ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)

School of Civil and Environmental Engineering

ASSESSMENT OF ADDIS ABABA LIGHT RAIL TRANSIT (LRT) STATION PLATFORMS (E-W LINE).

A thesis submitted to the Graduate School of the Addis Ababa Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Railway Engineering Stream)

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Addis Ababa Institute of Technology (AAIT)
School of Civil and Environmental Engineering

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DECLARATION

I, the undersigned, declared that this thesis work entitled “Assessment of Addis Ababa Light Rail Transit (LRT) Station Platforms (E-W line)” is my own work and has not been presented in any other university. All sources of material used for this thesis have been dully acknowledged.

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First and foremost I would like to thank God for giving me the ability and discipline to make it through.

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Abstract

Passengers expect and deserve an experience at railway stations, through service, facilities and access, which adds to their end-to-end journey experience. Research shows that integration with others modes, convenient facilities, readily available information and an environment which is pleasant to move around and wait in are significant influences on both the attractiveness of rail and determinants of passenger satisfaction.

In this thesis station platform capacity of Addis Ababa light rail transit for efficient and effective urban transport service provision is examined. This study is designed to help LRT in the development of more secure and capable station, in terms of passenger capacity on platform areas.

The assessment considers LOS (level of service) criteria, which is evaluated in two ways first by evaluating the LOS of long term and initial stage of predicted passenger flow and second evaluation of LOS of the proposed platform by considering unused spaces.

The evaluation will help to evaluate the capacity and safety of the platform for the forecasted passenger volume of selected stations which are selected based on the maximum and minimum passenger volume. The forecasted passenger volume is directly taken from Preliminary Design for Ethiopia Addis Ababa E-W & S-N（Phase I）Light Rail Transit Project.

The analysis conducted on seven stations, and the condition on the platform during the early years is stable because the number of passengers is almost constant. The resulting levels of service of platforms by considering all the proposed platform area ranges between A – D, and for the same stations which considers basic station facilities, the LOS ranges from D – E. The level of service reaches its lowest value for the year (2019-2021) especially on platforms EW10 and EW12, this is basically the result of increasing passenger flow and the analysis considers basic station facilities (benches, trash receptacles, advertising boxes…etc). This shows that when the year increases and with facility provision, the situation on the platform will not be very convenient or comfortable for the alighting and waiting passengers.

The analysis showed the difference on the level of service when the platform has basic station facility and without a facility over the years. But for as an overview the analysis showed current and future level of services of selected station platforms.

The analysis was conducted only by considering the predicted passenger flow (long term). This could raise a question about the level of service of actual passenger counts on each station which is not coved on this analysis and this will lead to further study.

Finally, the analysis recommends three improving techniques. First, by extending the length of platform, second reducing the headway time or increasing the frequency of trains, this technique refers only the station platform capacity not other complications. And the third one is increasing number of cars or extending the length of the train.

Keywords: *Light rail transit, Level of service, station facilities, passenger volume, platform.*

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CHAPTER 1. INTRODUCTION

1.1 Background

Light rail stations are typically 55 to 120 m long. Various platform configurations are possible, including center, side, or split on opposite sides of an intersection. Stations may be on-street, off-street, along a railroad right-of-way, or on a transit mall. High and low platforms have been used, although the trend in recent years has been the increasing use of an intermediate height for platforms that is approximately 0.35 m above the top of the rail to match the floor height of low-floor light rail vehicles.

Light rail stations usually include canopies over part of the platform, limited seating, and ticket vending machines. Fare collection on light rail systems is typically by the proof-of-payment system, so stations do not have fare gates or barriers.

On the basis of the light rail construction plan, the station position should be decided by referencing to surrounding environment, city planning, and facilities on both sides. Meanwhile, the entrance and exit of the station should be reasonably designed according to station types and actual passenger flow, so as to bring convenient, safe, and fast services to the passengers.

Moreover, the station position should be accommodated with urban traffic, surface architectures, underground pipelines, and underground architectures. It should also try to decrease the number of house demolition and pipeline removing, and achieve minimum effect to ground architecture, traffic and citizens during construction.

The outputs from the assessments can enable stations to improve the capacity of platforms for better safety and comfort.

1.2 Statement of the Research problem

- Since the project is in progress, there is no visible problem. But this thesis will try to evaluate the size of proposed station platform for present and future passenger demand and suggest improving techniques for better level of service.

1.3Study Objectives

The aim of this thesis is to evaluate the size of proposed station platform and to develop capacity improving techniques.

The specific objectives of this study, in relation to the Addis Ababa LRT system, are:

- To assess the proposed station platform size in terms of capacity and expected demand.
- To suggest improving techniques for better level of service.

CHAPTER 2. LITERATURE REVIEW

In the literature a large variety of papers dealing either with train station capacity or station platform can be found. But the theory and its application in railway station platform, like investigated in this present thesis, is considered only in a few papers and are most likely the same. The content of this section summarizes literature dealing with station platform capacity assessment and capacity calculations.

The concept of level of service was taken from the Highway Capacity Manual but first applied by John J. Fruin. [1]

2.1. Passenger Circulation and Level of Service around Platform Area.

Required space for pedestrian waiting areas is determined by estimating the maximum demand for waiting area during the peak period. And the required waiting area is the deduction of 0.5m buffer along any roadways, walls or other obstructions from the effective waiting area (platform area). [2,3,4,5,6,7,8]

There is also a study which describes the calculation of platform capacities for LOS A through F by dividing the net square footage by the lower limit in the range indicated for that LOS. [9]

Bankable Feasibility Study for Addis Ababa Light Rail Transit uses global level of service criteria which are considered in the implementation of the transit line. [10]

The other study which covers all systems of the east-west line, which mainly includes: rolling stock, marshalling, passenger flow forecast, route, clearance limit, track, station construction, sub grade structure, elevated structure, underground structure, power supply, communication, signal, automatic fare collection, ventilation and air condition, water supply and drainage and fire fighting, depot, control centre, environmental protection and cost estimate. [11]

The functional plans for the stations include basic station configuration and site fit, Station Access & Universal Access. [12]

The standards of basic station facility elements are Span-wire/Light Poles, Paving, Tactile Warning Strip, Handrails and Guardrails, Lighting, Benches & Newspaper Boxes [13].

Prior work has not focused on assessing and maximizing the capacity of a station platform in particular.

2.2. Types and Configurations of Stations

Preliminary Design for Addis Ababa E-W & S-N（Phase I）Light Rail Transit Project [12]. This design document is for the architecture design of all the stations and auxiliary buildings of station (substation) in the whole line.

Line E-W goes along the important E-W transportation corridor in Addis Ababa. This line goes through city center, and is one of the most important contacting lines between city center and city western parts and western suburbs. The eastern and central parts of this line go through highly populated areas, the busiest commercial areas and Ayat residential area with large traffic flow; the western part of the line goes through western city and western suburbs.

2.2.1 Overview

The east-west line project starts from Ayat and ends at Torhailoch. The total length is 17.4km. There are 22 stations, among which 5 are elevated stations, 1 underground station and 16 ground stations. The depot locates at the west ends of the project. The control center （commonly used by both lines） is temporarily considered to be placed inside the depot. At the east end of the line Ayat, another long dated parking yard is reserved.

The section from Lideta Light to La Gare of line E-W locates in Addis Ababa center with high population. This section is the convergence of E-W route and N-S route which have the largest passenger flow. And this section is also the shared section by line E-W and line N-S. As the population density decreases along the line and the road section is not shared by two lines, passenger flow decreases also.

The light rail lines are laid along the center of the road; ground stations are designed into the ones with side platforms; the stations are set in the road center along the light rail line, and the clear width of station platform is 2.5m and length is 60m.If the condition is allowable, for example, altitude differences in both ends of the station are small, accessible ramps should be set at the both ends to enable the disables and passengers to enter. While the station is at the ramp landform and the altitude differences in both are large, walking stairs should be set at one end with larger altitude difference, and accessible ramp should be set at the other end with smaller altitude difference.

Figure 2.1. Ground stations of the light rail line. [12]

Elevated section of the light rail lines are laid along the road center. Elevated stations adopt the side platform design. The stations are set in the road center along the light rail line. Clear width of the station platform is 3.5 m and its length is 60 m.

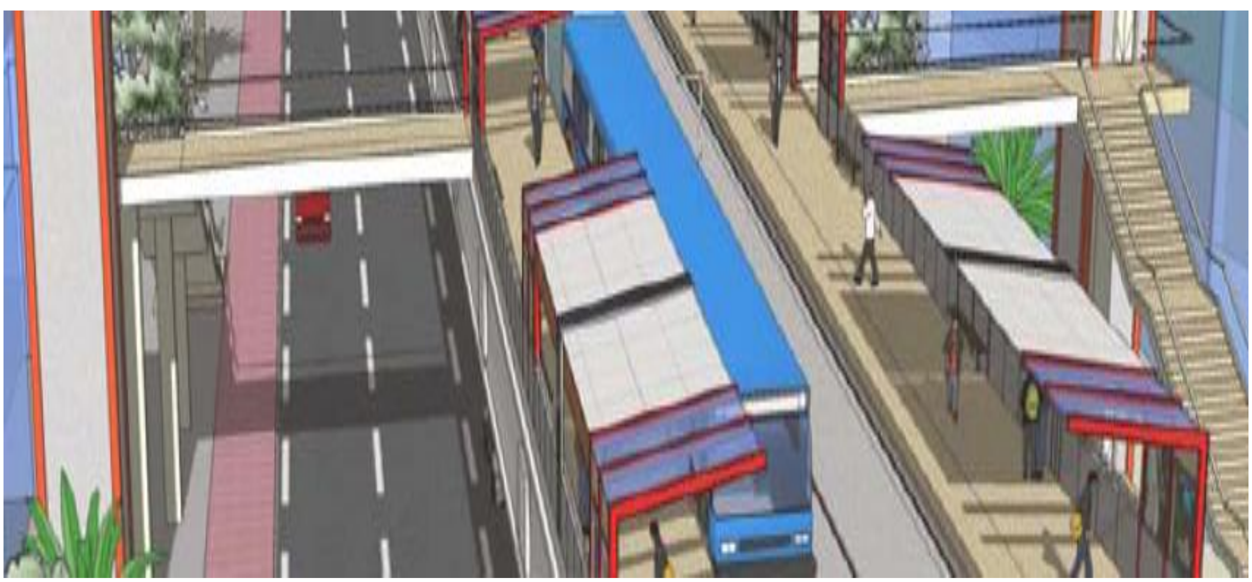

Figure 2.2. Elevated stations of the light rail line. [12]

Generally, the net clearance beneath the elevated station should be more than 5.4 m, which enables cars and trucks to pass through.

Passengers enter the stations and get on trains through overpasses. Two sides of the platforms are set with one elevator for assisting the disabled, old people with mobility difficulties, and pregnant women to get on trains.

Main Technical Standards

① Ground station

Length of platform: 60m

Clear height of decorated platform: ≥3200mm

Minimum width of side platform: 2,500mm

The distance from the platform edge to track center line in straight sections: 1,420mm

The gradient of ramps dedicated to the disabled: 1：12. [12]

② Underground and semi-underground station:

Length of platform: 60m

Minimum width of side platform: 2,500mm

Minimum width of island platform: 5,000mm

Clear height of decorated platform: 3,000mm

The clear height from the ground in the public area to top rail surface: 350mm

The distance from the platform edge to track center line in straight sections: 1,420mm[12]

③ Elevated station

Length of platform: 60m

Minimum width of side platform: 2,500m

The distance between the floor and awning in the public area: ≥3,000mm

The distance from the ground to elevated bottom beam: ≥5,400mm

The distance from the platform edge to track center line in straight sections: 1,420mm. [12]

2.3. Station Elements and Their Capacities

Station Capacity Assessment guide promotes a consistent 'best practice' approach to capacity assessments in planning and designing public areas in stations especially elements such as platforms, concourses and footbridges.

2.3.1 Station Platforms

Platforms function as queuing areas for passengers waiting for a transit vehicle to arrive and as circulation areas for both departing and arriving passengers. The effective platform area required is based on maintaining a minimum level of service for queuing and circulation. It is important to note that platforms have critical passenger holding capacities that if exceeded, could result in passengers being pushed onto tracks or roadways.

The total area of the platform is largely a function of the anticipated passenger load. Stations and stops that are too small can significantly increase dwell time and cause passengers to back up outside the station/stop.

In addition, consideration should be given to the area necessary for passenger circulation and passenger waiting areas. The passenger waiting area should be of sufficient size to accommodate the maximum number of passengers expected to wait for any particular vehicle, plus sufficient room for alighting passengers and others to circulate.

2.3.2 Role of a station

Good station can do the following:

- Provide shelter from the weather.
- Ensure safe accessibility for all, including people with disabilities.
- Provide passengers with information, including system maps and real-time arrival information.
- Enable passengers to board through multiple doors.
- Enable precise berthing at designated stopping points.

- Enable passengers to pay their fares before boarding using off-board fare payment equipment.
- Provide passengers with amenities such as newspaper boxes, signage, waste recycling, special lighting, seating and bicycle parking.
- Create a sense of place within the community, encouraging development and other activities to occur near the station or stop.

- Ensure ease of access to users of other modes, pedestrians and automobile drivers.
- Ensure easy connections with other local and intercity modes of transportation.

2.3.3 Types of station platforms

The type selected will depend on a number of parameters, including project budget, estimated passenger demand, surrounding area land use zoning, and available right-of-way. A single LRT corridor may use several station/stop types. The following is a summary of the basic types.

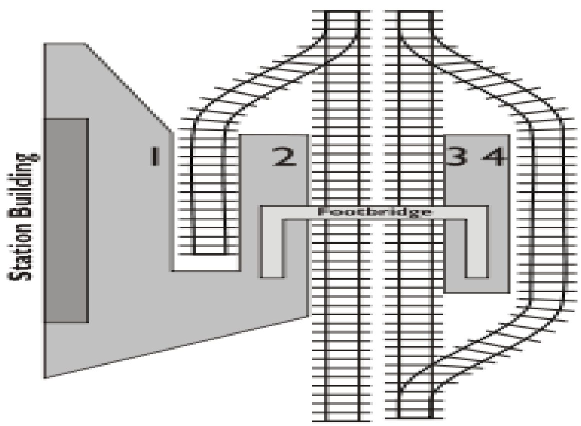

Figure 2.3. Basic station platform types [13].

This diagram illustrates different types of platform. Platform 1 is a "bay" platform, while platforms 2, 3 and 4 are "through" platforms. The platform accommodating 3 and 4 is an "island" platform.

- Bay platform is one at which the track terminates, i.e. a dead-end or siding. Trains serving a bay platform must reverse in or out.
- Side platform/through platform; is the more usual type, alongside tracks where the train arrives from one end and leaves towards the other

- Island platform; An island platform has through platforms on both sides; it may be indented on one or both ends, with bay platforms. To reach an island platform there may be a bridge, a tunnel, or a level crossing. The climb up to the bridge or down to the tunnel may use stairs, ramps, escalators, lifts, or a combination of the above.

Advantages of side platforms include:

1. Increased flexibility in locating emergency exits.
2. Ability to accommodate high-volume, bidirectional customer flows while avoiding bidirectional conflicts.
3. Potentially greater capacity for vertical circulation and emergency egress, since it is generally possible to provide more vertical circulation devices.
4. Better accommodation of long-term ridership changes (such as increases in the number of reverse commuters).

Disadvantages of side platforms include:

1. Need for directional decisions to be made prior to descending to the platform, in order to avoid backtracking and delay.
2. Need for clear signage to be provided so that customers can select the appropriate platform.
3. Need for passengers to change levels and cross tracks to change train directions.
4. Less space efficiency, resulting in wider stations.

2.3.4 Influencing Design Factors

This capacity is highly dependent on a number of infrastructure and operational factors, such as:

- Length of platform
- Siding length, spacing, and uniformity
- Intermediate signal spacing
- Peak train counts
- Average and variability in operating speed
- Heterogeneity in train types (train length, power to weight ratios).
- Maximum headway.

Capacity design factors which related specifically to the station entrance is described below:

A station entry shall provide:

A) Entry points that are easily identifiable, obstruction free and provide safe access to station platforms and staff operational facilities and passenger facilities.
B) An efficient and accessible circulation path from the station entrance to the platforms, with the minimum vertical travel and walking distances.
C) Smart card ticketing sales and card reading facilities.
D) Directional way finding, statutory signage, timetable and associated train operator information.
E) Security for staff and commuters.
F) Clear identification of the point at which passengers transition from the unpaid to paid area of the station.
G) Clear accessible connections to other modes of transport for exiting and interchanging passengers.
H) Staff and passengers facilities, as determined by the station category and the current and future staff and passenger numbers.
I) Incorporate connections between the station and surrounding local context, public roads, accessible and direct modal interchange links.
J) Accommodate anticipated queues free of obstructions both in regular and peak conditions.
K) Provide sufficient space to allow queuing that doesn’t conflict with passenger flows which satisfies as a minimum Level of Service (acceptable value is C).

The design requirements for fixtures, fittings and furnishings shall include:

- All platform furnishings shall be standardized to provide a uniform appearance and for ease of maintenance and replacement.
- Any structures, fixtures and furnishings required on the platform (e.g. waiting areas, bins and commercial vending machines) shall be located outside the warning strip, accessible path and circulation space. Any queuing generated by these facilities must not encroach into any of the spaces outlined previously.

- Passenger facilities on platforms (including vertical circulation, seats, public phones, and commercial vending machines) shall be distributed to avoid congestion at the entrance to the platform and to encourage passengers to spread out more evenly along the platform.
- Platforms should be free of unnecessary fixtures, fittings and furnishings.

Platform drainage construction elements shall meet the following design and engineering requirements:

- Surfaces shall be free draining.
- Single face platforms shall have drainage points located at the rear of the platform in sufficient numbers to prevent water collecting on the platform and/or overflowing from the rear of the platform;
- Island platforms shall have drainage points located in the centre of the platform in sufficient numbers to prevent water collecting on the platform.
- Surface water on the platform shall be directed away from station building entrances/exits so as not to allow the flow of water to enter or pool at these locations.
- All platform design shall incorporate overflow prevention in such a manner that water does not discharge onto the track.

Queuing level of service standards for platforms are based on average pedestrian space, personal comfort, and degrees of internal mobility. Passenger space in the level of service E category is experienced only on the most crowded platform. Level of service D represents crowding with some internal circulation possible; however, this level of service is not recommended for long-term waiting periods.

1.3.3 Evaluation Procedures

Transit Capacity and Quality of Service Manual; describes how to evaluate the size of a platform based on a desirable pedestrian level of service.

Transit platforms can be divided into the following four areas

- Walking areas
- Waiting areas

- Dead areas and
- Queue storage

Dead areas should be taken into consideration when choosing the size and configuration of a platform.

The size of a transit platform is based on maintaining a desirable pedestrian level of service. For transit platforms, the design level of service should be C to D or better. Following is a list of steps recommended for determining the desired platform size:

1- Based on the desired level of service, choose the average pedestrian space.
2- Estimate the maximum pedestrian demand for the platform at a given time.
3- Calculate the required waiting space by multiplying the average pedestrian space by the maximum pedestrian demand.
4- Calculate the additional walkway width needed by using the appropriate procedures for walkways described previously.
5- Calculate the queue storage space.
6- Consider the additional platform space that will used as dead areas.
7- Add a 1-meter (3-ft) buffer zone (0.5 meters, or 18 inches on each side) to the width of the platform.
8- Calculate the total platform area by summing required waiting space, walkway width, queue storage at exit points, dead areas, and buffer zone width.

This research will cover station capacity regarding passenger volume specially, on platform areas by comparing and assessing with the given volume.

The reviewed literature gives some ideas of methods that are also applicable to the line analysis in focus in this thesis.

CHAPTER 3 - RESEARCH METHODOLOGY

3.1 Introduction

This research performs the assessment of station platforms of the Light Rail Transit (LRT) along the E-W line as illustrated in Figure 3.1. The study focuses on the level of service (LOS) of station platforms.

The analysis covers the LRT station platform capacity along E-W line. The analysis is conducted for existing and future conditions using the level of service criteria. Then the analysis consisted of two criteria: platform having station facility and without station facility. Since, the analysis period is short some assumptions are considered such as uniform population growth rate.

3.2 Study area

The study areas include the E-W (east west) line that goes through Ayat to Torhailoch. The East-West route will serve the following major locations:

Figure 3.1 EW line stations.[11]

- ❖ Ayat village real estate development area
- ❖ CMC real estate
- ❖ Civil Service College
- ❖ Gurdshola residential area

- Megenagna junction where overpass bridge, tax/bus bays, and the Addis Dessie highway interface
- Lem Hotel Junction (residential and business area)
- Hayahulet junction (residential and business area)
- St. Urael Church junction, recently being a prominent business area
- Bambis junction (residential and business area)
- Meskel Square, the biggest square in Addis where political & social gatherings, religious festivities and exhibitions take place. Six major streets confluence at this square.
- The national stadium adjacent to Meskel Square, where football fans gather
- La Gare, where the Ethio-Djibouti railway formerly terminated and where the Anbessa City Bus Station is located
- Mexico Square, where six major streets confluence
- Lideta, an important business and religious gathering location
- Torhailoch, an important link to the vast western suburban area and an important link to the Addis Jimma Road via the ring road.

Based on the maximum and minimum predicted passenger flow in the long term, this thesis only considers 7 stations (EW1,EW8,EW10,EW12,EW16,EW17,EW19).

3.3 Research Design

This research evaluates the proposed platform by considering initial, short term and long term passenger flows on each stations.

And other Design Issues must be considered:-

- Is there enough space for passengers to wait and circulate?
- Are passenger processing elements (e.g., stairs, ramps and benches) adequately sized?
- What station element constrains capacity?
- Emergency evacuation needs

3.3.1 Data Collection and Sources

Addis Ababa LRT Main Design Principle and Technical Standard are stated as follows:- [12]

Main Technical Standards

Ground station

Length of platform: 60m

Clear height of decorated platform: ≥3,200mm

Minimum width of side platform: 2,500mm

The distance from the platform edge to track center line in straight sections: 1,420mm. [11]

According to city plan and the requirement of employer, Line E-W is planned to be completed in 2011. Forecasting year is proposed to be that initial stage is 2014, short-term is 2021 and long-term is 2036. [11]

The total unidirectional section passenger flows in initial stage, short-term and long-term are 38,462 persons/day, 70,308 persons/day and 115,385 persons/day respectively. The maximum passenger flows of initial stage, short-term and long-term in peak hours are 5,000 persons/hour, 9,140 persons/hour and 15,000 persons/hour respectively. [11]

Table.3.1 Initial, short term and long term predicted passenger flow (unit : passenger/hour) [12]

	Initial stage (2014)	Short term (2021)	Long term(2036)
No. of passengers (persons / day)	38,462	70,308	115,385
Peak hour flow (passengers / hours)	5,000	9,140	15,000

3.3.2 Data Analysis Procedures

The analysis starts with by calculating the growth factor from the maximum passenger flow of initial, short term and long term passenger flow.

Since, the analysis period is short i.e 2015-2021 and assuming on this interval the population growth is uniform. The analysis considers the equation of uniform growth factor.

$T_{ij} = t_{ij}(1+i)^n$ ……………………………………………………………………(1)

For each pair i and j, where i is the growth factor and n is the number of years.

- The growth factor between the short term and initial stage is:-

  70,308=38,462(1+i)^7

  i= 0.09

- The growth factor between the long term and short term is:-

  115,385=70,308(1+i)^15

  i= 0.0336

Peak hour factor = peak hour volume/flow rate

Typical peak-hour factors for freeways range between 0.60 and 0.80. [28]

PHF=0.8

Long term predicted passenger flow in (2036) = peak hour volume (passengers/hr)

Converting hourly volumes to peak 15-min volumes

- Highest entering volume occurs during p.m. peak:

$$P15 = \frac{\mathbf{Ph}}{\mathbf{4\ PHF}} \qquad (2)$$

Where, *P15*=peak 15-min volume

Ph= peak hour volume

PHF= peak hour factor i.e 0.8.

- Two, 3 car (6 axle) trains arrive in each direction in each 15min period.
- Under normal operating condition and 6min headway, half of the peak 15min demand could be on the platform just before trains arrived.

Then, LOS of 2036 (long term) = current platform area/half of peak hour flow

Table 3.2 Levels of Service for Queuing and Waiting Areas [14]

LOS	Average Pedestrian Area (ft^2/p)	Average Pedestrian Area (m^2/p)	Average Inter-Person Spacing (ft)	Average Inter-Person Spacing (m)
A	≥ 13	≥ 1.2	≥ 4.0	≥ 1.2
B	10-13	0.9-1.2	3.5-4.0	1.1-1.2
C	7-10	0.7-0.9	3.0-3.5	0.9-1.1
D	3-7	0.3-0.7	2.0-3.0	0.6-0.9
E	2-3	0.2-0.3	<2.0	<0.6
F	< 2	< 0.2	*Variable*	*Variable*

LEVEL OF SERVICE A

Standing and free circulation through the queuing area possible without disturbing others within the queue.

LEVEL OF SERVICE B

Standing and partially restricted circulation to avoid disturbing others within the queue is possible.

LEVEL OF SERVICE C

Standing and restricted circulation through the queuing area by disturbing others is possible; this density is within the range of personal comfort.

LEVEL OF SERVICE D

Standing without touching is impossible; circulation is severely restricted within the queue and forward movement is only possible as a group; long-term waiting at this density is discomforting.

LEVEL OF SERVICE E

Standing in physical contact with others is unavoidable; circulation within the queue is not possible; queuing at this density can only be sustained for a short period without serious discomfort.

LEVEL OF SERVICE F

Virtually all persons within the queue are standing in direct physical contact with others; this density is extremely discomforting; no movement is possible within the queue; the potential for pushing and panic exists.

Figure 3.2. The characteristics of LOS on waiting area [14]

CHAPTER 4. ANALYSIS, RESULTS AND DISCUSSION.

The acceptable amount of congestion and density of users in station site will influence the size of platform. In order to evaluate facility sizing, a methodology can be implemented that uses standards for acceptable level-of-service (LOS).

Platform capacities were calculated for LOS A through F by dividing the net square meter by the peak hour flow. For example, LOS B provides 0.2-1.2 m^2 per person, so for LOS B, the net square meter divided by peak hour flow gives value between the ranges. This number represents platform level of service. Any lower value will not provide LOS B, but rather, a lower level of service.

Platform traffic volumes of Addis Ababa LRT (E-W line) of selected stations are shown below. All passenger per hour flows are taken from Preliminary Design for Ethiopia Addis Ababa E-W & S-N（Phase I）Light Rail Transit Project.

4.1 Traffic Volumes of Selected Stations

Station EW1

① Location

Station EW1 is the first station on the E-W line starting from east. Its after-station works is the terminal point of the project in this phase. The station is located in the reserved zone for light rail of Asmara Rd. in Ayat in east-west direction.

- ❖ The station adopts the typical ground side station design, and is built in the middle road in the E-W direction.

L=60m

W=2.5m,

It's passenger flow depends on the morning peak in the long term:

Table 4.1---- Passenger flow of Addis Light Rail E-W in morning peak hours (unit:person)

Station Name	Predicted passenger flow	Up line			Down line			
		Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	
E-W 1	3909	0	1622	0	1635	0	1635	

By choosing the maximum passenger flow of Up line and Down line

Up line

Its designed incoming passenger flow: (0) × 1.2 = 0 (person/hour)

Its designed outgoing passenger flow: (1622) × 1.2 = 1946 (person/hour)

Its designed passenger flow: 0＋ 1946 = 1946 (person/hour)

Down line

Its designed incoming passenger flow: (1635) × 1.2 = 1962 (person/hour)

Its designed outgoing passenger flow: (0) × 1.2 = 0 (person/hour)

Its designed passenger flow: 0＋ 1962 = 1962 (person/hour)

Then, the designed passenger flow is = 1962 (person/hour)……Down line

The factor 1.2 is an over peak hour factor or over peak coefficient.[12]

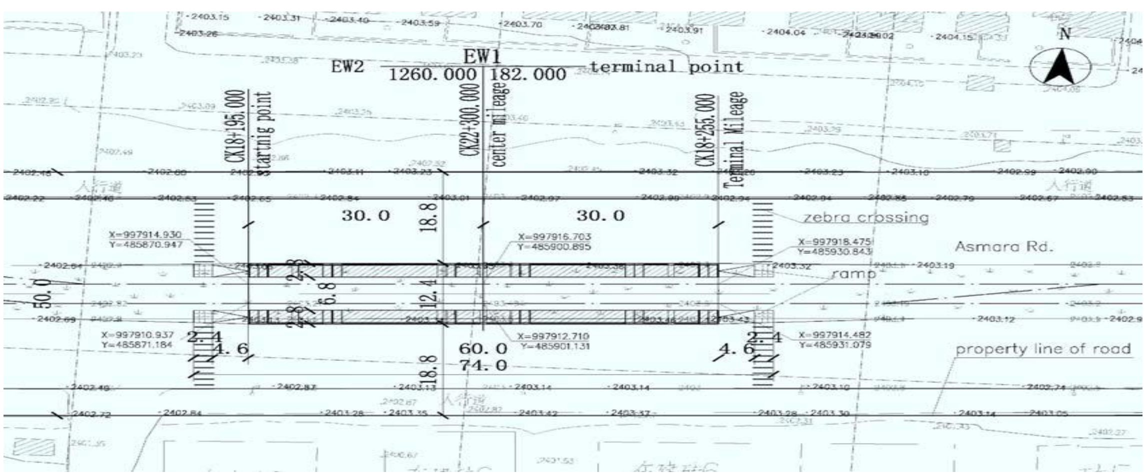

Figure 4.1. Station configuration and layout of E-W1

Station EW8

① Location

Station EW8 is the eighth station on the E-W line starting from east. The station is located in the reserved zone for light rail of Asmara Rd. for the E-W line.

- The station adopts the typical ground side station design, and is built in the middle road in the E-W direction

L=60m

W=2.5m

It's passenger flow depends on the morning peak in the long term:

Table 4.2----- Passenger flow of Addis Light Rail E-W in morning peak hours (unit:person)

Station Name	Predicted passenger flow	Up line			Down line			
		Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	
E-W 8	1477	148	377	7083	380	149	7367	

By choosing the maximum passenger flow of Up line and Down line

Up line

Its designed incoming passenger flow: (148) × 1.4 =207 (person/hour)

Its designed outgoing passenger flow: (377) × 1.4 = 528(person/hour)

Its designed passenger flow: 528+207 = 735 (person/hour)

Down line

Its designed incoming passenger flow: (380) × 1.4 = 532 (person/hour)

Its designed outgoing passenger flow: (149) × 1.4 =209 (person/hour)

Its designed passenger flow: 532＋ 209 = 741 (person/hour)

Then, the designed passenger flow is = 741 (person/hour) ……. Down line

The factor 1.4 is an over peak hour factor or over peak coefficient.[12]

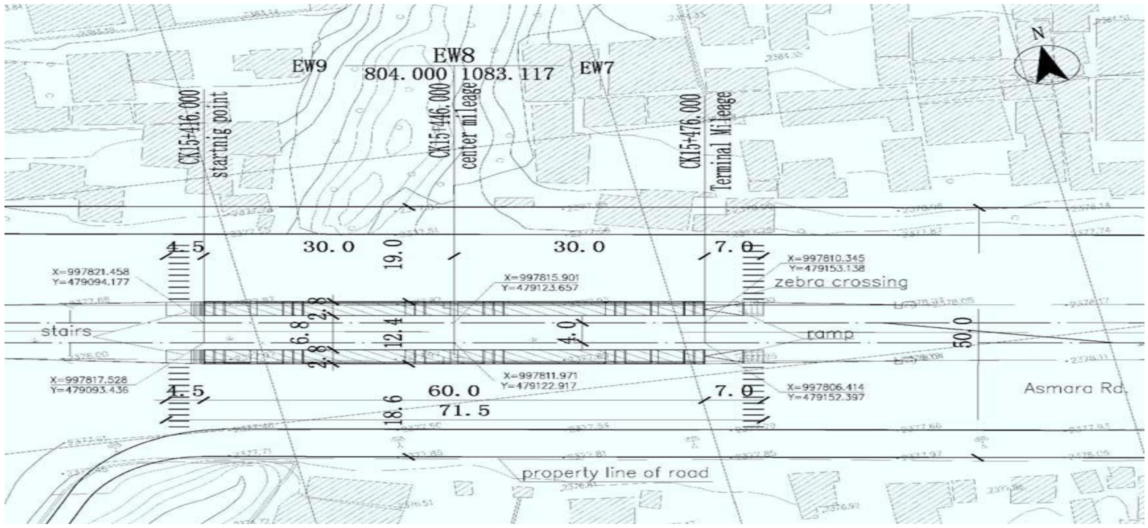

Figure 4.2. Station configuration and layout of E-W8.[12]

Station EW10

① Location

Station EW10 is the tenth station on the E-W line starting from east. The station is located in the Equatorial Guinea St. and east side of NOC gas station.

- ❖ The station adopts the typical ground side station design, and is built in the middle road in the E-W direction

L=60m

W=2.5m

It's passenger flow depends on the morning peak in the long term:

Table 4.3----- Passenger flow of Addis Light Rail E-W in morning peak hours (unit: person)

Station Name	Predicted passenger flow	Up line			Down line			
		Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	
E-W 10	1477	1895	1549	7451	1409	1909	7070	

By choosing the maximum passenger flow of Up line and Down line

Up line

Its designed incoming passenger flow: (1895) × 1.1 =2085 (person/hour)

Its designed outgoing passenger flow: (1549) × 1.1 = 1704(person/hour)

Its designed passenger flow: 2085+1704 = 3789 (person/hour)

Down line

Its designed incoming passenger flow: (1409) × 1.1 = 1550 (person/hour)

Its designed outgoing passenger flow: (1909) × 1.1 =2100 (person/hour)

Its designed passenger flow: 2100+1550 = 3650 (person/hour)

Then, the designed passenger flow is = 3789 (person/hour)…………. Up line

The factor 1.1 is an over peak hour factor or over peak coefficient.[12]

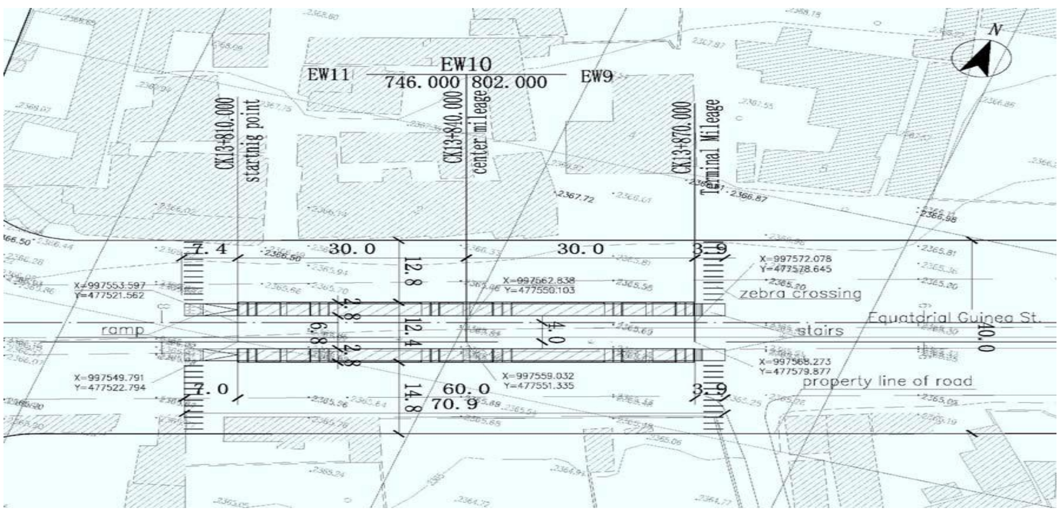

Figure 4.3. Station configuration and layout of E-W10. [12]

Station EW12

① Location

Station EW12 is the twelfth station on the E-W line starting from east and located in the Silase St. for the E-W line. This station is at LEX PLAZA, east of the junction of Silase St. and Mike Leyland St.

❖ The station adopts the typical ground side station design, and is built in the middle road in the E-W direction, L=60m

W=2.5m

It's passenger flow depends on the morning peak in the long term:

Table 4.4----- Passenger flow of Addis Light Rail E-W in morning peak hours (unit:person)

Station name	Predicted passenger flow	Up line			Down line			
		Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	
E-W 12	1477	1605	1499	6910	1513	1617	7132	

By choosing the maximum passenger flow of Up line and Down line

<u>Up line</u>

Its designed incoming passenger flow: (1605) × 1.2 =1926 (person/hour)

Its designed outgoing passenger flow: (1499) × 1.2 = 1799(person/hour)

Its designed passenger flow: 1799+1926 = 3725 (person/hour）

<u>Down line</u>

Its designed incoming passenger flow: (1513) × 1.2 = 1816 (person/hour)

Its designed outgoing passenger flow: (1617) × 1.2 =1940 (person/hour)

Its designed passenger flow: 1940+1816 = 3756 (person/hour）

Then, the designed passenger flow is = 3756 (person/hour）………. . <u>Down line</u>

The factor 1.2 is an over peak hour factor or over peak coefficient.[12]

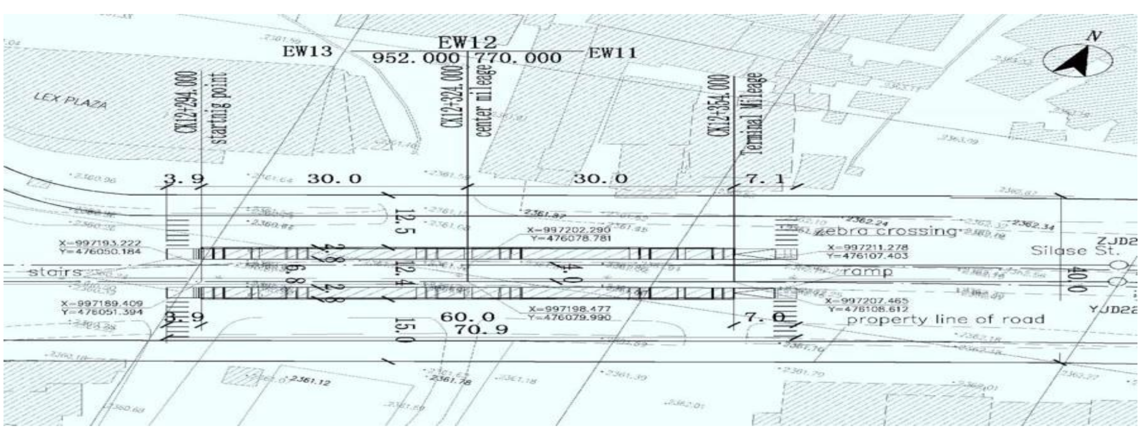

Figure 4.4. Station configuration and layout of E-W12. [12]

Station EW16

① Location

Station EW16 is the sixteenth station on the E-W line and the first common rail station starting from east. It is located at the stadium that is at west of the Meskel Sq. in the centre of city. The station is set at north of the road for the E-W line.

❖ The station adopts the elevated side station design.

L=60m

W=3.5m

It's passenger flow depends on the morning peak in the long term:

Table 4.5----- Passenger flow of Addis Light Rail E-W in morning peak hours (unit: Person)

Station name	Predicted passenger flow	Up line			Down line			
		Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	
E-W 16	8381	896+1094	576+1082	7627 +7594	580+1073	904+1083	7366 +7525	

By choosing the maximum passenger flow of Up line and Down line

<u>Up line</u>

Its designed incoming passenger flow: (896+1094) × 1.3 =2587 (person/hour)

Its designed outgoing passenger flow: (576+1082) × 1.3 = 2155(person/hour)

Its designed passenger flow: 2155+2587 = 4742(person/hour)

<u>Down line</u>

Its designed incoming passenger flow: (580+1073) × 1.3 = 2149 (person/hour)

Its designed outgoing passenger flow: (904+1083) × 1.3 =3536 (person/hour)

Its designed passenger flow: 2149+3536 = 3756 (person/hour)

Then, the designed passenger flow is = 4742 (person/hour) ……………. . <u>Up line</u>

The factor 1.3 is an over peak hour factor or over peak coefficient.[12]

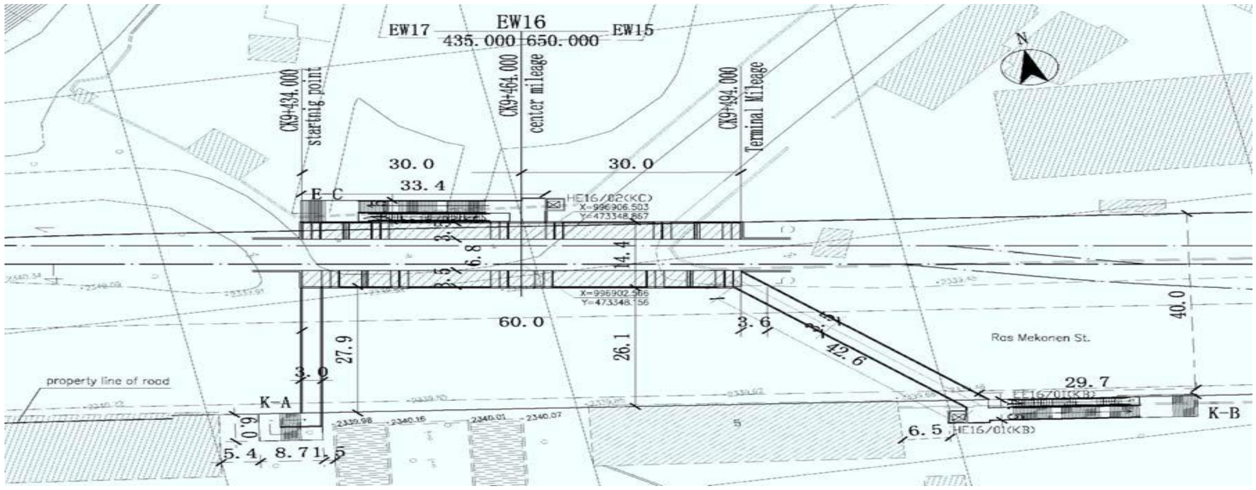

Figure 4.5. Station configuration and layout of E-W16. [12]

Station EW17

① Location

Station EW17 is the seventeenth station on the E-W line and the first common rail station starting from east. It is located at the stadium that is at west of the Meskel Sq. in the centre of city. The station is set at north of the road for the E-W line.

- ❖ The station adopts the elevated side station design.
- ❖ L=60m

W=3.5m

It's passenger flow depends on the morning peak in the long term:[12]

Table 4.6----- Passenger flow of Addis Light Rail E-W in morning peak hours

		Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	
E-W 17	9218	1097 +1220	373 +1182	7307 +7633	376+1174	1105 +1223	6637 +7534	

By choosing the maximum passenger flow of Up line and Down line

Up line

Its designed incoming passenger flow: (1097+1220) × 1.2 =2780 (person/hour)

Its designed outgoing passenger flow: (373+1182) × 1.2 = 1866(person/hour)

Its designed passenger flow: 1866+2780 = 4646(person/hour)

Down line

Its designed incoming passenger flow: (376+1174) × 1.2 = 1860(person/hour)

Its designed outgoing passenger flow: (1105+1223) × 1.2 =2794 (person/hour)

Its designed passenger flow: 2794+1860 = 4654(person/hour）

Then, the designed passenger flow is = 4654 (person/hour）………. . . Down line

The factor 1.2 is an over peak hour factor or over peak coefficient.[12]

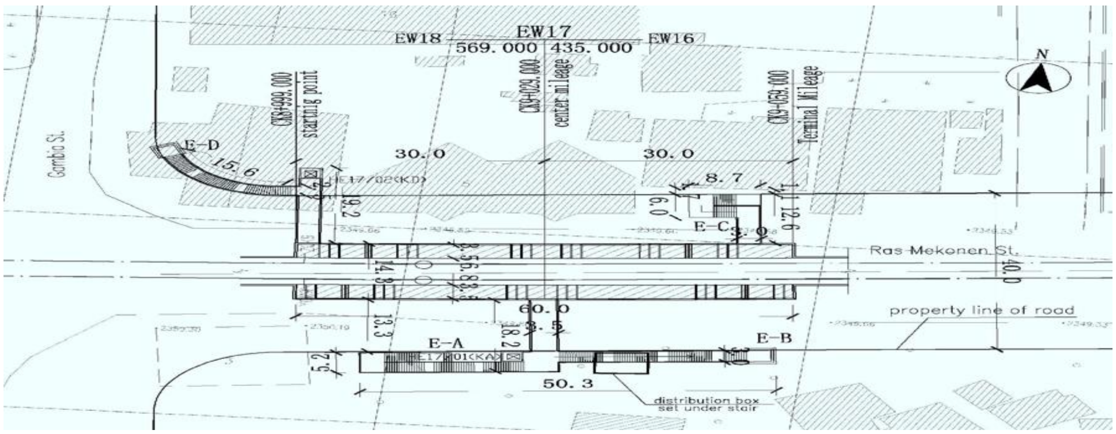

Figure 4.6. Station configuration and layout of E-W17. [12]

Station EW19

① Location

Station EW19 is the nineteenth station on the E-W line and the forth common rail station starting from east. It is located at the middle Chad St. in the west-east direction. It is located where the Technical school lies, at the west of the ring intersection of Roosevelt St., Ras Lulseged St., Ras Mekonen St., Ras Abebe Aragay St., and the Wolde Mikael St.

❖ It is a typical elevated side station,

L=60m

W=3.5m

Table 4.7----- Passenger flow of Addis Light Rail E-W in morning peak hours (unit: person)

		Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	Number of passengers getting on trains	Number of passengers getting off trains	Cross-section passenger flow	
E-W 19	8132	1064+794	76+973	5775 +7499	76+965	1072+788	4825 +7617	

It's passenger flow depends on the morning peak in the long term:

By choosing the maximum passenger flow of Up line and Down line

Up line

Its designed incoming passenger flow: (1064+794) × 1.4 =2601 (person/hour)

Its designed outgoing passenger flow: (76+973) × 1.4 = 1469(person/hour)

Its designed passenger flow: 1469+2601 = 4070(person/hour)

Down line

Its designed incoming passenger flow: (76+965) × 1.4 = 1457(person/hour)

Its designed outgoing passenger flow: (1072+788) × 1.4 =2604 (person/hour)

Its designed passenger flow: 2604+1457 = 4061(person/hour)

Then, the designed passenger flow is = 4070 (person/hour) ………. . . . Up line

The factor 1.4 is an over peak hour factor or over peak coefficient.[12]

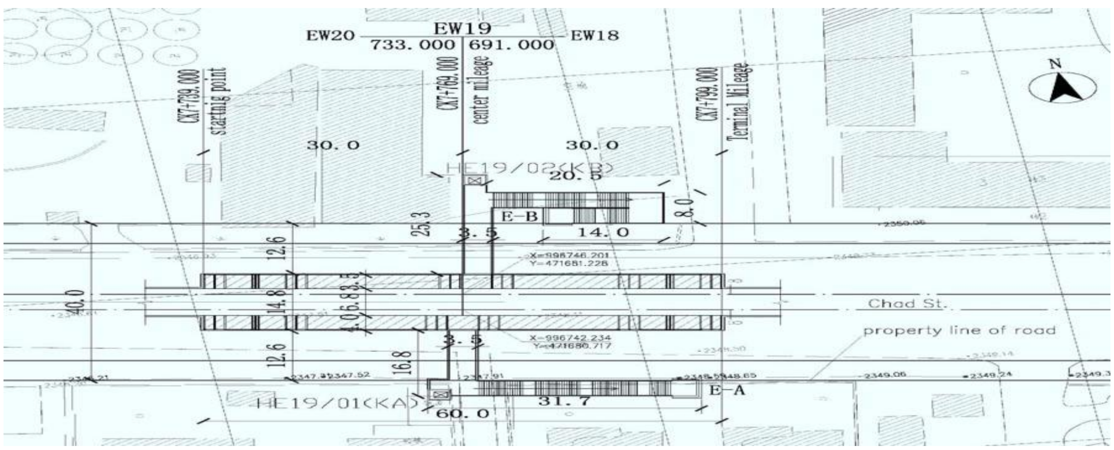

Figure 4.7. Station configuration and layout of E-W 19. [12]

4.2 Evaluation of LOS of initial Stage and long term predicted passenger flow.

The evaluation is conducted on each station based on design passenger flow, the size of platform, peak hour factor and the highest entering volume by choosing from the up line and down line during the peak hour.

Station EW1

Its design passenger flow= 1962

L=60m

W=2.5m

PHF=0.8

The platform has two sizes:-

For 2.5m wide platform, A = 60m*2.5m

= 150m^2

For 3.5m wide platform, A = 60m*3.5m

=210m^2

Long term predicted passenger flow in (2036) = 1962passengers/hr

Converting hourly volumes to peak 15-min volumes

- Highest entering volume occurs during p.m. peak:

$$P15 = \frac{Ph}{4\ PHF} \quad \ldots\ldots(2)$$

$$P15 = \frac{1962}{4\ 0.8} = 613 \text{ persons}$$

- Two, 3 car (6 axle) trains arrive in each direction in each 15min period.
- Under normal operating condition and 6min headway, half of the peak 15min demand could be on the platform just before trains arrived.

  i.e, 306 passengers are on the platform

  Then, LOS of 2036 (long term) = current platform area/peak hour flow

  = 150m^2/ 306 ped

  = 0.49m^2/ped, LOS D

Long term predicted passenger flow in (2036) = 1962 passengers/hr

Short term predicted passenger flow in (2021), $t_{ij} = T_{ij}/ (1+i)^{15}$

= 1962/1.0336^15

= 1196 ped/hr

Initial stage predicted passenger flow in (2014), $t_{ij} = T_{ij}/ (1+i)^7$

= 1196/ 1.09^7

= 653ped/hr

Converting hourly volumes to peak 15-min volumes

- ❖ Highest entering volume occurs during p.m. peak:

$$P15 = \frac{Ph}{4\ PHF} \quad \text{...(2)}$$

$$P15 = \frac{653}{4\ 0.8} = 204 \text{ ped}$$

- ➢ Half of the peak 15min demand could be on the platform just before trains arrived.

  i.e, 102 passengers are on the platform

  Then, LOS of 2014 (initial stage) = current platform area/peak hour flow
  = 150m2/ 102 ped
  = 1.47 m2/ped, LOS A

For 2015 = 653*1.09 = 712 ped/hr

2016 = 653*1.09^2 =776 ped/hr

2017 = 653*1.09^3 =846 ped/hr

2018 = 922 ped/hr

Tij=tij*(1+i)^n

tij=Tij/(1+i)^n

Table 4.8- initial, short and long term predicted passenger flow

	Initial stage (2014)	Short term (2021)	Long term(2036)
No. of passengers (persons / day)	38,462	70,308	115,385
Peak hour flow (passengers / hours)	5,000	9,140	15,000

If we assume the growth is uniform, then we can use the equation of uniform growth factor.

$Tij = tij(1+i)^{n}$

For each pair i and j, where *i* is the growth factor and n is the number of years.

- The growth factor between the short term and initial stage is:-

  70308=38462(1+i)^7

  i= 0.09

- The growth factor between the long term and short term is:-

  115385=70308(1+i)^15

  i= 0.0336

Table 4.9 - initial and Long term predicted passenger flow

Station Name	Tij=2036 (Ped/hr)	NO. of years	i	1+i	Tij=2021	i	1+i	NO. of years	Tij=2014	2018	2019	2020	2021
EW1	1962	15	0.0336	1.0336	1195.12	0.09	1.09	7	653.77	922.8	1005.9	1096	1195.12
EW8	741	15	0.0336	1.0336	451.3679	0.09	1.09	7	246.91	348.5	379.90	414	451.3679
EW10	3789	15	0.0336	1.0336	2308.007	0.09	1.09	7	1262.55	1782	1942.6	2117	2308.007
EW12	3756	15	0.0336	1.0336	2287.905	0.09	1.09	7	1251.56	1766	1925.6	2098	2287.905
EW16	4742	15	0.0336	1.0336	2888.511	0.09	1.09	7	1580.11	2230	2431.2	2650	2888.511
EW17	4654	15	0.0336	1.0336	2834.907	0.09	1.09	7	1550.79	2189	2386.0	2600	2834.907

Converting hourly volumes to peak 15-min volumes

P15= Ph/4(PHF)

Typical peak-hour factors for freeways range between 0.80 and 0.95. Lower factors are more typical for rural freeways or off-peak conditions.

Higher factors are typical of urban and suburban peak-hour conditions.

PHF=0.8

Table 4.10 - Hourly peak hour flow over the years

	HOURL VOLUME OVER THE YEARS						PEAK HOUR FLOW OVER THE YEARS			
Station	Tij=2014	2018	2019	2020	2021	PHF	2018	2019	2020	2021
EW1	653.7715	922.8519	1005.909	1096.44	1195.12	0.8	288.3912	314.3464	342.6376	373.475
EW8	246.9137	348.5389	379.9074	414.099	451.3679	0.8	108.9184	118.721	129.4059	141.0525
EW10	1262.559	1782.205	1942.603	2117.437	2308.007	0.8	556.939	607.0635	661.6992	721.2521
EW12	1251.563	1766.683	1925.684	2098.996	2287.905	0.8	552.0884	601.7763	655.9362	714.9705
EW16	1580.114	2230.461	2431.202	2650.01	2888.511	0.8	697.0189	759.7506	828.1282	902.6597
EW17	1550.791	2189.069	2386.085	2600.832	2834.907	0.8	684.0839	745.6515	812.7601	885.9085
EW19	1356.193	1914.377	2086.671	2274.471	2479.173	0.8	598.2427	652.0846	710.7722	774.7417

1. Two, 3 car (6 axle) trains arrive in each direction in each 15min period.
2. Under normal operating condition and 6min headway, half of the peak 15min demand could be on the platform just before trains arrived.

Then, LOS = current platformarea
Half of the peak 15mindemand.

Since, the platform is located on both side of the station:-

For 2.5m wide platform, A= 60m*2.5m

(actual station size) = 150m2

For 3.5m wide platform, A= 60m*3.5m

=210m2

Table 4.11 - Evaluation of LOS of long term and initial stage predicted passenger flow of E W 1 station.

Station	Year	P15	Half of the peak 15min demand	Current Platform area(m2)	LOS(m2/ped)	LOS
EW1	2015	222.69093	111.3454646	150	1.347158598	A
	2016	242.73311	121.3665564	150	1.23592532	A
	2017	264.57909	132.2895465	150	1.13387644	A
	2018	288.39121	144.1956056	150	1.040253615	A
	2019	314.34642	157.1732102	150	0.954361114	B
	2020	342.6376	171.3187991	150	0.875560655	B
	2021	373.47498	186.737491	150	0.803266656	C

Table 4.12 - Evaluation of LOS of long term and initial stage predicted passenger flow of E W 8 station.

Station	Year	P15	Half of the peak 15min demand	Current Platform area(m2)	LOS(m2/ped)	LOS
EW8	2015	84.104984	42.05249197	150	3.56697054	A
	2016	91.674433	45.83721625	150	3.272450037	A
	2017	99.925131	49.96256571	150	3.00224774	A
	2018	108.91839	54.45919663	150	2.754355725	A
	2019	118.72105	59.36052432	150	2.526931858	A
	2020	129.40594	64.70297151	150	2.318286108	A
	2021	141.05248	70.52623895	150	2.126867989	A

Table 4.13 - Evaluation of LOS of long term and initial stage predicted passenger flow of E W 10 station.

Station	Year	P15	Half of the peak 15min demand	Current Platform area(m2)	LOS(m2/ped)	LOS
EW10	2015	430.05909	215.029544	150	0.697578562	D
	2016	468.76441	234.3822029	150	0.639980332	D
	2017	510.9532	255.4766012	150	0.587137919	D
	2018	556.93899	278.4694953	150	0.538658641	D
	2019	607.0635	303.5317499	150	0.49418224	D
	2020	661.69921	330.8496074	150	0.453378202	D
	2021	721.25214	360.626072	150	0.415943304	D

Table 4.14 - Evaluation of LOS of long term and initial stage predicted passenger flow of E W 12 station.

Station	Year	P15	Half of the peak 15min demand	Current Platform area(m2)	LOS(m2/ped)	LOS
EW12	2015	426.31352	213.1567609	150	0.703707447	C
	2016	464.68174	232.3408694	150	0.645603162	D
	2017	506.5031	253.2515477	150	0.592296479	D
	2018	552.08837	276.0441869	150	0.543391265	D
	2019	601.77633	300.8881638	150	0.498524097	D
	2020	655.9362	327.9680985	150	0.457361556	D
	2021	714.97045	357.4852274	150	0.419597758	D

Table 4.15 - Evaluation of LOS of long term and initial stage predicted passenger flow of E W 16 station.

Station	Year	P15	Half of the peak 15min demand	Current Platform area(m2)	LOS(m2/ped)	LOS
EW16	2015	538.2265	269.1132482	210	0.780340624	C
	2016	586.66688	293.3334406	210	0.715908829	C
	2017	639.4669	319.7334502	210	0.656797091	D
	2018	697.01892	348.5094607	210	0.602566139	D
	2019	759.75062	379.8753122	210	0.552812971	D
	2020	828.12818	414.0640903	210	0.507167863	D
	2021	902.65972	451.3298584	210	0.465291618	D

Table 4.16 - Evaluation of LOS of long term and initial stage predicted passenger flow of E W 17 station.

Station	Year	P15	Half of the peak 15min demand	Current Platform area(m2)	LOS(m2/ped)	LOS
EW17	2015	528.23832	264.1191601	210	0.795095668	C
	2016	575.77977	287.8898845	210	0.729445567	C
	2017	627.59995	313.7999741	210	0.669216116	D
	2018	684.08394	342.0419718	210	0.61395974	D
	2019	745.6515	372.8257493	210	0.563265816	D
	2020	812.76013	406.3800667	210	0.51675763	D
	2021	885.90855	442.9542727	210	0.474089568	D

Table 4.17 - Evaluation of LOS of long term and initial stage predicted passenger flow of E W 19 station.

Station	Year	P15	Half of the peak 15min demand	Current Platform area(m2)	LOS(m2/ped)	LOS
EW19	2015	461.95315	230.9765753	210	0.909183105	B
	2016	503.52893	251.7644671	210	0.834112941	C
	2017	548.84654	274.4232692	210	0.76524123	C
	2018	598.24273	299.1213634	210	0.702056174	D
	2019	652.08457	326.0422861	210	0.644088233	D
	2020	710.77218	355.3860918	210	0.590906636	D
	2021	774.74168	387.3708401	210	0.54211618	D

4.3 Evaluation of LOS of the proposed platform by considering unused spaces.

The final factor affecting a walkway's capacity is the effective width available. Studies have shown that pedestrians keep as much as an 18-in. (0.5-m) buffer between themselves and adjacent walls, street curbs, platform edges, and other.

Obstructions, such as trash receptacles, sign posts, advertizing boxes and benches. In practice, the width of the unused buffer depends on the character of the wall or obstruction, the overall width of the available walkway, and on the level of pedestrian congestion. In general, 18 in. (0.5 m) should be deducted next to walls and platform edges and 12 in. (0.3 m) should be deducted next to other obstructions, including walls up to about 3 feet (1 m) tall.

The rear edge of a single platform where passengers shall be fenced to a minimum height of 1500mm above the ground level immediately adjacent to the platform. The height of the fence above platform level shall be sufficient to prevent a person falling off.

The station should be designed to meet the main functions required by the type of service that goes through it. This will include:-

- The passenger ticketing areas.
- Trash receptacles.
- Station platforms shall have at least two ticket vending machines.
- Benches, elevators
- Newspaper Boxes
- Advertizing box, customer information board. These are some of the facilities that must be included.

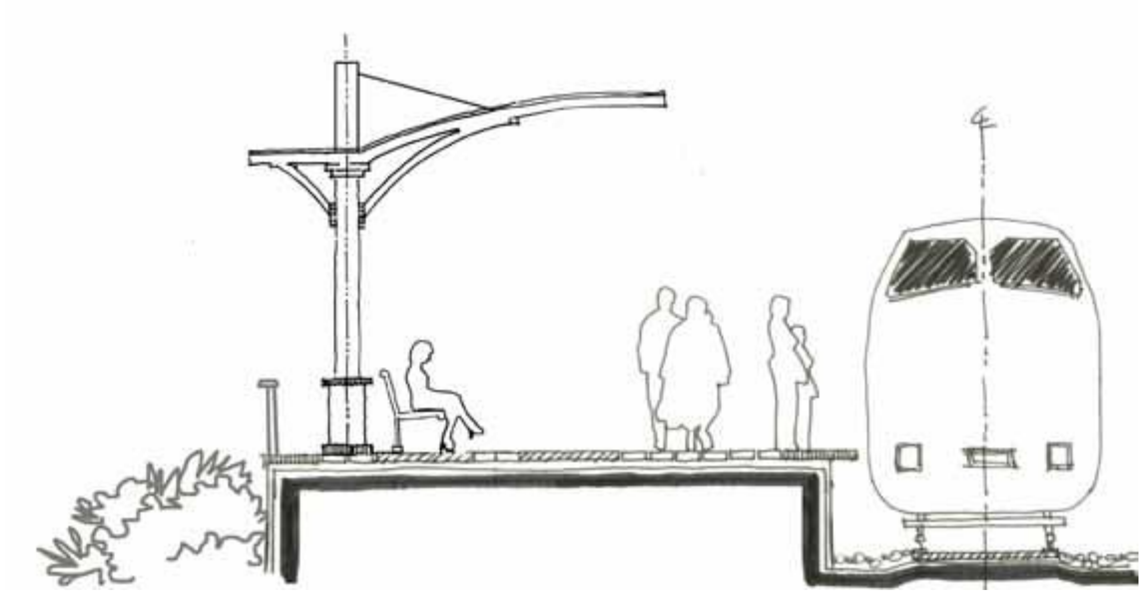

Figure 4.8 Typical ground station [16] .

Consider unused platform space

- Maximum bench length is 4 feet (1.33m) and width 0.5m, and dividers along the length of the bench are recommended.

Figure 4.9 Bench layout on station platform [16].

Trash receptacles should be located conveniently in all pedestrian gathering spaces, placed near seating areas. They should be designed as permanent features, with specified anchoring requirements per manufacturer instructions.

- Benches (Assuming to provide a minimum of 4 benches per station) , information displays, advertising displays, trash receptacles.

  Benches= 1.33*0.5*4=2.665m^2 (Assuming 4 benches)

Trash receptacles= $\pi d^2/4 = \pi*(0.5)*(0.5)/4*3 = 0.59m^2$ (Assuming 3 trash receptacles)

And for advertising and information displays $=1.75m^2$

$A=5m^2$

Calculate buffer area required

- Platform is 60m long on both sides.
- Provide 0.5m buffer next to platform edges
- 60*.5 = $30m^2$ required

Calculate buffer area to dead area and physical obstruction

- 60*.5=$30m^2$

To calculate the level of service:

- Calculate the total unusable platform area by adding the buffer zones , bench and Advertising areas
- Subtract the unusable platform area from the total platform area and divide by the maximum passenger demand.

Calculate total area required

- Passenger waiting area: 60*2.5=$150m^2$
- Queue storage: $0\ m^2$
- Unused platform space: $5m^2$
- Buffer space along the edge: $30m^2$
- Buffer area along physical obstruction : $30m^2$

$A=65m^2$(unusable platform area)

Net effective area=150-65=$85m^2$

Then, LOS of 2014 (initial stage) = net effective area/peak hour flow

$= 85m^2/ 102ped$

$= 0.83m^2/ped$, LOS C

For 2015= 653*1.09= 712 ped/hr

$$P15 = \frac{Ph}{4\ PHF} \text{.......................................}(2)$$

- $P15 = \frac{712}{4\ 0.8}$

= 223 ped

- Half of the peak 15min demand could be on the platform just before trains arrived.

  i.e, 111 passengers are on the platform

  Then, LOS of 2015 = current platform area/peak hour flow

  $=85m^2/\ 111ped$

  $= 0.76m^2/ped$, LOS C

2016=653*1.09^^{2}=776ped/hr

$$P15 = \frac{Ph}{4\ PHF} \text{.......................................}(2)$$

- $P15 = \frac{776}{4\ 0.8}$

= 243 ped

Half of the peak 15min demand could be on the platform just before trains arrived.

i.e, 121 passengers are on the platform

Then, LOS of 2016 = current platform area/peak hour flow

$=85m^2/\ 121\ ped$

$= 0.70m^2/ped$, LOS C

- ✓ Benches (assuming to Provide a minimum of 4 benches per station) , information displays, advertising Box, trash receptacles A=5m^2
- ✓ Platform is 60m long on both sides.
- ✓ Provide 0.5m buffer next to platform edges
- ✓ Unused platform space: 5m2
- ✓ Buffer space along the edge: 60*.5 = 30m2

NET EFFECTIVE AREA FOR STATIONS (EW1,EW8,EW10,EW12)= 150M2-65M2=85M2
NET EFFECTIVE AREA FOR STATIONS (EW16,EW17,EW19)=210M2-65M2=145M2
Buffer area along physical obstruction : 30m2

A=65m2(unusable platform area)

Table 4.18 - Evaluation of LOS of the proposed platform by considering unused spaces of E W 1 station.

Station	Year	P15	Half of the peak 15min demand	unused platform area(m2)	Current platform area(m2)	Net effective area(m2)	LOS (m2/ped)	LOS
EW1	2015	222.6909	111.3455	65	150	85	0.76339	C
	2016	242.7331	121.3666	65	150	85	0.700358	C
	2017	264.5791	132.2895	65	150	85	0.64253	D
	2018	288.3912	144.1956	65	150	85	0.589477	D
	2019	314.3464	157.1732	65	150	85	0.540805	D
	2020	342.6376	171.3188	65	150	85	0.496151	D
	2021	373.475	186.7375	65	150	85	0.455184	D

Table 4.19 - Evaluation of LOS of the proposed platform by considering unused spaces of E W 8 station.

Station	Year	P15	Half of the peak 15min demand	unused platform area(m2)	Current platform area(m2)	Net effective area(m2)	LOS (m2/ped)	LOS
EW8	2015	84.10498	42.05249	65	150	85	2.021283	A
	2016	91.67443	45.83722	65	150	85	1.854388	A
	2017	99.92513	49.96257	65	150	85	1.701274	A
	2018	108.9184	54.4592	65	150	85	1.560802	A
	2019	118.721	59.36052	65	150	85	1.431928	A
	2020	129.4059	64.70297	65	150	85	1.313695	A
	2021	141.0525	70.52624	65	150	85	1.205225	A

Table 4.20 - Evaluation of LOS of the proposed platform by considering unused spaces of EW 10 station.

Station	Year	P15	Half of the peak 15min demand	unused platform area(m2)	Current platform area(m2)	Net effective area(m2)	LOS (m2/ped)	LOS
EW10	2015	430.0591	215.0295	65	150	85	0.395295	D
	2016	468.7644	234.3822	65	150	85	0.362656	D
	2017	510.9532	255.4766	65	150	85	0.332711	D
	2018	556.939	278.4695	65	150	85	0.30524	D
	2019	607.0635	303.5317	65	150	85	0.280037	E
	2020	661.6992	330.8496	65	150	85	0.256914	E
	2021	721.2521	360.6261	65	150	85	0.235701	E

Table 4.21 - Evaluation of LOS of the proposed platform by considering unused spaces of E W 12 station.

Station	Year	P15	Half of the peak 15min demand	unused platform area(m2)	Current platform area(m2)	Net effective area(m2)	LOS (m2/ped)	LOS
EW12	2015	426.3135	213.1568	65	150	85	0.398768	D
	2016	464.6817	232.3409	65	150	85	0.365842	D
	2017	506.5031	253.2515	65	150	85	0.335635	D
	2018	552.0884	276.0442	65	150	85	0.307922	D
	2019	601.7763	300.8882	65	150	85	0.282497	E
	2020	655.9362	327.9681	65	150	85	0.259172	E
	2021	714.9705	357.4852	65	150	85	0.237772	E

Table 4.22 - Evaluation of LOS of the proposed platform by considering unused spaces of EW 16 station.

Station	Year	P15	Half of the peak 15min demand	unused platform area(m2)	Current platform area(m2)	Net effective area(m2)	LOS (m2/ped)	LOS
EW16	2015	538.2265	269.1132	65	210	145	0.538807	D
	2016	586.6669	293.3334	65	210	145	0.494318	D
	2017	639.4669	319.7335	65	210	145	0.453503	D
	2018	697.0189	348.5095	65	210	145	0.416058	D
	2019	759.7506	379.8753	65	210	145	0.381704	D
	2020	828.1282	414.0641	65	210	145	0.350187	D
	2021	902.6597	451.3299	65	210	145	0.321273	D

Table 4.23 - Evaluation of LOS of the proposed platform by considering unused spaces of EW 17 station.

Station	Year	P15	Half of the peak 15min demand	unused platform area(m2)	Current platform area(m2)	Net effective area(m2)	LOS (m2/ped)	LOS
EW17	2015	528.2383	264.1192	65	210	145	0.548995	D
	2016	575.7798	287.8899	65	210	145	0.503665	D
	2017	627.5999	313.8	65	210	145	0.462078	D
	2018	684.0839	342.042	65	210	145	0.423925	D
	2019	745.6515	372.8257	65	210	145	0.388922	D
	2020	812.7601	406.3801	65	210	145	0.356809	D
	2021	885.9085	442.9543	65	210	145	0.327348	D

Table 4.24 - Evaluation of LOS of the proposed platform by considering unused spaces of EW 19 station.

Station	Year	P15	Half of the peak 15min demand	unused platform area(m2)	Current platform area(m2)	Net effective area(m2)	LOS (m2/ped)	LOS
EW19	2015	461.9532	230.9766	65	210	145	0.627769	D
	2016	503.5289	251.7645	65	210	145	0.575935	D
	2017	548.8465	274.4233	65	210	145	0.528381	D
	2018	598.2427	299.1214	65	210	145	0.484753	D
	2019	652.0846	326.0423	65	210	145	0.444728	D
	2020	710.7722	355.3861	65	210	145	0.408007	D
	2021	774.7417	387.3708	65	210	145	0.374318	D

4.4 Discussion and Improving Techniques

Based on the Preliminary Design for Ethiopia Addis Ababa E-W & S-N (Phase I) Light Rail Transit Project, the station platform area is calculated based on the predicted passenger flow (long term) of passenger flow data.

Based on the analysis conducted this study makes the following three improving techniques:-

1) Extension of platform length.

Platform length is the distance of the station running parallel to the flow of vehicles. Generally, length is easier to accommodate than width.

In our current situation, the size of platform is 60m in length and 2.5m wide and based on the analysis conducted on previous chapters, the situation worsen when the analysis considers basic station facilities and approaches to the long term predicted passenger flow. Based on the resulting analysis, the stations which has lower LOS value can be improved by extending the length of platform and besides all ground stations on EW line has sufficient space to extend on both directions and this will allow also multiple vehicles to serve the station without interfering with one another. But for the elevated stations this improving techniques may not be workout because the space is limited and it's also difficult to access easily because it has only one entrance and the line is shared with SN line.

Figure 4.10 Typical ground station (meri)

If the length of the platform increased, the LOS can be easily improved. For example for E-W 1 station, the length is 60m and extending it by 10m then the total length will be 70m.

Calculate total area required

- Passenger waiting area: 70*2.5=175m^2
- Queue storage: 0 m^2
- Unused platform space: 5m^2
- Buffer space along the edge: 30m^2
- Buffer area along physical obstruction : 30m^2

A=65m^2(unusable platform area)

Net effective area=175-65=110m^2

Then, LOS of 2014 (initial stage) = net effective area/peak hour flow
= 110m^2/ 102ped
= 1.08m^2/ped, LOS A

For 2015= 653*1.09= 712ped/hr

$$P15 = \frac{Ph}{4\ PHF} \quad \text{..........(2)}$$

- $P15 = \frac{712}{4\ 0.8}$

= 223ped

- Half of the peak 15min demand could be on the platform just before trains arrived.
  i.e, 111 passengers are on the platform

Then, LOS of 2015 = current platform area/peak hour flow
=110m^2/ 111ped
= 0.99m^2/ped, LOS B

So, the difference is as shown bellow.

Table 4.25 - E-W 1 station LOS without extending the line (L=60m)

Station	Year	P15	Half of the peak15min demand	Unused platform area (m2)	Current platform area (m2)	Net effective area (m2)	LOS (m2/ped)	LOS
E-W1	2015	222.69	111.34	65	150	85	0.76	C
	2016	242.73	121.36	65	150	85	0.70	C
	2017	264.57	132.28	65	150	85	0.64	D
	2018	288.39	144.19	65	150	85	0.58	D
	2019	314.34	157.17	65	150	85	0.54	D
	2020	342.63	171.31	65	150	85	0.49	D
	2021	373.47	186.73	65	150	85	0.45	D

Table 4.26 - E-W 1 station LOS with extending the line to (L=70m)

Station	Year	P15	Half of the peak15min demand	Unused platform area (m2)	Current platform area (m2)	Net effective area (m2)	LOS (m2/ped)	LOS
E-W1	2015	222.69	111.34	65	175	110	0.98	B
	2016	242.73	121.36	65	175	110	0.90	B
	2017	264.57	132.28	65	175	110	0.83	C
	2018	288.39	144.19	65	175	110	0.76	C
	2019	314.34	157.17	65	175	110	0.69	D
	2020	342.63	171.31	65	175	110	0.64	D
	2021	373.47	186.73	65	175	110	0.58	D

2) Reducing the headway time (increasing frequency of trains).

Currently on the design manual the headway time is 6min [12]. To reduce waiting time and congestion on platform area, it’s a better solution to increase the frequency of trains by reducing the headway time. To balance the frequency of trains with waiting passengers, it needs fixed and accurate time schedule and considering the distance that one train can cover the whole line and the reduced headway time it’s also necessary to increase the number of trains so that it will balance with the headway time and distance. But this may cause complication on train management, traffic management especially at grade crossings and it may also needs additional manpower to control the traffic flow. Generally, this technique refers only the station platform capacity not other complications.

3) Increasing the number of cars (extending the length of the train).

This technique is directly related with extending the length of platform, i.e when the number of car increases the line needs to be extended so that it can accommodate more passengers and the train will also have a capacity to handle the waiting passengers.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The analysis showed the difference on the level of service when the platform has basic station facility and without a facility over the years.

The condition on the platform during the early years is stable because the number of passengers is almost constant. The resulting levels of service of platforms by considering all the proposed platform area ranges between A - D, LOS D starts from year 2017 for the stations (EW10,EW12,EW16,EW17 and EW19). And for the same stations which considers basic station facilities, the LOS ranges from D – E. The level of service reaches its lowest value for the year (2019-2021) especially on platforms EW10 and EW12, this is basically the result of increasing passenger flow and the analysis considers basic station facilities (benches, trash receptacles and advertising boxes). This shows that when the year increases and with facility provision, the situation on the platform will not be very convenient or comfortable for the alighting and waiting passengers.

5.2 Recommendations

During the process of the analysis some weak points appeared. First, the analysis was conducted only by considering the predicted passenger flow (long term). This could raise a question about the level of service of actual passenger counts on each station. But for as an overview the analysis showed current and future level of services of selected station platforms.

More research should be done on actual passenger counts to calculate the LOS. It would be interesting to find how the level of service drops or increases during the peak hour of actual count. And when the LRT becomes operational close observation and data handling in each station should be done so that it will be easy to predict the LOS of the stations.

Since, the light rail transit in Ethiopia is new there should be standards and manuals for the future which basically includes the general condition of stations based on the actual data’s that will be taken when the LRT becomes operational.

From physical observation also, it’s a better way if Addis Ababa LRT has basic station facilities and pedestrian crossing. For stations in the median of a roadway, access to platforms should be clearly marked and managed with traffic signals at roadway intersections, signage and railing or fencing.

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