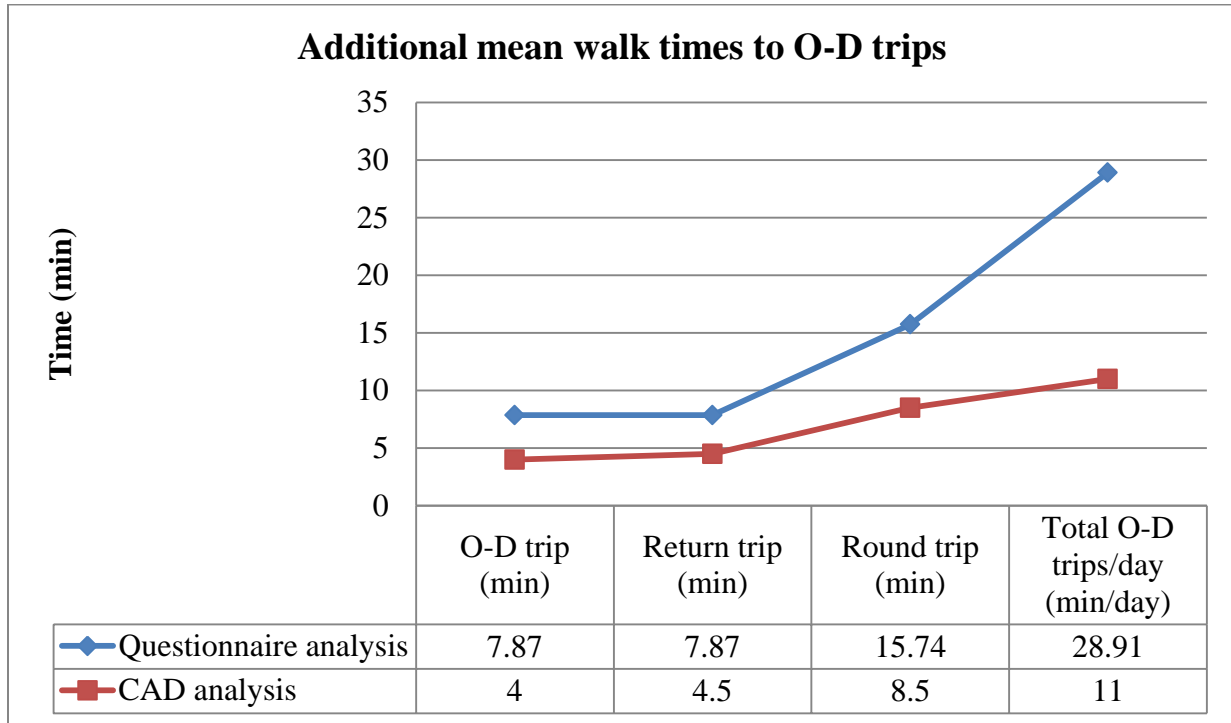


Chart 4.12 Additional mean walk times of pedestrians O-D trips

4.5.4 Additional walk distance to different mode choices

Distribution of number of users:

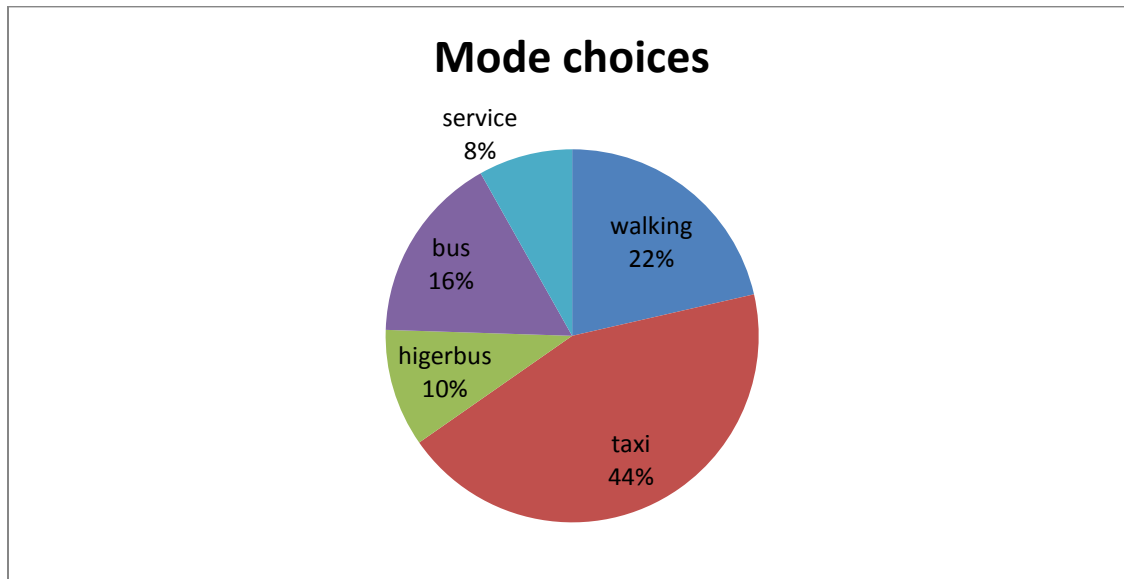


Chart 4.13 Mode choices of the sampled travelers

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Distribution of mobility distance to LRT crossways to different mode choice:

The additional walk distances due to LRT line to different mode choices are calculated using mean and SD.

Table 4.25 Additional Mean and SD walk distance to different modes in one O-D trip

Modes	Mean Distance(m)	SD (m)
Walk	335.2	394.8
Taxi	411.2	192.0
Bus	372.1	191.6
Midi bus (Higer)	311.3	262.5
Service	195.5	180.2

Table 4.26 Additional Mean and SD walk distance to different modes in total O-D trips/day

Modes	Mean Distance (m/day)	SD (m/day)
Walk	931.2	996.4
Taxi	746.0	532.1
Bus	558.8	373.7
Midi bus (Higer)	589.95	633.2
Service	233.8	232.2

All mode choices are affected by LRT system by addition of walking distance. The above mean distance indicates that walkers had more additional distance than other modes in total O-D trips per day. Walkers are more affected by LRT system because they travel long distances to crossways and their destination and high cross trips record per day by walk. On the contrary, service users are less affected by LRT than other modes.

Bus users travel additional distances after they cross through the LRT crossways on some stations. This is because the bus stop locations are far from the LRT crossways in some stations. One's a pedestrian travels from origin (home) with an additional distance to LRT crossways and to access bus should walk another additional distance to bus stops. The reason is at some stations LRT crosswalks are not integrated with bus stop locations. Bus stop locations from LRT

crossways were direct estimated from field survey in each station. The estimated bus stop distance from LRT crossway is shown table below.

Table 4.27 Bus stop location distances from LRT crosswalks

Flow direction	Bus stop location distance from LRT crosswalks (m)							
	EW1	EW2	EW3	EW4	EW5	EW6	EW7	EW8
East	200	0	0	200	0	0	0	0
West	300	0	150	200	100	70	60	0

At EW2 and EW8 stations both bus flow directions are integrated with LRT crossways but at EW1 and EW4 both directions are not integrated with LRT crossways.

4.6 Pedestrians waiting time

The average waiting time at the road sidewalk and LRT crosswalk until the vehicles flow to East and West are considered for the analysis.

The waiting time of pedestrians on crossing facilities:-

Table 4.28 North to South direction waiting time of pedestrians

Time (am)	North to South total waiting time of pedestrians (sec)			
	Road sidewalk to LRT station	Average	LRT station to road sidewalk	Average
7:30-7:45	160	22.86	248	35.43
7:45-8:00	149	21.29	239	34.14
8:00-8:15	163	23.29	251	35.86
8:15-8:30	159	22.71	279	39.86
8:30-8:45	162	23.14	280	40
8:45-9:00	150	21.43	267	38.14
Average		22.45		37.24
Sum	59.69			

Pedestrians waiting time to cross the entire road including LRT approaches to 1 min in N-S flow directions. It can also be on S-N flow directions because pedestrians can cross when the cars are stopped. This is due to high number of vehicles flow to East and West, on-street parking around crossways and form congestion, high number of pedestrian flow rate and less coverage rate at LRT crossings. Cross flow from North to South should wait on the LRT crossway until the South to North pedestrian cross the LRT crosswalk at peak hours. Currently the major waiting time is due to vehicles because the train is not in operation during the survey. The waiting time of pedestrians and passengers to cross both LRT and road may increase during operation of trains with passengers flow and pedestrians flow. Pedestrian movement, interaction with vehicles and

LRT crosswalks record on the video survey. The survey shows crossing difficulty on disabilities, elder persons, objects and delay.

4.7 Pedestrian and Traffic analysis

There may introduce delay of trains, congestion on at-grade crossings of vehicles and collision train with vehicles or pedestrians may occurred during operation of trains at AALRT because of high numbers of travelers and vehicles exist at peak hours. The pedestrians and vehicles at am and pm peak analyzed below.

1. Pedestrians and Vehicles at am peak from 7:00 – 9:00am

The flow of pedestrians at the morning time crosses in groups but sometimes cross individually. Some pedestrians cross by running because the vehicles have high speed and number. Pedestrians crossing to the North direction were high in number than who cross to the South. The flow of vehicles at the morning time was slow motion or congested at West side flow. On the opposite, the East side, traffic flow was free and no congestion observed. The West side had high traffic flow than the East.

2. Pedestrians and Vehicles at pm peak from 5:00 – 7:00pm

The flow of pedestrians at the evening time crosses in groups but sometimes cross individually. The flow of pedestrians was almost the same at both sides. The flow of vehicles at the evening time was slow motion at the east flow. On the opposite, the west side flow, traffic flow was free and no congestion observed. The East side had high traffic flow than the West side.

At am peak pedestrians to North and South flow direction were 3368ped/2hrs and 2838ped/2hrs respectively. Therefore to North flow direction there exist 29ped/min and to South 24ped/min on the crossway at am peak. The total pedestrian flow at am peak gives 53 ped/min on the crossway while cross to both directions. At pm peak pedestrians to North and South flow direction were 2281ped/2hrs and 2174ped/2hrs respectively. So to North flow 19ped/min and to South flow 18ped/min exist at the crossway. The total pedestrian flow at pm peak gives 37 ped/min on the crossway while cross to both directions. Compare with the previous geometry analysis gives 14 persons capacity of the crosswalk in one cross flow of each direction. On the video analysis waiting time was one minute to both directions. Therefore it is 14 ped/min means not enough for pedestrians' flows and as waiting places compared with the pedestrian count analysis result.



Figure 4.3 Less refuge space between the roadway and railway as waiting place

Vehicles at am peak to West and East direction were 4213veh/2hrs and 1790veh/2hrs respectively. At pm peak vehicle flow to West and East were 1913veh/2hrs and 2969veh/2hrs respectively. Ayat to Megenagna had 3 lane configurations but the side lane is not effectively used for traffic flow around the station areas because most drivers used the side lane for parking purpose. Therefore by using the 2 active lanes calculate vehicles at am peak to West and East flow gives 1054 veh/hr/lane and 448 veh/hr/lane respectively. Also vehicles at pm peak to West and East flow gives 479 veh/hr/lane and 743 veh/hr/lane respectively.

Table 4.29 Summarize pedestrian and traffic count analysis result

Time (am peak)	Pedestrians (ped/min)		Vehicles (veh/hr/lane)		Time (pm peak)	Pedestrians (ped/min)		Vehicles (veh/hr/lane)	
	South	North	East	West		South	North	East	West
7:00 – 9:00	24	29	448	1054	5:00 – 7:00	18	19	743	479
Total	53				Total	37			

On pedestrians and traffic count analysis path walkability variables were analyzed with respect to pedestrian volume, pedestrian crossing coverage rate, high number of vehicle flow and existence of on-street parking. As expected, pedestrian crossing coverage rate and more pedestrian crossings enhanced the sense of safety. The existence of on-street parking on both sides was associated with a greater sense of safety. Perhaps parking vehicles slow down traffic and thus increase the sense of safety but congestion occurs and delay with pedestrians and public

transport users will increase. So pedestrian crossing coverage rate are not enough at crossways of LRT EW line (Ayat-Megenagna) and parking around crossway area create a major safety issue.



Figure 4.4 Congestion around the LRT crosswalk due to high pedestrian and traffic flows

5. Findings and Discussions

5.1 Geometric analysis

The average crossing interval between stations is 956.875m, so a maximum distance to be covered by a pedestrian to find a crossing is half of the average crossing interval. This is 478.44m for East-West routes of Ayat to Megenagna section. Most ramps have high gradient compared to a standard (1:12; 8%). The average crossing and waiting area is 7 m² in each side and coverage rate of 14 ped/min to each flow direction.

5.2 Pedestrian trip analysis

i. The walking distance and time on O-D trips:-

The walking distance and time before the introduction of LRT to sampled pedestrians were 351.8 m and 5.3 min in O-D and/or return trips, 703.6 m and 10.6 min in a round trip and 939.2 m/day and 14 min/day in total O-D trips per day.

The walking distance and time after the introduction of LRT to sampled pedestrians would be 624 m and 9.5 min in O-D trip, 660 m and 10.1 min in return trips, 1283.8 m and 19.6 min in round trip and 1691.4 m/day and 25.2 min/day.

Therefore, the increase in distance and time due to LRT construction would be 272.1 m and 4.2 min in O-D trips, 308.1 m and 4.8 min in return trips, 502 m and 9 min in round trips and 752.2 m/day and 11.4 min/day in total O-D trips per day.

The Paired t-test statistic result ($9.759 > 1.663$) rejects the null hypothesis H_0 . Also the P-value result is $2.78 \times 10^{-16} < 0.05$ significant levels so reject H_0 and accept H_1 . Thus, there has been a significant increase in distance due to LRT construction. H_0 is resoundingly rejected at significant level 0.05.

The result illustrates that the difference in path walk distance creates a significant increase in travelers' walking distances. Therefore, it can be concluded that LRT affects both travel distance and time of pedestrians and public transport users'.

Overall additional average walking distance to total O-D trips per day is 752.16 m/day: the additional median walking distance is 568.5 m, with 25% of trips less than 321.5 m and 75% of walking trips less than 919.5 m.

ii. The walking distance and time need to access each crossway:-

The walking distance and time before the introduction of LRT to access each road crossway for the sampled pedestrians were 274.3 m and 4.1 min in O-D and/or return trip, 548.6 m and 8.2 min in a round trips and 587.4 m/day and 10.4 m/day in total O-D trips per day.

The walking distance and time after the introduction of LRT to access each LRT crossway to sampled pedestrians would be 486.3 m and 7 min in O-D trip to LRT crossways, 491.6 m and 7.5 min in return trip to LRT crossways, 944.6 m and 14.4 min in a round trip to LRT crossway and 1191 m/day and 17.8 min/day in total O-D trips per day to LRT crossways.

The difference walking distance and time to access each crossway is the increase distance and time to sampled pedestrians because of the introduction of LRT system. The increase distance and time to access LRT crossways would be 177.4 m and 2.8 min in O-D trip to LRT crossways, 217 m and 3.4 min in return trip to LRT crossways, 394.3 m and 6.1 min in round trip to LRT crossways and 485.6 m/day and 7.3 min/day in total O-D trips per day to LRT crossways.

The longest travel distance to access LRT crossway was observed at station EW2 with a mean distance of 809.7m in a round trip and 1127.6m/day in total trips per day while the shortest travel distance was at station EW6 with a mean distance of 108.6m in round trip and/or total trips per day.

Overall additional mean walking distance to reach/access each LRT crossway stations of EW1-EW8 in total O-D trips per day is 485.6 m/day: the additional median walking distance is 395.84 m, with 25% of trips less than 262 m and 75% of walking trips less than 785 m to access each LRT crossway stations per day.

5.3 Pedestrian perception on additional walk times analysis

As per pedestrian questionnaire response, the increased walking time on the walkers in O-D trips because of LRT introduction was 8 min in O-D and/or return trips, 15.7 min in round trips and 29 min/day in total O-D trips per day.

Likewise, the additional travel time perceived by users to access each LRT crossway was 6 min in O-D trips, 6 min in return trips, 12 min in round trip and 20 min/day in total O-D trips per day.

5.4 LRT effect on different mode choices analysis

LRT effect on different mode choices: all mode choices increased journey and walking distance and time because of the introduction of LRT system. Walkers had more additional distance than other modes. A walker in total O-D trips per day is additional mean of 931.2 m/day. On the contrary, service users are less affected by LRT than other modes with additional mean distance of 233.8 m/day.

Some persons went to 6 kilo or other place that had no LRT line uses bus transport for their trip. So it creates additional distance and time on pedestrians and public transport users' mobility. At EW2 and EW8 stations both bus flow directions are integrated with LRT crossways but at EW1 and EW4 both East West directions are not integrated with LRT crossways.

5.5 Waiting time analysis

Pedestrians waiting time to cross the road and LRT was approximately 1 min in North-South flow direction. This is due to high number of vehicles flow to east and west, on-street parking around crossways and congested, high number of pedestrian flow rate and less coverage rate at LRT crossings.

5.6 Pedestrian and Traffic analysis

Pedestrians flow across LRT crossing at EW4 station to North and South direction was 29 ped/min and 24 ped/min at am peak and 19 ped/min and 18 ped/min at pm peak respectively. Vehicles flow to West and East direction was 1054 veh/hr/lane and 448 veh/hr/lane at am peak and 479 veh/hr/lane and 743 veh/hr/lane at pm peak respectively.

As expected, pedestrian crossing coverage rate and more pedestrian crossings enhanced the sense of safety. The pedestrians flow was high compared to crossing coverage rate on the geometry analysis. On the geometry crossway area analysis, the capacity was only 14 ped/min but the above result shows that high numbers of pedestrian flow exists. So pedestrian crossing coverage rate are not enough at crossways of LRT EW line (Ayat-Megenagna) and parking around crossway area create a major safety issue.

So safety concern might be a major issue to pedestrians and waiting time may increase due to the crossing coverage rate is not enough for travelers and parking around crossway area. Perhaps

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(Addis Ababa E-W (Ayat-Megenagna) LRT line)

parking vehicles slow down traffic and thus increase the sense of safety but congestion occurs and delay with pedestrians and public transport users will increase.

6. Conclusions and Recommendations

6.1 Conclusions

Analysis results show that the factors affecting mobility of pedestrians and public transport users' due to LRT system in Addis Ababa are:-

- ✓ Geometry of crossways including location intervals, crosswalk capacity and ramp gradient
- ✓ Number and flow rate of pedestrians and vehicles
- ✓ Waiting time
- ✓ Mode choice and public transport transit locations

Depending on the findings and discussions, it is concluded that:-

- ✓ Geometry of LRT crossing facility:-
 - All LRT crossways are located at a long distance from pedestrians' origin destination.
 - Ramps have high gradients.
 - Crossway width and area not enough for pedestrians and passengers flow.
 - Lack of refuge space between the railway and roadway has safety concerns for pedestrians.
- ✓ Walking distance and time:-
 - Most pedestrians faced distance increment and time delay as much as 752.2 m and 11.4 min in total O-D trips per day on their trip when walking is used as a primary mode and/or an access mode to public transport.
 - The pedestrians waiting time to cross the road and LRT increased because of high numbers of pedestrians flow rate and less coverage rate at LRT crossings.
 - During operation time it may be able to increase the waiting time and pedestrians flow who are walk and other public transport users on crosswalk because of passengers and trains flow on both tracks but not on train users.
- ✓ Mode choice delay:-
 - Users of different modes including walk and public transport increased journey and walk distance and time because of the introduction of LRT system at Addis Ababa city transportation.
 - Walk mode users are the most affected among the different modes. On the contrary, service users are less affected by LRT than other modes.

6.2 Recommendations

Depending on the concluding remarks and concept designs, the following recommendations are proposed for the Addis Ababa Light Rail Transit pedestrian and public transport users crossing facilities.

- Geometric improvements:-
 - Crossways of ramps should be reconstruct:- pathway users with disabilities can safely traverse the crossing if a safe ramp gradient for disables and elder persons are constructed. The maximum gradient for a disabled traveler should be minimized to be safer.
 - LRT crosswalks area should be reconstructed. Enough coverage rate for pedestrian and passenger flow while crossing must be ensured.
- Pedestrian crossings:-
 - Overpass bridges should be designed: - with in an acceptable crossing distance and time. Crossway facilities at stations are best designed as overpass bridges rather than ground crossway to prevent the pedestrians from both train and vehicle collision accidents.
 - Pedestrian refuge area between tracks and roadways should be provided at crossings and stations to protect pedestrians from opposing vehicular traffic.
 - Priorities need to given for pedestrians rather than vehicles and mobility management should be developed.
- Bus stops: -
 - Bus stop or transit location should be integrated with LRT crossway facilities: - to minimize the distance and time delay of public transport users' mobility.
- Awareness creation:-

Can potentially reduce the impact on safety so there should create awareness of pedestrians how to cross the LRT line and which crossways they should use for their mobility. Some pedestrians cross the LRT by jumping on the fences because of the lack of patience to access the crossing facilities. This awareness includes:

 - Awareness on the danger of jumping should be created by using warning signs that show jumping is restricted on fences.

- Rule and regulations should be developed: - like a person who crosses the LRT by being jumped on the fences and through at-grade crossings of vehicles will pay some birr or other punishments.
- By providing passive warning signs (e.g. 'Do not cross tracks while lights are flashing or alarm sounding' and 'Danger – look out for trains on two tracks' signs) can create awareness between users.
- Behavior change by education: educations are often the first solution proposed to resolve safety problems, pedestrians who crossed fences and against signals. Provide behavior change messages by a large variety of types of messages through media, vehicles etc. which may target pedestrians' knowledge, attitudes, perceptions of crossings facilities and benefits of particular actions.

7. Proposed for future studies

Transport planning on mobility of pedestrians and public transport users' is an essential study. Even though the country is planning to implement different transport projects in the coming years, no detail is being conducted on the impact on all users. Therefore detail research is critical. Some proposed studies include:-

- ✓ Preparation of Walking Distance Guidelines for pedestrians and transit users. Currently studies on walking distance are undertaken by interpretation of other procedures developed by other countries. Therefore there is a need for the preparation of local standard walking guidelines.
- ✓ Methods to Improve the Capacity of LRT-Highway Crossings. Further researches on the area of crosswalk, demand, capacity or level of service can be performed to identify methods that can help to improve the capacity of crossings.
- ✓ Evaluation of At-Grade Vehicle Crossings on LRT-Highway Operation: A research may be conducted to evaluate the feasibility and crossing distance of at-grade vehicle crossings in detail. Risks associated with this kind of facilities have to be identified and corrective traffic and transport measures can be devised.
- ✓ This study was undertaken when the train is not in operation so when the train starts its operation there may decrease the effect on mobility on train users by reduction in travel time, cost and waiting time but on other transport users' which have no LRT line it will not be reduced. So further study should be conducted depending on the modal splits effect.
- ✓ This study was performed manually; it is better performed by simulation software like PTV VISWALK for pedestrians' mobility analysis and PTV VISSIM for traffic analysis of at-grade crossings.

References

AGRAWAL et al., (2008) *How far, by which route and why? A spatial analysis of pedestrian preference*, Journal of Urban Design 13 (1), 81-98

ALLAN G. BLUMAN. (2009)*Elementary Statistics a Step by Step Approach*, seventh edition

CA O'FLAHERTY. (2003) *Transport Planning and Traffic Engineering*

CERVERO, R., SARMIENTO, O., JACOBY, E., GOMEZ, L. and NEIMAN, A. (2009) *Influences of Built Environments on Walking and Cycling: Lessons from Bogotá*, International Journal of Sustainable Transportation 3 (4), 203-226.

CHAD, C. and Dr. LESTER, A. (2004) *Effects of Light Rail Transit on Traffic Congestion*.

CREC (CHINA RAILWAY GROUP LIMITED, 2009), *Addis Ababa LRT Project East-West and North-South Line Project Study Report*

CREC (CHINA RAILWAY GROUP LIMITED, 2012), *Schematic Design of Addis Ababa East-West and North-South (phase 1) LRT Project*

CORPUZ, G., HAY, A. and MEROM, D. (2005) *Walking for transport and health: trends in Sydney in the last decade*, Papers of the 28th Australasian Transport Research Forum, Sydney, 28-30 September 2005. www.patrec.org/atrf.aspx

DANIELS, R. and MULLEY, C. (2010a) *A proposal for accessibility planning in NSW: research and policy issues*, Proceedings of the 33rd Australasian Transport Research Forum, Canberra, www.patrec.org/atrf.aspx

DANIELS, R. and MULLEY, C. (2011) *Explaining walking distance to public transport: the dominance of public transport supply*

DIMTS (DELHI INTEGRATED MULTI-MODAL TRANSIT SYSTEM) (2014), *Feasibility and Operational Planning Study of BRT – B2 Corridor – Demand and Forecasting Report*.

DDA (DISABILITY DISCRIMINATION ACT, 2005) *guide: Inclusive mobility*

DON, C., ALLISON, C., JONATHA, B., MAURICE, M., HERBERT S. LEVINSON (2009)*TCRP report 137 Improving Pedestrian and Motorist Safety along Light Rail Alignments*.

DOUGLAS, C. MONTGOMERY and GEORGE, C. RUNGER (2003) *Applied Statistics and Probability for Engineers third edition*

JESSICA, E., BRETT, H., and CHRISTINA M. RUDIN-BROWN(AUGUST 2011): *pedestrian non-compliance at railway level crossing gates.*

ORTUZER and WILLUMSEN (2001) *Modeling transport third edition*

RESEARCH BY INTERNATIONAL ASSOCIATION OF PUBLIC TRANSPORT (UITP) and AFRICAN ASSOCIATION OF PUBLIC TRANSPORT (UATP), 2010

RICHARD, C. (2008) *Pedestrian-Rail Crossings in California*

ROUPHAIL and ALLEN (1998), *Capacity Analysis of Pedestrian and Bicycle Facilities. Recommended Procedures Chapter 13, "Pedestrians," of the Highway Capacity Manual*
<https://www.fhwa.dot.gov/publications/research/safety/pedbike/98107/98107.pdf>

SEAN, O'S. and JOHN, M. (1996), *Walking Distances to and from Light-Rail Transit Stations*, Transportation research record 1538.

SUNGJIN, P. (2008), *Defining, Measuring, and Evaluating Path Walkability, and Testing Its Impacts on Transit Users' Mode Choice and Walking Distance to the Station.*

TRL593 REPORT (2004), *The Demand for Public transport: a practical guide*

WIBOWO, S.S. and OLSZEWSKI, P. (2005) *Modeling walking accessibility to public transport terminal, Case study of Singapore Mass Rapid Transit, Journal of the Eastern Asia Society for Transportation Studies* 6, 147–156.

WRIGHT (1996) *Highway Engineering, J. Wiley (Chapter 5)*

XINYU (JASON), C. and RACHEL, J. (2009), *Understanding Transportation Impacts of Transit ways: Demographic and Behavioral Differences between Transit way Riders and Other Transit Riders*

Appendixes

Appendix A: Questionnaire

Questionnaire

Thick on your answers:-

1. Sex
 Male Female
2. How old are you?
 Under 19 years 19-29 years 30-49 years 50-65 years >65 years
3. What is your labour force status?
 Full-time work Part-time work Economically inactive
 Student Other _____
4. Day of week of walk trip?
 Monday to Friday Saturday Sunday All
5. How many times you will cross the LRT line per day? _____
6. Time of day of walk trip by cross the LRT line?
 Am peak Inter peak Pm peak Evening
7. What is your Purpose of trip?
 Work Education Social/Recreational Shopping
 Personal business Church/Mosque Other _____
8. Where is your origin? _____
and destination of your trip? _____
9. Where is the location of the crosswalk that you use for your purpose of trip by specifying building name or other surrounding known name? _____
10. Walking time from home to the crosswalk to cross the LRT?
 <5min 5-15min 15-30min 30-45min >45min
❖ Also distance you will travel to cross the LRT?
 <50m 50m-100m 100m-200m 200m-500m >500m
11. Before the construction of LRT walking time from home to cross the road?
 <5min 5-15min 15-30min 30-45min >45min
❖ Also distance you will travel to cross the road?
 <50m 50m-100m 100m-200m 200m-500m >500m

12. Which type of mode transport do you use for your purpose of the trip?

.Bus .Higer bus .Taxi .Service . Walk

i. If you use Bus where is the stop station location of the bus that you use for your purpose of trip by crossing LRT line? _____

ii. How much time do you walk from home to the bus station?

.<5min .5-15min .15-30min .30-45min .>45min

❖ Also how much distance?

.<50m .50m-100m .100m-200m .200m-500m .>500m

iii. If you use Taxi/ Higer bus/ Service where is the stop location of taxi/ higer/ service that you use for your purpose of trip by crossing LRT line? _____

iv. How much time do you walk from home to Taxi/ Higer bus/ Service stop by crossing LRT line?

.<5min .5-15min .15-30min .30-45min .>45min

❖ Also how much distance?

.<50m .50m-100m .100m-200m .200m-500m .>500m

13. Generally how much time the LRT line increased on your trip? _____

14. Do you think the travel demand and crossing facility capacity (stairs/ramps) that you use enough for pedestrians and public transport users to cross the LRT crosswalk?

. Enough . Not enough

15. Physical disabilities restricting walking cause of LRT system?

. Difficult . Not difficult . Not seen

16. What is your walking habit to cross the road and LRT after the LRT had constructed?

. Patience . Impatient . Anger . Sadness

መጠይቅ

1. ያታ

ሀ. ሴት ለ. ወንድ

2. እድሜህ/ሽ ስንት ነው ?

ሀ. ከ 19 አመት በታች ለ. ከ 19- 29 ሐ. ከ 30-49 መ. ከ 50-64 ሠ. ከ 65 አመት በላይ

3. የስራህ/ሽ ሁኔታ ምንድን ነው ?

ሀ. ሙሉ ሰአት ስራ ላይ ለ. ግማሽ ሰአት ስራ ላይ ሐ. ስራ የለኝም መ. ተማሪ
ሠ. ሌላ ካለ _____.

4. በሳምንት ውስጥ በተደጋጋሚ የእግር ጉዞ የሚያደርጉበት ቀናት የቶች ናቸው ?

ሀ. ከሰኞ እስከ አርብ ለ. ቅዳሜ ሐ. እሁድ መ. ሁሉም

5. በቀን ውስጥ ምን ያህል ጊዜ ሀዲዱን እና አስፓልቱን ያቋርጣሉ ?

6. ሀዲዱን በማቋረጥ አብዛኛውን ጊዜ የእግር ጉዞ የምታደርጉት ስንት ሰአት ላይ ነው ?

7. ሀዲዱን በማቋረጥ የእግር ጉዞውን የምታደርጉት ለምንድን ነው ?

ሀ. ለስራ ለ. ለትምህርት ሐ. ለማህበራዊ ጉዳይ መ. ለመዝናናት ሠ. ለመገበያየት ረ. ቤተክርስቲያን/ መስጊድ .
ሰ. ሌላ ካለ _____

8. የጉዞህ/ሽ መነሻ ቦታ የትኛው ?

መድረሻ ህስ/ሽ ?

9. የምትጠቀመው የባቡር ማቋረጫ መንገድ የቱ ነው ? (መጠሪያ ስም ካለው ወይም አካባቢው ላይ

ያለ የህንፃ ስም ጥቀስ/ሽ). _____.

10. ከቤትህ/ሽ እስከ ባቡሩ ማቋረጫ ድረስ ለመሄድ ምን ያህል ሰአት ይፈጅብህል/ሻል ?

ሀ. ከ5 ደቂቃ በታች ለ. ከ5-15 ደቂቃ ሐ. ከ15-30 ደቂቃ መ. ከ30-45 ደቂቃ ሠ. ከ45 ደቂቃ በላይ

❖ ርቀቱስ ምን ያህል ነው ?

ሀ. 50 ሜትር በታች ለ. 50-100 ሜትር ሐ. 100-200 ሜትር መ. 200-500 ሜትር ሠ. 500 ሜትር በላይ

11. የባቡሩ ሀዲድ ከመገንባቱ በፊት ከቤቶ እስከ አስፓልቱን ለማቋረጥ ምን ያህል ሰአት ይፈጅቦት ነበር ?

ሀ. ከ5 ደቂቃ በታች ለ. ከ5-15 ደቂቃ ሐ. ከ15-30 ደቂቃ መ. ከ30-45 ደቂቃ ሠ. ከ45 ደቂቃ በላይ

❖ ርቀቱስ ምን ያህል ነው ?

ሀ. 50 ሜትር በታች ለ. 50-100 ሜትር ሐ. 100-200 ሜትር መ. 200-500 ሜትር ሠ. 500 ሜትር በላይ

12. ወደ ምትሄዱበት ቦታ ለመሄድ የትኛውን የመጓጓዣ አይነት ይጠቀማሉ ?

ሀ. አውቶቢስ ለ. ባቡር ሐ. ሃይገር ባስ መ. ታክሲ ሠ. ሰርቪስ ረ. የአግር ጉዞ

i. አውቶቢስ የምትጠቀም/ሚ ከሆነ የምትሳፈሩበት ቦታ ሀዲድ በማቋረጥ የት ነው ? (መጠሪያ ስም ካለው ወይም አካባቢው ላይ ያለ የህንፃ ስም ጥቀስ/ሽ).-----

ii. ከቤትህ/ሽ እስከ አውቶቢስ ማቆሚያው ድረስ ሀዲድ በማቋረጥ ለመሄድ ምን ያህል ሰአት ይፈጅብህል/ሻል ?

ሀ. ከ 5 ደቂቃ በታች ለ. ከ 5-15 ደቂቃ ሐ. ከ 15-30 ደቂቃ መ. ከ 30-45 ደቂቃ ሠ. ከ 45 ደቂቃ በላይ

❖ ርቀቱስ ምን ያህል ነው ?

ሀ. 50 ሜትር በታች ለ. 50-100 ሜትር ሐ. 100-200 ሜትር መ. 200-500 ሜትር ሠ. 500 ሜትር በላይ

iii. ታክሲ ወይም ሃይገር ባስ/ ሰርቪስ የምትጠቀም/ሚ ከሆነ የምትሳፈሩበት ቦታ ሀዲድ በማቋረጥ የት ነው ?

(መጠሪያ ስም ካለው ወይም አካባቢው ላይ ያለ የህንፃ ስም ጥቀስ/ሽ). .

iv. ከቤትህ/ሽ እስከ ታክሲ ማቆሚያው ድረስ ሀዲድ በማቋረጥ ለመሄድ ምን ያህል ሰአት ይፈጅብህል/ሻል ?

ሀ. ከ5 ደቂቃ በታች ለ. ከ5-15 ደቂቃ ሐ. ከ15-30 ደቂቃ መ. ከ30-45 ደቂቃ ሠ. ከ45 ደቂቃ በላይ

❖ ርቀቱስ ምን ያህል ነው ?

ሀ. 50 ሜትር በታች ለ. 50-100 ሜትር ሐ. 100-200 ሜትር መ. 200-500 ሜትር ሠ. 500 ሜትር በላይ

13. በ አጠቃላይ ሀዲዱ ምን ያህል ደቂቃ ከ ድሮው ጉዟችሁ ጨመረ ? .

14. የባቡሩን ሀዲድ ለማቋረጥ የሚጠቀመው እግረኛ ብዛት እና የማቋረጫው ቦታ በቂ ነው ብለው ያስባሉ ?

ሀ. አዎ ለ. አይደለም

15. አካል ጉዳተኞች ሃዲዱን ሲያቋርጡ ይቸገራሉ ወይስ ?

ሀ. ይቸገራሉ ለ. አይቸገሩም ሐ. አላየሁም

16. ቀላል ባቡር ፕሮጀክት ከተገነባ በኋላ አስፋልቱንና ሃዲዱን ለማቋረጥ ርቀቱ በውስጣችሁ የፈጠረው ስሜት ምንድን ነው::

ሀ. ትዕግስት ለ. ትዕግስትማጣት ሐ. ብስጭት መ. ማዘን

Effects of LRT System on Pedestrians and Public Transport Users' Mobility
(Addis Ababa E-W (Ayat-Megenagna) LRT line)

Appendix B: Trip distance before and after LRT introduction of 98 sampled walkers

Table 1. Before and after LRT introduction- in one O-D, return and total trips/day (m)

no	no. crosses	Station	speed m/s	Before LRT		After LRT			Differences		
				O-D or return trip distance	Total trips/day distance	O-D distance	return trip distance	Total trips/day distance	After-Before in O-D trip	After-Before in return trip	After-Before total trips/day
1	2	EW8	1.2	601	1202	713	713	1426	112	112	224
2	2	EW4&EW8	1.2	366.5	733	935	628.5	1563	568.5	262	830.5
3	4	EW8	1.2	601	2404	713	713	2852	112	112	448
4	4	EW8	1.2	230	920	798.5	230	2057	568.5	0	1137
5	2	EW8	1.2	230	460	342	342	684	112	112	224
6	8	EW8	1.2	601	4808	713	713	5704	112	112	896
7	1	EW4	1.2	250.5	501	250.5	512.5	763	0	262	262
8	4	EW4	1.2	0	0	0	0	0	0	0	0
9	2	EW4	1	447	894	709	709	1418	262	262	524
10	2	EW5&EW8	1.2	588.5	1177	588.5	936.5	1525	0	348	348
11	4	EW7	1.2	289.5	1158	577.5	289.5	2310	288	0	1152
12	2	EW7	1.2	289.5	579	577.5	577.5	1155	288	288	576
13	3	EW7	1.2	289.5	868.5	577.5	289.5	1734	288	0	864
14	2	EW7	1.2	289.5	579	577.5	577.5	1155	288	288	576
15	2	EW7	1.2	289.5	579	577.5	577.5	1155	288	288	576
16	2	EW7&EW8	1.2	660.5	1321	772.5	948.5	1721	112	288	400
17	2	EW7&EW8	1.2	660.5	1321	772.5	948.5	1721	112	288	400
18	1	EW6	1.2	293	586	293	444	737	0	151	151
19	2	EW1	1.2	514	1028	818.5	818.5	1637	304.5	304.5	609
20	2	EW2	1.2	757	1514	2125	2125	4250	1368	1368	2736
21	4	EW1&EW2	1.2	527.5	2110	1007	1007	4028	479.5	479.5	1918
22	2	EW2	1.2	337.5	675	644	644	1288	306.5	306.5	613
23	4	EW2	1.2	514	2056	1703.5	1703.5	6814	1189	1189	4758
24	2	EW2	1.2	527.5	1055	1007	1007	2014	479.5	479.5	959
25	2	EW2	1.2	337.5	675	644	644	1288	306.5	306.5	613
26	3	EW2	1.2	337.5	1012.5	644	644	1932	306.5	306.5	919.5
27	3	EW2	1.2	337.5	1012.5	644	644	1932	306.5	306.5	919.5
28	2	EW2&EW4	1.2	474	948	736	780.5	1516	262	306.5	568.5
29	4	EW2	1.2	473.5	1894	870.5	870.5	3482	397	397	1588
30	4	EW1&EW2	1.2	945.5	2836.5	1946.5	1946.5	5839	1001	1001	3003
31	3	EW2	1.2	337.5	1012.5	644	644	1932	306.5	306.5	919.5
32	4	EW2	1.2	337.5	1350	644	644	2576	306.5	306.5	1226
33	7	EW2	1.2	337.5	2362.5	644	644	4508	306.5	306.5	2145
34	2	EW2	1.2	527.5	1055	1007	1007	2014	479.5	479.5	959
35	4	EW2	1.2	337.5	1350	644	644	2576	306.5	306.5	1226
36	2	EW4	1.2	1643.5	3287	1751	1751	3502	107.5	107.5	215
37	2	EW2	1.2	337.5	675	644	644	1288	306.5	306.5	613
38	4	EW2	1.2	540	2160	846.5	846.5	3386	306.5	306.5	1226
39	2	EW2	1.2	250.5	501	1119	1119	2238	868.5	868.5	1737

Effects of LRT System on Pedestrians and Public Transport Users' Mobility
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40	3	EW2	1.2	337.5	1012.5	644	644	1932	306.5	306.5	919.5
41	2	EW2	1.2	337.5	675	644	644	1288	306.5	306.5	613
42	2	EW2	1.2	250.5	501	1119	1119	2238	868.5	868.5	1737
43	6	EW2	1.2	136	816	226.5	226.5	1359	90.5	90.5	543
44	2	EW3	1.2	269	538	516.5	516.5	1033	247.5	247.5	495
45	4	EW1&EW7	1.2	540	1080	1149.5	1149.5	2299	609.5	609.5	1219
46	2	EW1	1.2	540	1080	846.5	846.5	1693	306.5	306.5	613
47	1	EW1	0.5	250.5	501	250.5	572	822.5	0	321.5	321.5
48	6	EW2	1.2	0	0	0	0	0	0	0	0
49	2	EW2	1.2	683.5	1367	990	990	1980	306.5	306.5	613
50	1	EW1	1.2	250.5	501	572	250.5	822.5	321.5	0	321.5
51	1	EW1	1.2	250.5	501	572	250.5	822.5	321.5	0	321.5
52	2	EW4&EW7	1.2	282.5	565	282.5	748	1030	0	465.5	465.5
53	2	EW7	1.2	289.5	579	577.5	577.5	1155	288	288	576
54	1	EW7	1.2	146	292	349.5	146	495.5	203.5	0	203.5
55	1	EW7	1.2	146	292	146	349.5	495.5	0	203.5	203.5
56	2	EW7	1.2	289.5	1158	289.5	577.5	1734	0	288	576
57	1	EW3	1.2	166	332	166	694	860	0	528	528
58	1	EW7	1.2	163.5	327	163.5	506	669.5	0	342.5	342.5
59	1	EW7	1.2	366	732	708.5	366	1074.	342.5	0	342.5
60	2	EW7	1	416.5	833	1298	1298	2596	881.5	881.5	1763
61	1	EW3	1.2	269	538	269	516.5	785.5	0	247.5	247.5
62	1	EW7	1.2	250.5	501	250.5	629.5	880	0	379	379
63	2	EW7	1.2	621.5	1243	1000.5	1000.5	2001	379	379	758
64	1	EW7	1.2	250.5	501	250.5	629.5	880	0	379	379
65	1	EW7	1.2	163.5	327	163.5	506	669.5	0	342.5	342.5
66	4	EW4&EW7	1.2	387	1161	766	649	2122	379	262	961.5
67	1	EW7	1.2	368.5	737	368.5	871	1239	0	502.5	502.5
68	2	EW2&EW7	1.2	675	1350	675	1613	2288	0	938	938
69	1	EW7	1.2	166	332	668.5	166	834.5	502.5	0	502.5
70	2	EW1&EW2	1.2	387	774	708.5	708.5	1417	321.5	321.5	643
71	2	EW7	1.2	166	664	668.5	166	1669	502.5	0	1005
72	2	EW7&EW8	1.2	129	516	197.5	129	653	68.5	0	137
73	2	EW1&EW8	1.2	379.5	759	769.5	379.5	1149	390	0	390
74	1	EW8	1.2	113.5	227	113.5	316	429.5	0	202.5	202.5
75	2	EW6&EW8	1.2	406.5	813	406.5	760	1166	0	353.5	353.5
76	2	EW1&EW8	1.2	480.5	961	480.5	1370.5	1851	0	890	890
77	1	EW8	1.2	344.5	689	344.5	913	1257	0	568.5	568.5
78	4	EW3&EW8	1.2	380	1520	635	582.5	2435	255	202.5	915
79	1	EW6&EW7	1.2	226	452	226	287.5	513.5	0	61.5	61.5
80	1	EW4	1.2	136.5	273	398.5	136.5	535	262	0	262
81	2	EW4	1	473.5	947	1071	1071	2142	597.5	597.5	1195
82	1	EW8	1.2	79	158	379	79	458	300	0	300
83	1	EW5	1.2	182.5	365	546.5	182.5	729	364	0	364
84	1	EW5	1.2	217.5	435	217.5	453.5	671	0	236	236
85	4	EW6	1.2	0	0	0	0	0	0	0	0
86	2	EW6	1.2	0	0	0	0	0	0	0	0
87	4	EW6	1.2	0	0	0	0	0	0	0	0

Effects of LRT System on Pedestrians and Public Transport Users' Mobility
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88	4	EW6	1.2	0	0	0	0	0	0	0	0
89	1	EW6	1.2	517.5	1035	517.5	1053.5	1571	0	536	536
90	1	EW4	1.2	310.5	621	811.5	310.5	1122	501	0	501
91	1	EW5	1.2	310.5	621	310.5	440.5	751	0	130	130
92	1	EW3	1.2	266.5	533	521.5	266.5	788	255	0	255
93	4	EW1&EW2	1.2	683.5	2734	1684.5	1684.5	6738	1001	1001	4004
94	1	EW2	1.2	122.5	245	645.5	122.5	768	523	0	523
95	2	EW2	1.2	432.5	865	1186	1186	2372	753.5	753.5	1507
96	2	EW2	1	473.5	947	870.5	870.5	1741	397	397	794
97	1	EW2	1.2	149	298	149	822.5	971.5	0	673.5	673.5
98	1	EW4	1.2	136.5	273	136.5	398.5	535	0	262	262
Total	226			34475.5	92044	61140	64671	165757	26665	30195	73711
Mean	2.31			351.79	939.22	623.88	659.91	1691.4	272.1	308.1	752.16
SD				228.16	909.64	423.41	438.67	1420.3	294.4	287.5	763.03

Appendix C: Percentage Points $t_{\alpha, v}$ of the t-Distribution

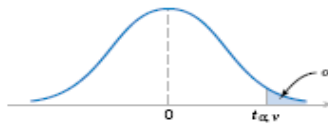
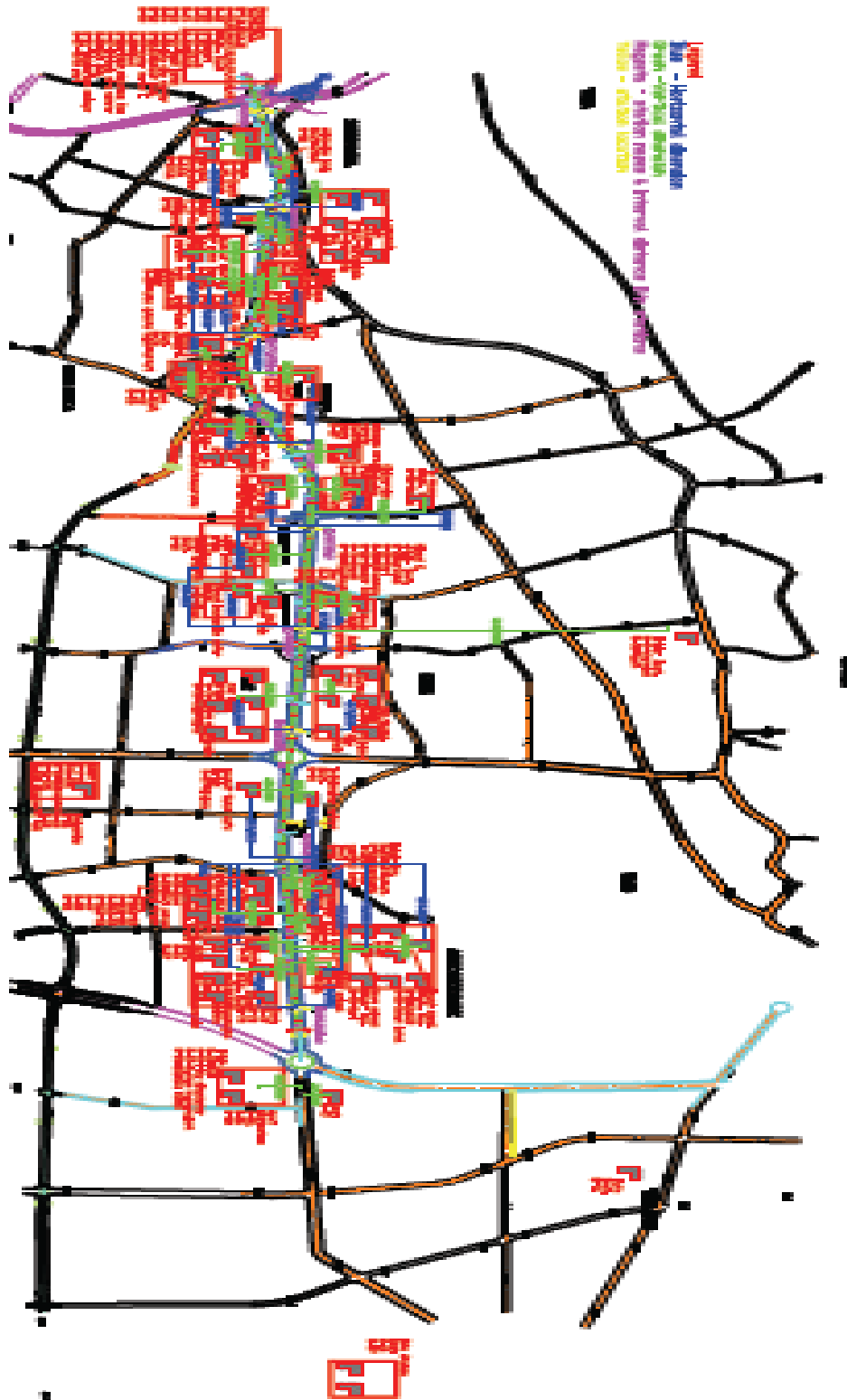


Table 2. t-Distribution table

$\alpha \backslash v$	.40	.25	.10	.05	.025	.01	.005	.0025	.001	.0005
1	.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31	636.62
2	.289	.816	1.886	2.920	4.303	6.965	9.925	14.089	23.326	31.598
3	.277	.765	1.638	2.353	3.182	4.541	5.841	7.453	10.213	12.924
4	.271	.741	1.533	2.132	2.776	3.747	4.604	5.598	7.173	8.610
5	.267	.727	1.476	2.015	2.571	3.365	4.032	4.773	5.893	6.869
6	.265	.718	1.440	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7	.263	.711	1.415	1.895	2.365	2.998	3.499	4.029	4.785	5.408
8	.262	.706	1.397	1.860	2.306	2.896	3.355	3.833	4.501	5.041
9	.261	.703	1.383	1.833	2.262	2.821	3.250	3.690	4.297	4.781
10	.260	.700	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11	.260	.697	1.363	1.796	2.201	2.718	3.106	3.497	4.025	4.437
12	.259	.695	1.356	1.782	2.179	2.681	3.055	3.428	3.930	4.318
13	.259	.694	1.350	1.771	2.160	2.650	3.012	3.372	3.852	4.221
14	.258	.692	1.345	1.761	2.145	2.624	2.977	3.326	3.787	4.140
15	.258	.691	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16	.258	.690	1.337	1.746	2.120	2.583	2.921	3.252	3.686	4.015
17	.257	.689	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18	.257	.688	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.922
19	.257	.688	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	.257	.687	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.850
21	.257	.686	1.323	1.721	2.080	2.518	2.831	3.135	3.527	3.819
22	.256	.686	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23	.256	.685	1.319	1.714	2.069	2.500	2.807	3.104	3.485	3.767
24	.256	.685	1.318	1.711	2.064	2.492	2.797	3.091	3.467	3.745
25	.256	.684	1.316	1.708	2.060	2.485	2.787	3.078	3.450	3.725
26	.256	.684	1.315	1.706	2.056	2.479	2.779	3.067	3.435	3.707
27	.256	.684	1.314	1.703	2.052	2.473	2.771	3.057	3.421	3.690
28	.256	.683	1.313	1.701	2.048	2.467	2.763	3.047	3.408	3.674
29	.256	.683	1.311	1.699	2.045	2.462	2.756	3.038	3.396	3.659
30	.256	.683	1.310	1.697	2.042	2.457	2.750	3.030	3.385	3.646
40	.255	.681	1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.551
60	.254	.679	1.296	1.671	2.000	2.390	2.660	2.915	3.232	3.460
120	.254	.677	1.289	1.658	1.980	2.358	2.617	2.860	3.160	3.373
∞	.253	.674	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

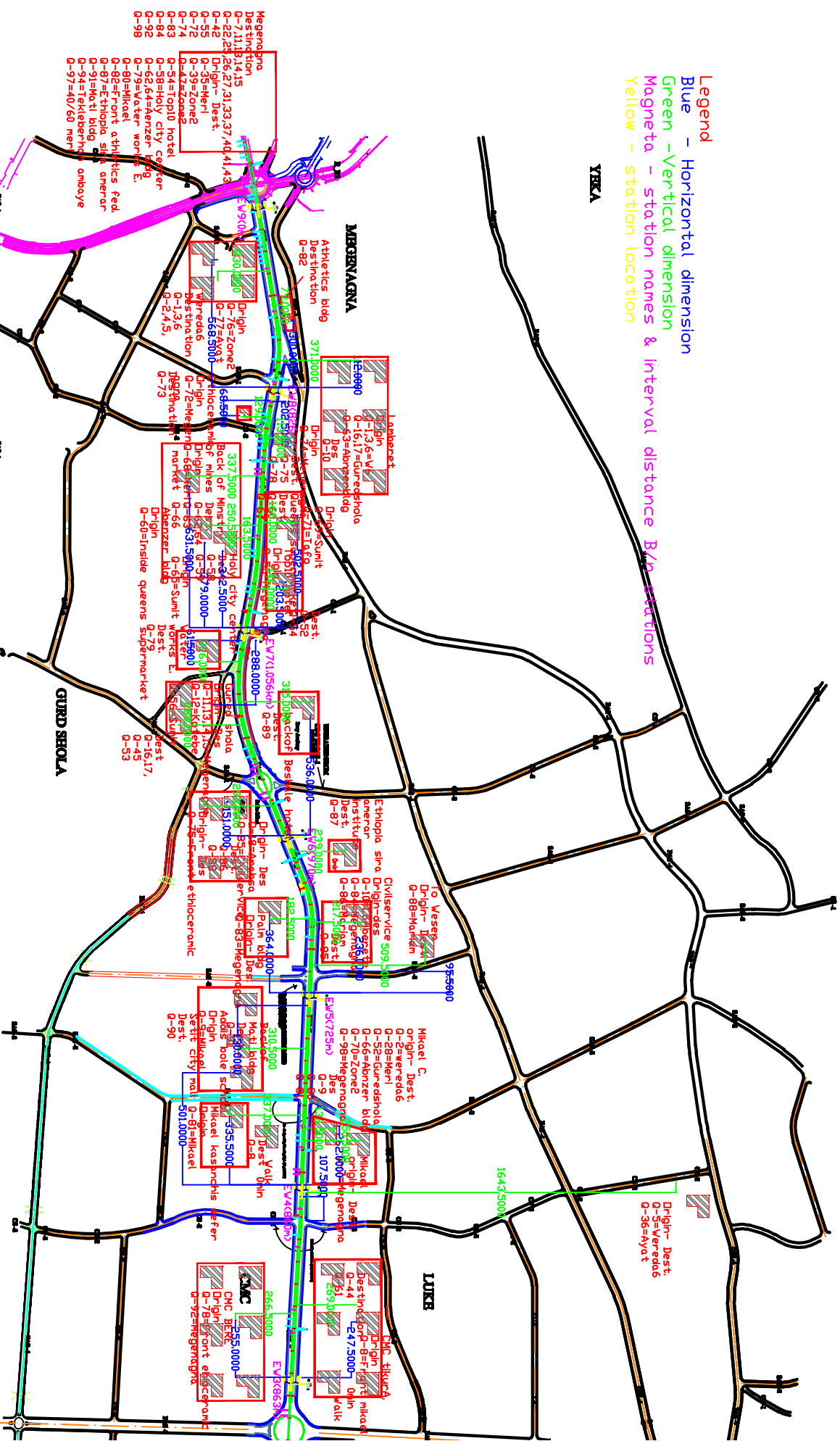
ν = degrees of freedom.

Appendix D: ERC road network plan and profile AutoCAD drawing and road network distance.



Legend
 Blue - Horizontal dimension
 Green - Vertical dimension
 Magenta - station names & interval distance B/w stations
 Yellow - station location

YBEA



- 0-71=11B,14,15
- 0-72=24,26,27,31,33,37,40,41,43
- 0-42=Drigin- Dest.
- 0-55=0-35=Meri
- 0-72=0-39=Zone2
- 0-74=0-47=zone6
- 0-83=0-54=Top10 hotel
- 0-84=0-58=holy city center
- 0-92=0-62,64=Menzen bldg
- 0-79=Vater worke E.
- 0-80=Mikael
- 0-82=front athletics fed.
- 0-87=Ethiopia sirra amaran
- 0-91=Ma,ti bldg
- 0-94=Tekeberna ambaeye
- 0-97=40/60 men

KOTBERE

LUKE

GURD SHOOLA

MEBRYAYANA

Athletics bldg
0-82

Lalabecet
0-1,3,6=W-Drigin
0-16,17=Gureedshola
0-53=Abnzer bldg
Des
0-10

Diplos Sumit
0-42=K. M. K. Des
0-43=K. M. K. Des
0-44=K. M. K. Des
0-45=K. M. K. Des
0-46=K. M. K. Des
0-47=K. M. K. Des
0-48=K. M. K. Des
0-49=K. M. K. Des
0-50=K. M. K. Des
0-51=K. M. K. Des
0-52=K. M. K. Des
0-53=K. M. K. Des
0-54=K. M. K. Des
0-55=K. M. K. Des
0-56=K. M. K. Des
0-57=K. M. K. Des
0-58=K. M. K. Des
0-59=K. M. K. Des
0-60=K. M. K. Des
0-61=K. M. K. Des
0-62=K. M. K. Des
0-63=K. M. K. Des
0-64=K. M. K. Des
0-65=K. M. K. Des
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0-67=K. M. K. Des
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0-69=K. M. K. Des
0-70=K. M. K. Des
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0-72=K. M. K. Des
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0-74=K. M. K. Des
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0-82=K. M. K. Des
0-83=K. M. K. Des
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0-85=K. M. K. Des
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