ADDIS ABABA INSTITUTE OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

ADAPTATION OF RAILWAY STATION DESIGN PARAMETERS FOR ETHIOPIA NATIONAL RAILWAY NETWORK

By

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Abstract

Railway transportation, which is needed in the achievement of effective development, is an efficient, cost-effective and it is environmental friendly transport system. An important subject in the planning of a new railway line is the design of the railway stations since they affect the capacity, flexibility and the safety of the rail transport system. However, Ethiopian railway transport has no standardized guidelines to design the railway stations.

The main objective of this thesis is to adapt station design parameters standards for Ethiopia national railway system by comparison of (AREMA, Chinese and Ethiopia standard proposed by Russian) based on Ethiopian topography, climatic condition, economy and interoperability to other countries. Hence, this study helps to provide: safe, cost effective and convenient access to train services, and to make convenient operation and management of the station and clear circulation routes with minimum travel distances.

In this study an attempt was made to framework for national railway station design specifically station locations along the route and track and platform technical aspect for Ethiopian national railway network. To achieve the objectives the research had a methodology of a task involving literature review; comparison of different countries standardization practice, and then adaptation of station design parameters for Ethiopia on the basis of topography, and climatic conditions.

In conclusion, economic and topographic aspect of station locations, track and platform technical aspect are basis for identifying station design parameters for Ethiopian national railway system. In the planning of a new railway line it has to be decided where stations should be located and where in the cities. Those decisions are governed by factors such as topography. In addition this capacity (demand), costs, city planning (future developments) and travel time requirements are factors to locate stations. In track and platform technical aspect; Number of arrival departure tracks, placement of platforms in relation to tracks, gradient in station and platform dimension (length, width and height) are appropriate parameters for Ethiopia national railway station design.

Key Words: Station design parameters, station locations, track and platform technique.

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1. Introduction

1.1. Background

Transport or transportation is the movement of people, animals and goods from one location to another. Transports create time utility as well as place utility. It is performed by modes, such as air, rail, road, water, cable, pipeline and space. The field can be divided into infrastructure, vehicles, and operations. It is important because it enables trade among peoples, which is essential for the growth of both economy and society of countries.

In addition these infrastructures play crucial roles in the effort to achieve the goals of poverty eradication and sustainable development. Universally it is also witnessed that both cargo volume and loads are going on increasing from year to year with alarming rate all over the world. Such growth demands better transportation means for efficient and reliable transport of without delay.

Railway transportation is one of the important infrastructure facilities that are needed in the achievement of effective development; and provides an efficient, cost-effective and environmental friendly transport system which can quickly haul large volumes of goods which are not easily transported through motor vehicles for long distances with safety, comfort and convenience.[69]

Before 100 years, Ethiopia has a 781-kms meter gauge diesel railway jointly owned by the Ethiopian and Djibouti Governments and is operated by Chamin de Fer Djibouti-Ethiopian (CDE) that stretches from Addis Ababa to Djibouti and served almost 100 years. During its time it has served as a major means of passenger and freight transport to the eastern part of the country and contributed to the establishment and expansion of major economically active urban centers along its line like Adama and Dire Dawa. This line passes through 32 cities and it has 34 stations out of which Addis Ababa, Dire Dawa and Djibouti are the major one. While the main stations provide both passenger and freight services the rest provide passenger services only.[56]

Nevertheless, as time passed by its capacity deteriorated and currently it is out of service. Though, the government was trying to rehabilitate this railway and frequently signed an agreement with few companies, it did fail due to many reasons. Some reasons for the development of railway transportation on the existing lines were lack of maintenance, poor management, lack of commercial focus, dominant single line operation; insufficient infrastructure capacity and performance, tight curves and high gradients, lack of automatic signaling systems on major line sections and insufficient number of skilled and non-skilled staff employed are few among others. Both the passenger service as well as the freight service has been falling year after year. Since its inception, there has been minimal investment in the railroad assets. This has resulted in general deterioration of rail assets - both rails and rolling stock and has affected the system as a whole.

In addition to the low railway network connectivity like other developing countries [56] the existing line (Chemin de fer Djibouto -Ethiopien (CDE) is not good enough to facilitate transit trade and insignificant to transport passengers and small parcels of goods in the corridor.

Hence, to speed up the country's development effort, the government of Ethiopia has given a special attention to the transport sector in general and to the railway sector in particular. Thus, Ethiopia has planned to construct new standard Gauge (1435mm) railway network in phase I and II. This new railway lines has eight railway corridors and its total estimated length is around 5,000 km and expected to connect about 49 Ethiopian towns. Within these corridors many railway stations where passengers can get on and off trains and /or goods may be loaded or unloaded are expected to be designed and constructed. [1] A good station design will give due consideration to the location, role and function the station will play and the different users it will serve.

At present, railway stations perform a variety of functions among other such as meeting places, shopping centers and very often urban land mark. Railway Stations, the major component of any railway system are key to the success of the railway networks. A well positioned and designed station enables passengers to easily access the service they require safely.

To determine well positioned and design a railway station, design parameters are essential to design and construct safe, efficient and convenient stations. Therefore, station design parameters are essential for each station in order to identify the station's design objectives and to evaluate design proposals based on their specific purpose.[3] Therefore, adapting appropriate and functional railway station design parameters for the Ethiopia National Network is a timely need.

- Railway station design parameters are components that are needed to design railway stations to achieve objective and functions of stations.
- A railway station is defined as any place on a railway line where trains regularly stop to load or unload passenger or freight.

In this research an attempt was made to standardize guidelines to design railway station for Ethiopia National railway network.

1.2. Statement of the problem

The past couple of years saw Ethiopia registering accelerated double digit of economic growth. The growing economy demanded the expansion for various utilities and infrastructural facilities in various sectors, among which railway transportation is one. In line with this there is a strong need for having better transport access to the various corners of the country in order to exploit the underutilized potentials of the country.

However, as some studies indicate 70% use of transportation in the country is traditional non-motorized, while modern motorized transport constitutes only a small per cent. Apart from that, the increasing foreign trade necessitates the country to spend a large amount of money for transportation. In some documents, it is stated that Ethiopia spends about 18% of its imported value and 8% of its export earnings on transportation that in turn will affect the country's competitiveness in the international market.

The significance of railway systems in an economy is paramount. This led Ethiopia to see railway transport as an important alternative in the country's transportation system.

Rail transports carry passengers and goods in the amount of mass at a relatively less expensive cost. It is also energy efficient, land saving, high safety level, environmentally friendly, comfortable, adaptive to technology development, and free from traffic jam. Those characteristic makes railway primary public transportation.

Despite the above benefits in developing countries like Ethiopia, the rail network connectivity is not only low but also it is not good enough to facilitate transit trade; most section of the existing line except for some kilometers is more or less not functional for so many years now. There are vast movement of the people, huge import and export of goods which are not efficiently supported by railway transport. In addition to less availability of railway transport in Ethiopia, the available and old one is not modern; has low capacity and is insufficient to facilitate transit trade; and also Ethiopian railway transport has not standardized guidelines to design the system.

Currently, Ethiopia in its first phase of Growth and Transformation plan has targeted to construct around 2510 km of railway line. However, Addis/Sebeta – Meiso- Djibouti line design based on Chinese standard and Awash- Wolidia- Hargebeya- Mekele line designed by Turkish based on European standard. Along this line many stations with different purposes are expected to be constructed. Hence, unlike the previous one it is paramount important to Ethiopia to adapt its own railway station design parameters rather than importing and using them without contextualizing the objective realities of the country. Similarly, as literature shows, station design parameters standards are not necessarily the same in all countries. Countries need to have their own peculiar railway station design parameters which emanates from the context of that country.

Therefore, unless appropriate design parameters are adapted and recommended, those many stations which are going to be constructed will not serve the purpose they are meant for. So in this study an attempt was made to adapt stations design parameters for Ethiopia national network.

1.3. Objective of the Research

Since the railway transport is becoming a reliable and regular form of transporting bulk goods and train travel brings much safety, convenience and comfort to passengers than other means of transportation system; this study was done in this sector in order to do further research in the development of modern system of railway transportation in Ethiopia.

The main objective of this study is to adapt a railway station design parameters for the Ethiopia National railway system. And more specifically the study is intended to meet the following specific objectives.

- To review the practices and experiences of selected countries in railway station design.
- To identify and know the major station design parameters standards among countries.

- To adapt and recommend appropriate railway stations design parameters for Ethiopian National rail way system.

1.4. Research Methodology

The research methodology for this study involves the following major tasks: literature review; comparison of different countries station design parameters practice; and different documents that contribute for standardization of guidelines for railway system in Ethiopia. The collected document review includes topographic map, climatic conditions, Ethiopia economy and interoperability of Ethiopia national railway network. Then, adaptation of Ethiopian railway station design parameters is derived taking Chines standard, Ethiopia standard proposed by Russia and AREMA. Finally conclusions and recommendations for future work are presented.

1.5. Scope of the research

Adaptation of station design parameters for railway system of Ethiopia is limited to mixed railway stations excluding depot /terminals stations. For this mixed stations, the study basically concentrates on station parameters such station locations, track and platform technical aspect (track and platform arrangement, number of parallel tracks and platforms, effective length of arrival departure tracks, gradient on stations, platform dimension and distance between tracks and between tracks and platform edge). This thesis also limits its focus only to those stations which mainly serve as passenger and freight (mixed) along the line.

2. Literature Review

2.1. General

A railway station, also called a railroad station or train station is a railway facility where trains regularly stop to load or unload passengers or freight. Sometimes only one of these functions is carried out at station and accordingly it is classified as flag station or block station. In the case of flag station there are arrangements for dealing with traffic but none for controlling the movement of trains. In the case of block stations, a train cannot proceed further without obtaining permission from the next station and traffic may or may not be dealt with. However most railway station performs both the functions indicated above. [2]

Station is a basic production unit of railway transportation, integrating technical equipment relating to transportation. Various passenger traffic service and goods traffic service, such as passengers' boarding and alighting, consignment, loading and unloading, delivery and safekeeping of goods, etc, can only be realized at the station. Various technical operations of railway transportation , such as train reception and departure, passing, overtaking, disassembly and marshalling, change of locomotive and train crew, train technology and freight examination , are all done at stations,.[2]

In most developed countries, where railway is dominant means of transportation millions of people use the railway stations every day. Towns and cities have often developed around them, placing railway stations in the heart of many communities. The stations can often help to provide an identity or symbol for the towns or cities; it can act as a point of reference as well as a civic amenity for people who want to use the stations' facilities, whether they are travelling or not. Done well, their design and operation helps to facilitate the success of the national rail network.[3]

A successful railway station will add to the passenger experience as well as support the economic, social and environmental benefits of rail. Their effective integration with other modes of transport and the surrounding areas can provide for an end-to-end journey experience that makes sustainable public transport a real alternative to private vehicle usage. Given these varying demands on stations, it is vitally important that they are properly selected, planned, designed and improved in a manner that recognizes all that they have to offer. [3]

2.2 .Historical Background of Railway station

2.2.1 History of Railway Stations in the world

In medieval times people mostly travelled by foot or horseback and any form of transportation was mainly for moving goods. The history of Railway is highly connected with the result of industrial Revolution. The first Railway was laid down in the 17th and 18th century for horse drawn train of wagons in collieries and quarries “Hauling ways”. The industrial revolution progressed, the new idea was develop by adding railway consisted of rails, locomotives, cars and terminal where people wait for train and pay for the journey. Then few stations began to build and this has continued through the ages till the present day. [1]

As the industrial revolution progressed, the Railway station at the onset started off as a single pole among a number of trees and has developed to platform with roof. This development now a day transfers into a complex building Cinema hall, shopping mall, Restaurants, stairways, lifts, escalators and what not; and all this due to technological advancements, Social changes and changes in the economical structure of the countries. [4]

In addition, according to the importance of the station or the pressure of passenger traffic, provision is made for separate waiting rooms for passengers of various classes, and for men and women, and for refreshment rooms and restaurants, the platforms, covered or uncovered, vary in number and in dimensions, separate station offices, platforms, and sheds are generally provided to deal with goods traffic. Overhead bridges and in recent time’s underground subways enable passengers to cross from one platform to the other. [1]

Various other civil engineering skills were also involved in the construction of early railways. These include railway terminal, building of bridges, tunnels and gravity walls as well as drainage. One of the most important aspects of a railway terminal is its design parameters. Always, the design of a station building connects the viewer with the period in history, when it was built. In some regions of countries, the terminal was made to look like a house, fortress or church etc. One may notice that the form of the railway station and use of materials and finishes and the visual aspects are all dependent upon the country, its climatic conditions, social structure economical condition etc. For instance, in third world countries, stations have never been designed until recently. They have developed on their own, with the changes in functional requirements. On the contrary, in countries like America and Britain, most of the stations have been designed by qualified or specialized people. [4] Below are pictures of stations depicting their historical evolutions through as time goes on.

Figure 2.1: Old railway stations

Figure 2.2: Modern railway stations

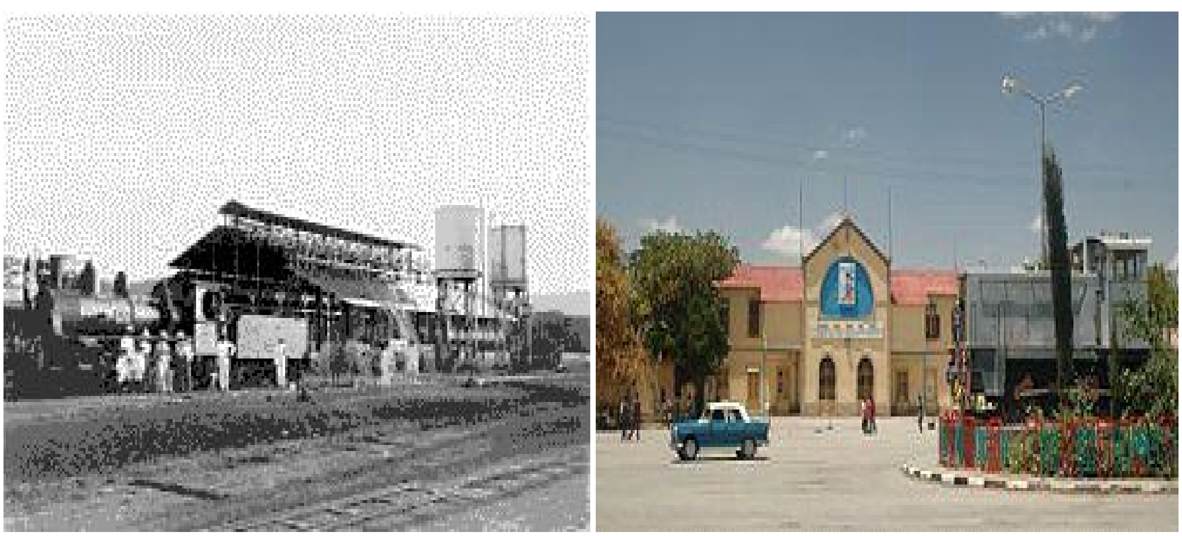
2.2.2 Railway Stations in Ethiopia

The old diesel railway of 781km which is single track, a meter gauge (1000 mm), with steep gradients on the long haul up from sea level to the Ethiopia highlands was owned by Ethiopian government jointly with the government of Djibouti that operated by CDE (*Chemin de fur Djibouti Ethiopian*) is now almost abandoned due to many reasons, and by now it is deteriorated and malfunctioning.

The rail line passes through 32 cities between Addis Ababa and Djibouti. It has 34 stations out of which Addis Ababa, Dire Dawa and Djibouti are the main stations and they provide both passenger and freight services the rest provide passenger service only. [5]

Figure 2.3: Ethio- Djibouti railway line [5]

However, all the stations along the old Ethio- Djibouti railway system where not critically selected and designed initially. Due the course of time as technology advances and needs increases, some of the stations have been showing progress. Typical instance in this regard is the Dire Dawa railway terminal, La Gare is one of these progresses. The figure 2.4 shows below.



(a) At the onset (beginning) (b) After innovation

Figure 2.4: The progress of old Dire Dawa railway station (a) 1st train station in Dire Dawa (b) Progressed station in Dire Dawa

(a)

(b)

(c)

Figure 2.5: (a), (b) and (c) are Ethio -Djibouti Old Railway station

The old railway stations along the line do not function anymore because of many reasons and to quest its developmental needs now Ethiopia has launched the construction of about 5,000 km new standard gauge (1435mm) railway network which aims to link the capital, Addis Ababa, to various regions of the country which is part of the country's five-year transformation plan. [1]

2.3. Railway station Design parameters

2.3.1 Introduction

In planning stage of a new railway line, the main part is the design of the railway stations because they affect the capacity, flexibility and the safety of the rail transport system.[20] A well positioned and designed station enables passengers to easily access the service they require. In other word, stations are key to the success of the railway networks. Therefore, railway stations design requires different data such as annual traffic tonnage, number of train to be accommodated, additional track requirement, train length and locomotive type, train width and structure gauge, design speed, required platform capacity, available area and functions of stations etc. [13] Therefore, station design parameters are criteria or principle to design railway terminals.

The economic and topographic aspects of station design are related to station location and station gradient. In the case of track and platform technical aspects, platform and station dimensions, passenger service and comfort factors are economic aspects for railway station design parameters.[21] Those aspects will be discussed in detail in the next sub topic.

In the design parameters of railway stations there are a large number of aspects that should be considered. The aspects are connected to different levels of detail and are therefore interesting in different stages of the designing process. This part of review literature shows the aspects of station design parameters that have been found in the studied literature. There are number of aspects that can be considered in railway station design parameters, However some aspects pertinent to this study are mentioned below to provide a more complete picture of the subject.[13]

2.3.2 Economic and Topographic Aspect

2.3.2.1 Railway Stations Location

Railway station location is defined as locating places along a route or line at which train load or unloads passengers or goods. The station locations has economic implication as it is determined/

influenced by a number of factors such as costs of cut and fill materials and accessibility to other modes etc.

The location of stations in rail transport is an important and strategic aspect for the success of the system as a whole. Hence, Railway stations must be well located to benefit from the advantages of the reduced travel times offered and at the same time, they must be well connected with other mode of transport.[30] This implies that, market accessibility, topography and economic factors significantly affect the location of a station. Therefore, when we design railway station, it needs to be considered as design parameter. Most of the times, the station is the first image of the customer about railway transport. Just like airports, railway stations have to transform into profit-generating hubs.[30]

A successful station is the product of well located stations, designed infrastructure, information and signing systems appropriate for the purpose, and a clear well promulgated management philosophy. Therefore, a railway station's location in a built environment and its degree of accessibility is essential to reach as many travelers as possible. [11] By asking local residents for opinions such as public comments to identify what kind of station they desire, we build attractive stations with their cooperation which are perfectly integrated into the surrounding environment, reflect local climates and cultures, or serve as landmarks. [12]

A successful railway system will only result from a clear understanding of the interaction between the train service and the stations it serves, both in normal and abnormal operating conditions. Station jamming may not always be remedied simply by the provision of more space. In many cases the solution may often lie in running a different pattern of train service, different signing of passenger routes or the application of changed management methods. [11]

Hence, in the planning stage of a new railway line it has to be decided where stations should be located. That includes also how many stations the line should have in short and long term and in which cities, and also where in the cities the stations should be located. Those decisions are governed by many factors such as population, labor market, and city planning and travel time requirements between stations. [12]

Beside station location, it needs to identify station site selections based on many factors such as the site should be fairly leveled ground which means that permissible maximum gradient and it should be well drained.[11] Another factors to be considered for railway station site selection are available of sufficient land for the purpose of future extensions along both sides, the location of station yards should be located neither near a curve nor on a curve but it can be on a summit.[ibid]

Based on the above mentioned factors, the station site should be well developed and efficient transportation system which leads the people and their goods to station with much ease and easily accessible from city or town or vice versa.[12]

2.3.3 Track and Platform technical Aspect

2.3.3.1 Track and platform arrangement

The track and platform arrangement at a station is one of the most critical elements determining the operational efficiency and capacity of the station. In addition, the sitting of new stations must carefully consider the future requirements for tracks and platforms arrangement.[32]

Placement of platforms in a relation to tracks can be classified as center platform (sometimes referred to as an "island" platform), side platform relative to the train. Other platform types are variations or combinations of center and side platforms (Bay platform).[22] Large railway station have their railway platforms are the combinations of center and side platforms. It depends on the number of track inside the station, traffic volume, design speed, station type, etc [22]

Center/ Island platform location is between tracks and passengers board and alight to and from a train from either side of a platform. To determine the capacity of the platform is by assuming two trains discharging simultaneously.[34]

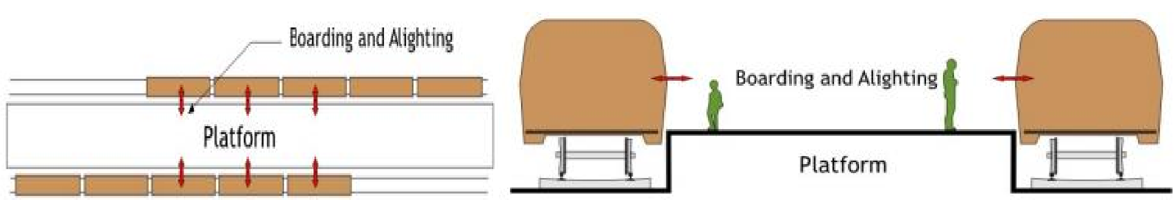


Figure 2.6: Center/island Platforms and track arrangement [34]

Advantages of center platforms

- ✓ Deferred directional decision-making, which simplifies way finding, free flow of customers, and cross-platform transfers.

- ✓ More efficient use of space, since customers traveling in both directions can share platform space and vertical circulation escalators.
- ✓ Platform width that may be less than combined width of equivalent side platforms; the resulting station may be smaller and less expensive.
- ✓ Fewer elevators to the platform level are required to provide equivalent accessibility.
- ✓ Possible reduction in the need to cross oncoming traffic (in order to reach vertical circulation) when a single concourse is provided.
- ✓ Ability of passengers to change train directions without crossing tracks and changing levels.

Disadvantages of center platforms

- ✓ Queuing for vertical circulation must mix with queuing for vehicle boarding along the platform.
- ✓ Limited options for elevator placement (than for side platform stations) since elevators must be placed in the center of the platform width.
- ✓ Less accessible wall area available for signage, advertising, and art.
- ✓ Limited flexibility for future expansion (future connections, capacity, space, VCEs).
- ✓ Less ability to accommodate increased vertical circulation demands and surges in reverse commuters.

Side platform: The arrangement of **s**ide platforms is to provide access to trains along one side of the track. The passenger must decide between platforms based on their direction of travel prior to descending to platform level. [34]

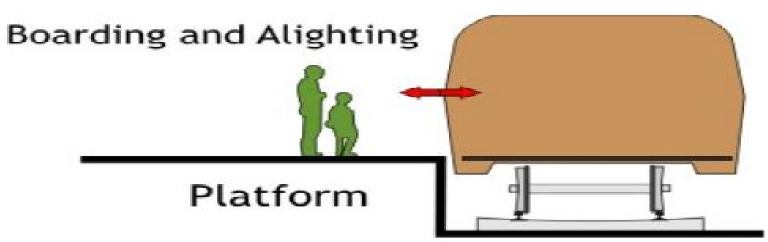


Figure 2.7: Side Platforms and track arrangement [34]

Flow- Through platform: Flow-through platforms allow passengers to board and alight the train from dedicated platforms, thereby eliminating conflicting passenger flows. Flow-through platforms speed boarding and alighting and therefore reduce vehicle dwell time at the platform.[34]

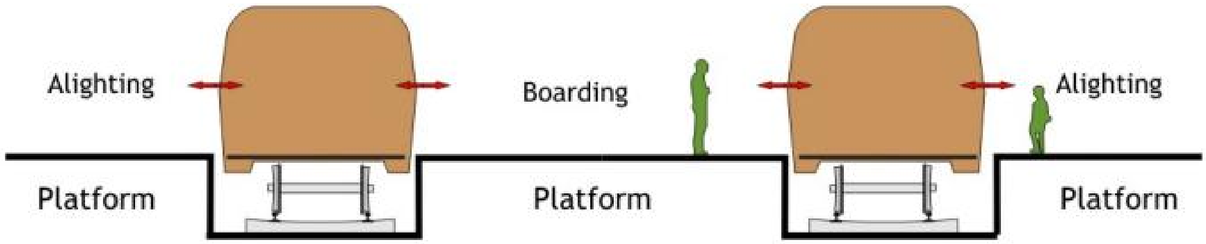


Figure 2.8: Flow-Through Platforms [34]

Advantages of flow-through platforms

- ✓ Unidirectional customer flow, which eliminates conflicts between boarding and alighting customers
- ✓ Facilitation of movement of customers with baggage
- ✓ Greater capacity for vertical circulation and emergency egress

Disadvantages of flow-through platforms

- ✓ Less efficient use of VCEs
- ✓ Operational complexities

2.3.3.2 Number of Parallel tracks and platforms

Determining numbers of tracks and platforms are basic and important parts of a railway station design parameters. For each station it must be decided, how many tracks and how many platforms there should be and also how the tracks and platforms should be arranged. This is because each railway station has its own purpose, functions and facilities. However, it is difficult to find any general guidelines for this part of the station design. But every railway line has its own unique conditions in terms of for example traffic mix and number of passengers.[12]

The purpose of designing station track and platform is used to accommodate the planned schedule of passengers and trains stopping at that station, trains passing through it, sections combining or splitting, special cars on or off, locomotive changes, delayed trains, special movements, and future increases in traffic. In general, to decide the number of tracks required for a railway station it is necessary to know the planned traffic intensity and traffic pattern since that decides the required capacity of the station. [12]

For instance, when using a single track for multiple trains between two stations, it may happen that a train must wait for a long time before it can use the track, especially when the track is long. The reason is that only one train is allowed on a single block of tracks to prevent train collisions.

To solve this, it advisable to construct additional tracks so that trains can pass each other in other places than just the station. One way to do this is to add one or more passing sidings and another way is just double the complete track. The passing siding is a short section of track that is partly doubled, guarded by signals. It is a cheap solution, but it still allows for delays when trains don't synchronize well enough. Key to the passing siding is to make it long enough that it can fit the longest train that will use it.

2.3.3.3 Effective length of arrival departure tracks and Gradient in station

In a railway station, there are different types of tracks to serve different purposes. To achieve good efficient in break-up and make –up operations, the arrival tracks, sorting tracks and departure tracks are laid out in series. The sorting track will have an effective length, which is long enough to accommodate whole sections of a train.

Besides the main line, station tracks are (arrival- departure track, lead track, freight track, vehicle storage track) turnout line (branch, special line and industrial enterprise line) and tracks for special purposes (safety line and refuge siding).

Based on their function generally tracks are categorized into the following:-

- **Main track**:- track that handle train movements between and through stations and terminals as opposed to switching and terminal movement. It generally refers to a root between two towns as opposed to a root providing suburban or metro services for capacity reasons. Main line track is typically operated at higher speed and higher train volumes than branch lines and generally built and maintained to a higher standard than yards and branch lines.

- **Arrival-departure track**:- are utilized to receive and send passenger trains or freight trains. The number of arrival- departure track depending on main track, number of train or transport amount and its characteristics.
- **Passing track-** track connected to the main track on both ends and allowing a train to stop either for commercial reasons (in a station for example) or for operating purpose (in order to deal with delayed train or train with technical incident but also to allow train overtaking).
- **Loop track-** is a branch from the main line that again terminates at the main line. Loops can have different arrangements based on the specific job they are intended to perform. The main purpose of loops is to enable stations to cross each other.
- **Slip siding**:- It is a short length siding to be provided outside the outermost facing points having capacity to hold few wagons. Normally position of the points remains set and locked for the slip siding concerned and generally protected by a stop signal/ point indicator. It prevents the obstruction of the block section by holding any wagon, which may escape accidentally or inadvertently from the station. [23]
- **Catch siding: -** the catch siding is one of the separating equipment of approach road. The catch siding is to prevent trains on special sidings or station tracks from conflicting with trains on main lines without passing through the open approach road. Effect length of the catch siding should not be less than 50 m, the slope should be designed as an upslope of plane oriented bumper post. Catch siding need to be arranged in following places:
- **Refuge siding** :- To prevent trains on the abrupt long slope from overturning and conflicting with other trains in the front station by losing control because of brake device failure, the refuge siding should be arranged.
- **Through track:** Some trains may not require any switching at all. A mainline bypass for trains that don't stop, or a storage siding or yard for trains that only change crews or locomotives keeps this traffic out of the gridlock

In this sub section the main and only focus on, effective length of arrival departure track in a station. This is because unlike the other tracks the effective length of a station track is used where trains and wagons can stop without interfering nearby tracks to allow traffic route. Generally to determine the effective length of arrival departure track the following factors should be defined:[28]

- Position of fouling post and starter signal.
- Connector of turnout stock rail.
- Transport Capacity of the line (locomotive and wagon type, Mass of wagons)

In addition, effective length of receiving and departure tracks can be determine length of station site on the basis of the long term or in the far future. However, the station size and architectural presence will vary from station to station; each will be uniquely sized accommodate the number of passengers, future growth, frequency of trains during peak times on typical days, and anticipated surges of passengers during special events.[10]

Gradient in Stations

Railway station gradient should be sufficiently flat due to prevent movement of standing vehicle and to prevent additional resistance due to grade. Due to these reasons station gradients are completely avoided on platform and maximum limit must be specified. In any arrival departure track form grade or gradient to provide uniform rate of raise or fall, to reduce cost of earth work and to reach different stations level. [26] Factors affecting critical gradients are hauling power of the engine and position of the gradient.[36]

Determination of train length

To calculate total mass of wagons (cars) factor of traction power of locomotive (kg-force), mass of locomotive (kg- force), traction resistance of car and locomotive and ruling gradient.

$$\frac{Frp}{wrp' + irp} = Q_{rp} \geq Q_W = \frac{Fpl - P(wo' + ir)}{wo'' + ir} \quad [29]$$

Where:- Q_W , Q_{rp} = Mass of train in the line and in the station respectively(kg- f)

$F_{rp,}$ F_{pl} = locomotive traction power (kg- f)

P = Locomotive mass (kg-f)

Wo”, Wo’(Wrp’) = traction resistance of wagons and locomotives respectively

i_{rp} , i_r = gradient in station and ruling gradient ($^0/_{00}$) respectively.

q_i = mass of a wagon

- Number of wagon (assume all wagons are the same type) $n = Q_{W} / qi$

Therefore, the total length of train $L_{tr} = n\, L_w + L_{loc} + 50m$

- Where, 50m indicate 25m to the left and 25m to the right for safety purpose.

2.3.3.4 Platform Dimensions

Platform is a level surface from where passenger board and alight from trains or loading and unloading of goods is done. Generally, passenger and goods platforms are provided at the stations and its number and location can be match with the arrangement of station building and passenger train arrival and departure tracks.[27]

Station platforms are an important part of the infrastructure of any railway system and proper design can give great assistance to good operation. As such functional and accessible paths of travel should be designed or considered first. To enable passengers to board and alight from trains in a safe and efficient manner, station platform therefore is one of the railway station design parameters.[41]

Platform Length

The platform length is a fixed dimension that determines the capacity of the railway system based on the operational needs of rolling stock currently operating across the rail network and for the type of rolling stock proposed in the future. [3]

All platforms should accommodate the full length of a typical train consist and allow for maximum flexibility. While the minimum required platform length will vary depending on the type of rail service provided, platform lengths should be as standardized as possible, both within the individual station, and across multiple stations serving a corridor.[42]

In other word, the length of passenger trains generally has to match the length of platforms, especially high-level platforms. These platforms cannot always be extended to suit extended train lengths due to bridges, tunnels, point work, narrowing track centers and stabling yards, though "selective door opening" can help long trains stop at short platforms.[70]

Platform Width

The dimension of the platform width will need to be ascertained to ensure that sufficient space is provided on platforms to allow: Passenger circulation to, from and along the platform; Operational and passenger facilities where provided, Passengers to wait for trains in relative comfort and provide protection from the weather (including sun, wind, rain). [33]

Platform width is in many aspects a matter of safety for the travelers. There must be enough spaces for passengers to move and reside on the platform without getting too close to the tracks.[45] There are several different factors that affect the necessary platform width, among others the expected amount of passengers that will use the platform simultaneously must be taken into account so that platform width has enough spaces. [45]

Platform Height

To the greatest extent possible, platform heights should provide level boarding, which not only supports compliance with accessibility requirements, but is also safer, more convenient, and moves passengers on and off trains more quickly, an important factor in reducing dwell times and speeding service. Level boarding platforms tend to reduce injuries due to the elimination of the steps that are required for boarding at low-level platforms. Level boarding platforms are considered essential for high speed railway stations for efficient performance.[67]

When determining the platform height during design, there are three primary considerations: the floor height of the passenger trains that use or will use the station; whether or not freight trains operate or will operate on the track adjacent to the platform.[43]

2.3.4 Passenger service and comfort factors

These parts of parameters to design railway station are not directly connected to the railway technology but it is important for the travelers comfort and service that are using the railway stations. In this station design parameters, passenger service and comfort factors are based on station facilities, modal transfer and accessibility.

The facilities available in stations vary from country to country depending on the level of socio economic development. As *Satish Chandra and M.M Agarwal(2013)* explain, Railway stations are important public spaces that allow all users, including the elderly and physically impaired, to use the station safely and comfortably. In many countries, people in the community view stations as a community facility and take an active role in maintaining the station. [13]

Facilities for passengers and goods in railway stations are one of the key parameters for both effective railway transport operation and passengers´ comfort. The range of needed accessory depends on many types of outer influence that may be stable or can be variable in time. By the station facilities it implies ticket offices, separate waiting areas, areas for short-time waiting, refreshment points, stores and shops and other supplementary commercial activities. [15]

Figure 2.9: Information display bored [3]

Hence, railway stations facilities, amenities and spaces for activities should be appropriate to the station ensure that persons of reduced mobility between station access points and trains via step-free routes and also to minimize congestion and be resilient to surges in demand and train service disruption. [14]

Railway is generally operated to land transport, against remuneration, passenger and freight. A railway station represents, simply a place where train to allow passenger to board or to alight, and freight to be loaded or unloaded. In addition, the station should be comfortable and aesthetically appealing, functionally efficient (efficient layout and planning of station will ensure efficient circulation) stations for the purpose of embarking and disembarking passengers, selling tickets to them, and allowing them to wait for the departure of their trains. Freight, too, has to be warehouses, loaded and off-loaded. Locomotives, passenger carriages and good wagons have to be maintained and serviced in workshops, and have to be stored on sidings. These activities are better accommodated in enclosed structures or at least under shelter, for weather protection, safety and access-control, the exception being the storage of carriages and wagons. [9]

A successful railway station will add to the passenger experience as well as support the economic, social and environmental benefits of rail. Integration with other modes and the surrounding area can provide for an end- to- end journey experience that makes sustainable transport and attractive to private vehicle usage. Hence, efficient connection between transport modes and services is a core function of stations.[3] Therefore, station should be located where they are well connected to other aspects of the urban or regional infrastructure. These mean a good central location in a town, a position where bus and road access is direct in the suburbs, and where interchange is easy with other form of public transport in a large city. It also makes sense to choose a site with good visual links, as actual prominence helps with the travelers perception of where the station is, and how it can be reached. Such considerations lead to public gathering space at the perimeter of stations.[48]

To make accessible for disables people, the station design should help the passenger to find their way around and separate facilities with suitable design by providing such as appropriate high ticketing window, disabled friendly toilet, and reserved car parking slots etc, [39]

Accessibility is an issue that concerns everyone. *Ross, 2000* [50] envisions that disabled people using railway stations are not only people in wheelchairs, but they include blind and partially sighted people, deaf people and those with poor hearing, people with learning disabilities, people with heavy luggage, people with young children, and elderly people. Impediments to access should not be considered only physically, but also psychologically. In addition to solving the problems of steps, curbs, stairs, long walkway, steep ramps, and narrow doorways, some psychological impediments needs to be identified and relieved at the design stage. Examples include fear of crowded conditions, perceived unhelpfulness of staff, unreliable provision of toilets, etc. Those demand attention from both railway operators and designers.[50]
Accessible station design is making places easy to use for all passengers and station users. Accessible design relates to stations, their amenities, surrounding context and information

systems that support movement, use and understanding. The Equality Act makes it a legal requirement to ensure disabled people are not discriminated against. Transport providers therefore have a duty to demonstrate reasonable efforts in reducing, or removing altogether, barriers to access or use, both to and within stations.[3]

Figure 2.10: Accessibility in the train station [ibid]

2.3.5 Railway Station Dimension

To allowing multiple tracks to accommodate passenger and goods the station dimension should be large. Because a larger station is that more tracks can be provided, increasing the number of arrivals and departures at any given time, thus increasing the passenger flow through that station. The more passengers in the station, the larger the waiting area needed. Near the waiting area there should be restaurants and shops so that passengers have options as to how to utilize their time spent at the station. Each of these sections adds up making for a larger station. [10]

Therefore, sufficient area is necessary for stations operationally, in addition to station commercial aspects where large amounts of passengers are expected. An important element to decide the scale of station is traffic demand capacity. Scale of station is planned based on total passenger volume per day which is estimated for 10, 15 and 20 years after operation starting. Future extension of station shall be taken into account because increase of passenger volume is feasible by the development of areas complemented by new railway lines.[39]

Basic factors that influenced Station dimensions are:- [10]

- **Train length:** the primary determinant of platform length
- **Platform type and number:** determined by operational needs
- **Track count:** a station with more tracks will be wider
- **Station function:** determined by operational needs, terminal or intermediate functioning
- **Vertical configuration:** elevated, at-grade or underground platforms will influence overall station height'
- **Patronage:** station circulation space, waiting areas, and passenger service facilities are proportionate to projected passenger loads i.e. more passengers necessitate more circulation area.
- **Fare collection:** method for separating paid and unpaid patrons
- **Internal interchange with other transit systems:** transferring passengers increase the needs for passenger circulation areas and shared facilities with bus, BRT and other rail providers
- **Future commercial provisions:** adjacent or integrated retail space will attract patrons
- **Site context:** zoning and existing buildings will influence station massing.

2.4 Practices of railway station design parameters in Ethiopia

Ethiopia has a 781-kms meter gauge diesel railway that stretches from Addis Ababa to Djibouti and served almost 100 years being owned by the Ethiopian and Djibouti Governments. This historical line was built by the initiative and the authority of Emperor Menelik II. The rail line passes through 32 cities between Addis Ababa and Djibouti and it has 34 stations out of which Addis Ababa, Dire Dawa and Djibouti are the main stations. This stations provide both passenger and freight services while the rest provide passenger services only.[55]

The average distance between the stations varies between 10 km and 47 km (Adigala to Mello).[56] Nevertheless, as time passed by this old line capacity deteriorated and currently it is out of service.

Figure 2.11: old railway station Addis Ababa and Dire Dawa [54]

Even though it is expected that all stations should have at least one second track to effect the crossing and overtaking of the trains, With exception of the main stations mentioned above, which are equipped with a proper passenger buildings, with adjoining offices for carrying out the various freight and passenger services, all the other stations have only a small single room building (approximately 15 m2), in which the station employee receives and/ or issues the telephone dispatches regarding the running of the trains.[56] The remaining station are shunting station, equipped with other material use for freight transport.

As discussed earlier for railway design, station location is one of railway station design parameters. In the old Ethio-Djibouti railway line, the stations are located based on freight traffic source, along flat terrain and city centered, with 0% station gradient of design speed for passenger and freight is 80km/hr and 60km/hr respectively.[56]

The other station design parameters are platform and track arrangement. In the old railway line the platform in all stations is sided platform designed and built without considering the traffic capacity and accessibility for disabilities.

The new railway lines which is expected to be completed in two phases comprises eight railway corridors and its total estimated length is around 5,060 km and expected to connect about 49 Ethiopia towns. [60]

The first phase of the lines are composed of five railway projects such as Addis Ababa - Djibouti Railway Project, Mekele - Woldia/Hara Gebeya - Semera-Tadjourah Port Railway Project, Addis Ababa - Ijaji-Jimma-Dima including Jimma - Bedele Railway Project, Awash- Kombolcha- Hara Gebeya Railway Project and Mojo- Shashemene-Arbaminich-Weyto Railway Project.[60] The second phase includes six projects, Jimma-Guraferda-Dima diorected to Boma , Ijaji-Nekemet-Assosa-Kumuruk, Mekele-Shire, Fenoteselam-Bahirdar-Wereta-Woldia, Wereta Azazo-Metema and Adama-Indeto-Gassera-Ginir.

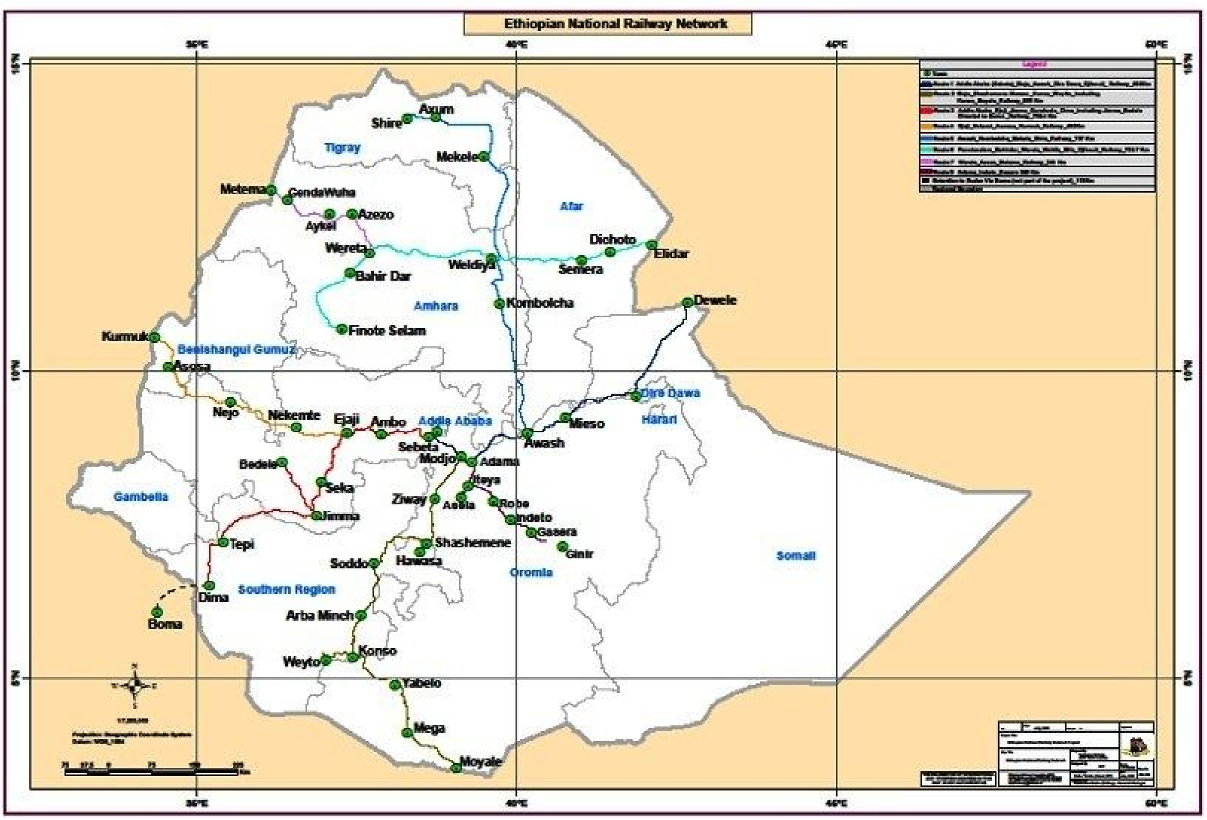


Figure 2.12: Ethiopia National Railway Network (NRNE)[60]

Addis Ababa - Djibouti railway line is the primary transportation link for mobility of goods and people. The route is also used for import and export purposes through Djibouti port. This railway line originates at Addis Ababa and terminates at Djibouti port traversing an approximate distance of 819 km. The line also needs operations and maintenance infrastructure viz. station buildings, maintenance sheds, manufacturing units, office buildings, freight and passenger terminals, utilities and other open areas, green belt etc. On any railway system there is a need to establish uniform standards for the design of stations. This applies to any system but is particularly relevant where new lines or stations are being constructed on existing systems.[61]

The Addis Ababa – Djibouti line will have thirty passenger stations (major, minor and very minor) and five freight (major and minor) stations. Among this eight stations will be major stations, of which three stations - one each at Addis Ababa, Djibouti and Dire dawa will be major passenger terminals. Out of the five freight stations, Mojo and Djibouti will be major freight terminals.[59]

Although Addis Ababa/ Sebeta – Djibouti railway line is designed and constructed based on Chinese standard. The practice of station design is useful for adapting ours parameters.[57] The parameters they used for railway station design are station locations, station tracks, track and platform arrangement, number of parallel track, gradient, effective length of arrival departure track, distance between tracks and between tracks and platform, passenger safety on the platform, station facilities, accessibility and other modes of transfer.[57] In case of Sebeta- Meiso railway line, all the above mentioned station design parameters are used.

Station Location

According to short term and long term traffic development (capacity), station locations are based on land availability, avoid excessive demolish, highway access and geological conditions of area and to handle passenger and freight service. Beside this, in the case of Sebeta – Meiso railway line appropriate number of station along the line is determine to satisfy the traffic demand.[57] Along the line Eight stations will be opened at first out of the total of 25 stations and planned to be established on the line in the short term and twenty more stations are planned to be established for the long term. The eight major stations of the line are Sebeta, Labu, Indode, Mojo, Adama, Metehara, Awash, and Mesio. The rest are small immediate stations or passing stations.[57]

The other factors considering station location in Ethiopia national railway network is function or purpose of station. According to Addis Ababa – Meiso railway line planning, locomotive inspection and repair base built at Indode Station; turnaround depot for stationed locomotives will be respectively built at Sebeta Station, Awash Station and Mieso Station; locomotive turnaround depot will be respectively built at Lebu Station, Modjo Station, Adama Station and Metehara Station.[63]

Track and Platform Arrangement

As mentioned before, the track and platform arrangement at station used to determine the capacity of station and efficiency of the operation.

For instance, based on Chinese standard the Sebeta – Mesio railway line platform arrangement is; Sebeta in double track, Metehara, Awash, Mesio in a single track, the stations has one side platform of 200m* 8m*1.25m which positioned to the side of a pair of tracks at a railway station. In addition Indode and Mojo station in a double track has single sided platform of 200m * 12m* 1.25m and 300m*10m*0.3m respectively.

In the contract agreement of ERC and agreed CREC that designing and construction for one overpass in stations with two platforms of 400m*12m*1.25m and 400m*10.5m*1.25m will be located respectively at Labu station and Adama station, and the rest six stations shall be designed and constructed as one platform.[59]

Number of Parallel stations Track

In the same mentioned line number of parallel station tracks; passing stations and intermediate stations in single track section shall be designed with 3 tracks (including main line). On the other hand a station which is handling freight service will be of 4-5 arrival-departure tracks according to traffic volume (including main line). When the traffic volume increases more, number of tracks in intermediate station is large, the number of tracks should be determined according to calculations with development conditions reserved.[59]

Effective length of arrival- departure track

Similarly, the effective length receiving-departure track will be 850m in the section with single-locomotive traction and 880m in the section with double-locomotive traction. In all station the distance between parallel tracks in a station is between 5m – 5.3m. [59]

Gradient in station

Addis Ababa – Mesio line the station site are on the flat slope; under difficult conditions, the intermediate station on the grade section not more than 0.1%, and the passing station or overtaking station can be set on the grade section not more than 0.6%.[59]

Platform and Station Dimension

According to traffic study in the Addis Ababa- Mesio corridor, the passenger flow density of Addis/Sebeta – Bishoftu Section is the largest with 10 pairs and 17 pairs of passenger train for the short term and long term respectively; the freight traffic volume of Metehara – Mieso Section is the largest with 806×10^4 t for the short term and 1732×10^4t for the long term. The traffic volume design result indicates that Addis/Sebeta - Adama Section of the line shall be designed as per double-track line, and single-track line for Adama – Mesio section.[59]

Hence, passenger platform Width: generally 8m~10.5m for the main platform and 8m~14 m for the intermediate platform. In passenger platform height: the platform side adjacent to the receiving-departure track not for out-of-gauge freight trains is 1.25m higher than track level and the other platforms are 0.3m higher than track level.[59]

Freight Length of platform and storage yard: generally being integral multiple of 14m; for the platform with goods warehouses, it should be determined as per the setting conditions of warehouses. Freight Width of platform: it can be 19.5m, 22.5m or 25.5m depending on the specific conditions, and there should be conditions for forklift operation. Height of platform: the platform on the side adjacent to the railway is 1.0m higher than track level, and that adjacent to the yard is 1.3m higher than the yard. [59]

3. Basis for the selection of railway station design parameters

This chapter presents general description of Ethiopia, which are needed to select station design parameters for Ethiopian national railway network. The bases for selecting station design parameters are topographic conditions, climatic condition, Ethiopia economy, compatibility and interoperability of station design standards with other neighbouring countries. Hence, this basis of selection parameters are used for the adaptation of Ethiopian National railway station design parameters. Accordingly, these factors are explained below.

3.1 Ethiopian Topography

Ethiopia is located in the Horn of Africa, which is the eastern-most part of the Africa land mass. It is bordered by Eritrea to the north, Djibouti and Somalia to the east, Sudan and South Sudan to west, and Kenya to the south. Ethiopia is a country of great geographical diversity with high and rugged mountains, flat topped plateaus, deep gorges, incised river valleys and rolling plains. Such diversity of terrain leads to wide variations in climate, soil, natural vegetation, and settlement pattern.

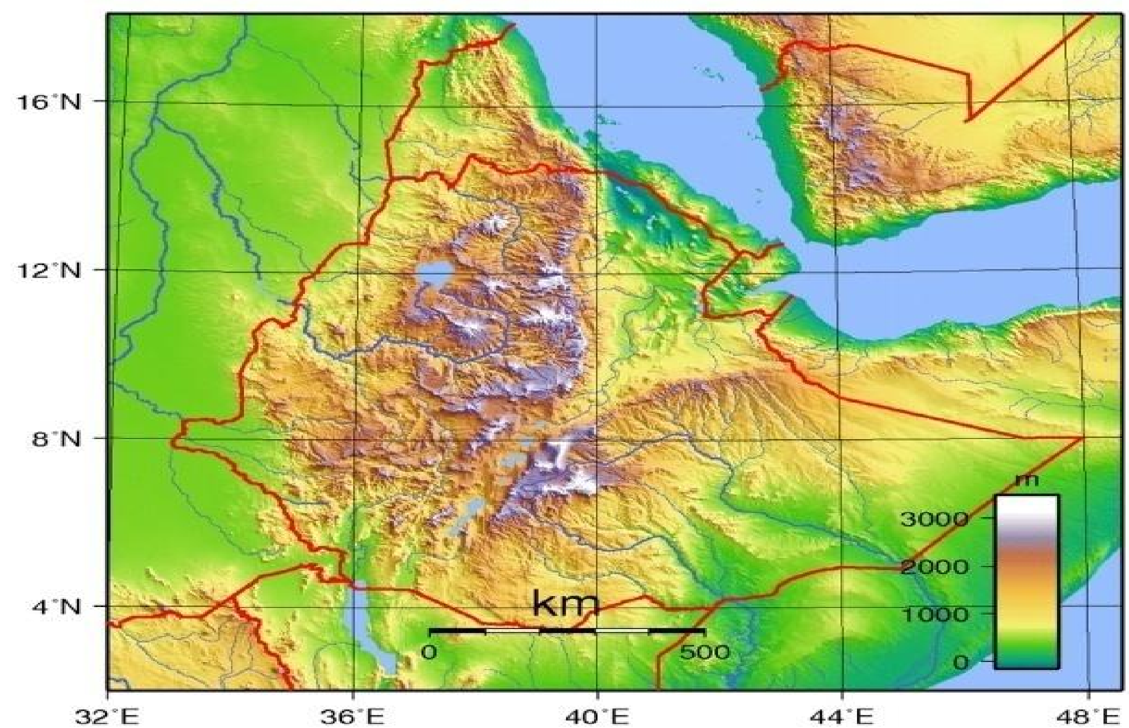


Figure 3.1 Topographic map of Ethiopia [22]

The dominant features of the topography of Ethiopia are the highland, the lowland and the rift valley regions. The highland covers 56% of the total area with an average elevation ranging from 2000 meters to 3000 meters above sea level and the lowland covers 44% of the total area commonly associated with the border line of the country.[22]

The eastern margin of the plateau is elevated to between 3000m and 4000m, towards the West, while the plateau surface descends to between 1200m and 1000m. The Western highlands are massive with an average height of 2000m -2500m. The western and the eastern highlands are divided by Rift Valley.[22]

Topography and land form of Addis Ababa- Djibouti project

Sebeta -Mieso Section

The area that the line goes through belongs to the landform of the Ethiopian plateau plat form, low mountain and shallow hill . The ground is wide, the topographical relief is not great, and part of the zone has low mountain and river valley landform. The elevation of road surface is about 850 ~2300m, the relative elevation difference is scores of meters, and the traffic condition is relatively poor. Due to perennial scouring and undercutting of seasonal flood, the surface-incised dry gullies can be seen, which has a width of 2~5m, depth of 3~12m and length of hundreds kilometers. Both sides of the trench wall are almost vertical sidewalls and the bottom of the trench is mainly sandy soil.

Mieso- Dewele Section

This sect ion of the line belongs to the Ethiopian plateau platform and shallow hill landform. Part of the zone has low mountain and river valley landform, the ground is wide and the topographical relief is not great, The elevation of road surface is about 700~1200m, and the relative elevation difference is scores of meters. The climate is hot and the surface tropical plants is scarce with coverage of approximately 10% to 30%. There is dry riverbed. Bulk Gobi phenomenon can be seen with few roads and poor traffic conditions.

3.2 Climatic Conditions

Ethiopia climate varies according to the different topographical regions. The central plateau has a moderate climate with minimal seasonal temperature variation. The mean minimum during the coldest season is 6° C (43° F), while the mean maximum rarely exceeds 26° C (79° F).[22]

Although there are considerable differences between Highland and Lowland Ethiopia in the average monthly and annual temperatures, they are more or less similar in their small annuals range and large daily range of temperatures. In Ethiopia, temperature is greatly influenced by changing altitude. Lateral variation of relatively few kilometers may result in vertical changes of 1000 meters or more in some of the major canyons, on the slopes of high mountains and along the rift valley escarpments. As a result Ethiopia has a diversified climate ranging from semi-arid desert type in the lowlands to humid and warm (temperate) type in the southwest. Mean annual temperature ranges from < 15^0 C over the highlands to > 25^0 C in the lowlands; and the mean annual rainfall distribution ranges a maxima (>2000 mm) over the Southwestern highlands and minima (<300 mm) over the Southeastern & Northeastern lowlands.

In addition, the extreme temperature variations in certain interval of time with specific areas are an important parameter in the design of rail.

Table 3.1 Recorded extreme temperature in Ethiopia.[22]

Place	Extreme Temperature (^{0} c)		Temperature Variation(^{0} c)
	Maximum	Minimum	
Addis Ababa Airport	36	-2	38
Addis Ababa City	34	-3.5	37.5
Dire Dawa	42	5	37
Jimma	38	-8	46

3.3 Ethiopian Economy

Ethiopian economy is largely an agro based economy. It contributes almost 45.9% during 2006/07 fiscal year, to the national production and provides employment to more than 80% of the working population. The industry is in nascent stage. The domestic construction industry contributes 47% of the industry contribution in GDP. The services sector is growing with business opportunities in trade, banking and tourism.

Ethiopia is fast marching towards self-sufficiency in Agriculture. Major agro commodities being produced in Ethiopia are cereals, pulses, coffee, oilseed, cotton, sugarcane, potatoes, cut flowers; cattle, sheep and goat. Agriculture production recorded a growth of 12% in 2008 over the year 2007. Ethiopian industry grew at 6 % during 2008. Industry is dominated by food products and beverages, textile, leather products, paper, chemicals etc. Basic industries viz. cement, steel etc are negligible.

Two areas where Ethiopia is expected to excel in the immediate future are Electricity production and sugar production. Electric power generation is being ramped up by setting up hydro power generation projects and Ethiopia is expected to export power to nearby countries within a year from now. Likewise, Ethiopia has launched three sugar production complexes with a combined capacity to product one million tons of sugar per year, the major portion of production will be exported. The services sector is growing modestly - IT, education, and NGO services etc providing vital support. Successful implementation of railway network is expected to increase GDP with additional contribution from services sector.

International trade, Ethiopia is dominated by imports. 82% of the goods movement consists of imports - major items being, petroleum and petroleum products, chemicals, machinery, motor vehicles, heavy engineering and consumer durables. Saudi Arabia 17 %, China 15.9 % and India 7.8 % are major import destinations. Ethiopian exports consist of coffee, qat, gold, leather products, live animals, flowers and oilseeds. The major export destination are Germany 8.2 %, Saudi Arabia 7 %, US 6.9 %, Djibouti 6.6 %, China 6.5 %, Italy 6.5 %, Japan 5.9 % and Netherlands 4.8% . Ethiopia enjoys positive balance of payment on capital account. However, the trade balance is negative due to large imports and corresponding lack of exports.

Hence, Transportation system and the associated costs play a very important role in determining the cost of products in Ethiopia.

3.4 Compatibility and Interoperability

Interoperability refers to the ability of a transport network to operate trains and infrastructures to provide, accept and use services so exchanged without any substantial change in functionality or when we say interoperability it is the compatibility of the standards among other countries.

Railways have greater or lesser interoperability depending on conforming to standards of gauge, couplings, brakes, signaling, communications, loading gauge, structure gauge, and operating rules, to mention a few parameters. For passenger rail service, different railway platform length, height and width clearance standards may also cause interoperability problems.

In the development of the railway infrastructure in Ethiopia, there is plan to interconnect East Africa countries and the whole Africa. So each African country will use their own design standard which causes missing of the interoperability. Therefore, the preparation of the standards considers the interoperability case.

Therefore, based on the above mentioned basis for the selection of railway station design parameters the experiences of some selected countries is thoroughly investigated in relation to the selected parameters.

4. Discussion on Different Standards and Experience

Following the discussion on economical aspects of station locations and track and platform technical aspect are made based on the standards of different countries and as stated in literatures. The discussion also based on master thesis, Ethiopian railway corporation reports, feasibility studies and researches presented by different companies.

4.1 Discussion on Station Location standards

Under this topic railway station locations of different standards are compared based on economic and topographic aspect of Ethiopia. In railway station design, determining the location/places of station along the line where passengers/good easily and safely access the service they require and more eco- friendly service is important for generate profit and success of the network.

With this regard AREMA and Chinese standards provide a short term station locations in mixed lines based on the functions/type of stations that serves customers. In general they recommended this by considering freight transport demand, freight flow directions, availability of land, accessibility to business and civic activities and other modes of transportation. Furthermore, terrine conditions, goods category and handling capacity, utility services, possible need of future expansions and visibility etc are also considered.

On the other hand, the standards that Russia proposed to station location for Ethiopia national railway network considers steady growth of traffic and carrying capacity on the basis of interdependent selection of line to calculate travel time between stations based on type of locomotive, alignment gradient, design speed, traction power, and mass calculated theoretically travel time equals to design travel time. In addition to this number of stations on the railway line is done simultaneously with the design of rout plan and profile using weight -average travel time.

4.2 Discussion on Track and Platform technical aspect

In general, platforms are an integral component of the station and cannot be designed as stand-alone elements. In developing the platform design, elements such as station track layout, station gradient, signaling and catenary supports must be considered and arranged so as to not hinder circulation on the platforms. Number of platform determines according to, their spacing and accessibility based on number of train per day, station services type, and function of stations.

Hence, designing new stations must carefully consider the future expansion requirements for track and platforms arrangement. Since, it is important to determining the operation efficiency and capacity of stations.

In most countries track and station platforms are located on straight unless the particular geographical characteristics of the site and the characteristics of the railway infrastructure at the proposed location of the platform do not provide a reasonable opportunity for achieving this.[32]

4.2.1 Track and Platform arrangements

As discussed from the literature review earlier, provision of track and platform design by different standards has similar arrangements; with the main difference in safety, construction cost and considering convenience for passengers to get on/off trains. Hence, the arrangement depends on track numbers (double or single track), train movement direction and number of parallel arrival- departure tracks. [27]

According to *AREMA, 2001, Chinese, Russia standards*, Platforms are can be located both on a single track lines and multiple track lines. On single track lines platforms are provided on the same side of the track as the station building. When three or more tracks are used for passenger services island platforms are used. Island platforms are also used where site conditions and/or station configuration make outside platforms difficult to build. Therefore, to facilitate safe movement of passengers, platforms should be located on tangent track whenever possible in order to provide train crew with the full view of the passengers, and to allow the passengers a view of oncoming trains. Therefore, with this regard there is no difference among the standards of the three countries.

4.2.2 Number of parallel Tracks and Platforms

To keep railway system safe and reliable, careful planning, design and construction, operation schemes are essential. To design a railway station one of the basic parameters is deciding number of track and platform.

According to *AREMA, 1985* standard, the number of station tracks should be determined by the schedule of trains and switching desired; allowances for delayed or special trains, schedules changes and future expansion. In addition layover time and the proximity of the passenger yard; track lengths available, and the type of operation used are also considered.[28]

On the other hand *GB 50091- 2006* and standards proposed by Russia to Ethiopia, the number of arrival-departure track (excluding mainline track) in passing, overtaking, intermediate, district and marshaling station are determined similarly by considering such factors; type and volume of train traffic according to the accepted operation point layout, natures, numbers of approach line and the technical operation process in a station, which can be selected from the following Table. Furthermore, when number of originating and arriving passenger trains is more than 50 pairs, the number of arrival-departure tracks can be determined through analysis and calculation.[27][29]

Table 4.1 Quantity of arrival departure tracks.[27][29]

Type of station	Number of arrival- departure tracks in bi directional (excluding main line)			
	Single track line with the capacity showed in pairs of trains with constant interval time table			Double track line
	Less than 12	13 - 24	More than 24	
Passing station	1	1-2	2	-
Overtaking station	-	-	-	1-3
Intermediate station	2	2	2-3	2-3
District station	3	4	6-8	-
Marshalling Stations	-	3	4-5	-

Note*: It is allowed to add one receiving departure track*[29]

: *Locomotive running track may be set separately as required.*[27]

When selecting values from this table, if the number of receiving tracks connected in a yard is as many as 3 and above. it may add another track. [27]

:*In case there are more than 5 passenger trains per day on single-track section or more than 20 passenger trains per day on double-track section, one more receiving-departure track shall be added to the quantity showed in the Table.*

4.2.3 Effective length of arrival- departure Tracks

Most standards assume the effective length of receiving- departure track in the near future and the far future is determined during preliminary stage design. As mention in the literature designing station track length is used to accommodate the planned schedule of trains stopping at that station; by identifying trains passing through it, sections combining or splitting, special cars on or off, locomotive changes, delayed trains, special movements, and future increases in traffic of mixed rail system.

According to *Chinese and Ethiopia standard proposed by Russia* railways standards, to determine the effective length of receiving-departure tracks for freight and mixed transport use the same by considering the train length planned, traffic capacity requirement, types and number of locomotive, terrain condition and the coordination with the effective length of adjacent railway arrival and departure track, etc. Hence, they use the effective length of arrival departure freight train to be 1050m, 850m, 750m or 650m. The railway station designed mainly for combined transport (passenger and freight) may use the effective arrival and departure track length of not more than 1050 m. But in passenger train the effective length is not more than 650m.[27][29]

According to *AREMA, 2000,* standard the track length is design to accommodate a complete length of train, including assisting locomotive based on maximum platform length available, and allowances for flexibility in the assignment of tracks for the longest train.[28]

4.2.4 Gradient in Stations

As mentioned before, station gradient provided sufficiently low, due to prevent movement of standing vehicle and to prevent additional resistance due to grade. If the gradient is steep, they require more powerful locomotives, smaller train loads, lower speed, resulting in costly hauling. The locomotive of the freight train produce sufficient tractive force in order to bring the train into motion and to maintain a certain speed or acceleration. The tractive force has firstly to balance the total running resistance, including gradient resistance, secondly to accelerate the train. The basic requirement is to overcome the resistance at the starting moment and thus bring the train in to motion.[37]

According to the *AREMA* standard, the maximum desirable gradient at stations is 0% to 3.5%. Where as in *Indian standard and Ethiopia railway standard proposed by Russia*, the maximum gradient permitted is 0% to 2.5% in station yards. [28] On the other hand, according to the *china* railways standard, the gradient of station depends on the effective length of arrival and departure tracks. Thus the gradient they use is between 0% to 1.8%, where passenger carriages are intended to be regularly attached or detached.

Table 4.2: Gradient Difference between Adjacent Grade Sections Chinese standard ($^{0}/_{00}$)[27]

Terrain conditions	Effective length of arrival and departure track(m)			
	1050	850	750	650
Common section	8	10	12	15
Difficult section	10	12	15	18

On the other hand, according to technical regulatory Standards on Japanese Railway, the maximum gradient of the track in traveling areas and stopping areas is 2.5% on tracks traveled by trains pulled by locomotive (including parking areas and areas for coupling and decoupling the rolling stock). This can be determined in considering the performance of motive device, braking device, operation speed and other such factors of the rolling stock.[35] According to Indian railway system, the maximum gradient permitted for all gauges in station is 2.5% whilst a gradient of 1 in 1200m is recommended.[24].

4.2.5 Platform Dimensions

Station platforms are an important part of the infrastructure of any railway system and proper design can give great assistance to good operation. As such functional and accessible paths of travel should be designed or considered first. To enable passengers to board and alight from trains in a safe and efficient manner, station platform therefore is one of the railway station design parameters.[41]

Platform dimensions are one of the station design parameters since they affect the overall size of the station area. It is often desirable to minimize the land use of a station. If there is limited land available at a station location it might be necessary to choose a compact station layout.[38]

4.2.5.1 Platform Length

The length of a platform depends on the longest train running on that section. Longer platforms allow more seats for passenger and allow longer trains. On the other hand, it is not desirable to build longer platforms than necessary due to economic reasons and land use restrictions.[38]
All platforms should accommodate the full length of a typical train consist and allow for maximum flexibility. While the minimum required platform length will vary depending on the type of rail service provided. Platform lengths should be as standardized as possible, both within the individual station, and across multiple stations serving a corridor.[42]

According to *AREMA, 2001*, platform lengths are based upon car length, plus number of cars and a margin of 12.20 meters for braking. Actual platform lengths will vary according to site constraints and train operational requirements. Platforms will vary in length depending on the service being provided and whether or not the station is served by either diesel or electric type motive power. Minimum platform lengths may vary from 64 lineal meters in length (3cars for diesel, 2 cars for electric) to 272 lineal meters (11 cars for diesel).[28]

On the other hand, according to *Chinese standard*, to determine the length of platform in passenger stations is accorded on passenger traffic flow in the near future and actual situations, and it shouldn't be less than 300 m. However, the station located in rarely populated areas or with less passenger traffic, the length of passenger platform may be shorter accordingly. Hence, the length of passenger platform in a passenger station should be 550 m. In freight station, the length of platforms is not more than 280m. [27]

According to *technical specification for interoperability* the minimum platform length in high speed passenger train station is 415 m.[38] The reason for this is high speed railways are built where the demand is high and hence, long platforms are necessary to accommodate longer train sets.[38]

4.2.5.2 Platform Width

Platform width is in many aspects a matter of safety for the travelers. There must be enough spaces for passengers to move and reside on the platform without getting too close to the tracks.[45] There are several different factors that affect the necessary platform width, among others the expected amount of passengers that will use the platform simultaneously must be taken into account so that platform width has enough spaces. [45]

Generally, Island platforms are wider than side platforms since they serve two tracks instead of one. The type and placement of obstacles should be considered in deciding platform width; such as benches, walls, lifts and stairs etc. But all are important for passengers to be easy move around them, used for people with reduced mobility. Therefore, there must be sufficient width or spaces for suitable movements. The platform width of high speed rail station might be wider since there has to be room for a wide safety zone or other safety measures.[40]

AREMA 2001, the platform width shall be sufficient to allow reception and movement for the maximum number of passengers based on projected ridership at each station. The platform width shall meet the requirements of NFPA 130 and ADA, including requirements for vertical access and circulation.[28] In addition AREMA stresses that platforms should provide room for people to: wait on the platform without overcrowding, alight the train without running into obstacles or other people, and be a safe distance from the platform edge and stopping and/or passing trains. Platforms at terminal stations may require additional platform width because of higher passenger loads, the concurrent boarding and alighting of multiple trains, and operational requirements.[66] Based on the above factors the minimum platform width shall be use from the following table:[28]

Table 4.3: Minimum standard platform width (AREMA 2001**)** [28]

Platforms	**Minimum standard platform width**
Side platform	3.048 m
Island platform	4.572 m
NOTE:- *Minimum may vary according to individual railroad standards, state/regulatory requirements.*[28]	

On the contrary, according to the *Chinese standard*, the width of passenger platform is determined based on passenger traffic density, luggage carrying tools, buildings on platform and section design speed and other factors. Accordingly, the passenger platforms width i.e. within the range of passenger station buildings and other larger buildings is supposed to be 8m ~ 20 m. In addition, the width of sided platform within the range of station building from the outer wall edge of the building edge to the platform edge shall be no less than 6m and the other part not less than 4m.[27]

Furthermore, the widths of island/center passenger platforms: when the platform bridges and underground paths with approach ramps at both ends, in a large-sized passenger station it shall be not less than 11.5 m. But in case of without ramp or bridge platform width should be not less than 8.5 m .When over pass facilities are provided the platform shall be widened as needed.[27]

In Freight station platform width shall be subject to the sum of warehouse may be 9m, 12m, 15m, and 18m. The two passageways shall be wide enough for convenient loading and unloading. It is recommended that the width by the railway side be 3.5 to 4m.[27]

According to *Amtrak*, platform width is a balance between accommodating the peak passenger load and the physical constraints. In other words, wider platforms will generally be preferred over narrower ones as being safer, better able to handle service baggage vehicles, and able to provide for growth in passenger volume.[42]

Table 4.4: Amtrak passenger platform minimum width [42]

Platform	Preferred width(m)	Minimum width(m)
Center island	7.3	6.1
Side w/Baggage Loading	4.6	3.6
Side w/passenger service only	3.6	3.1

4.2.5.3 Platform Height

When determining the platform height during design, there are three primary considerations, such as high level, middle level and low level above the top of the rail. By considering the floor height of the passenger trains that use or will use the station; whether or not freight trains operate or will operate on the track adjacent to the platform.[43] Accordingly, experience of three countries platform height above the top of the rail is summarized under the following table: [43]

Table 4.5: Platform height from the top the rail

	High Level(mm)	Middle Level (mm)	Low Level (mm)
Amtrak	1219	381	203
China	1100	500	300
Russia	1100	550	200

4.2.6 Distance between tracks and tracks and platform

Distance between tracks in stations

Distance between tracks except platform dimensions, the overall dimensions of the station area can be determined. Distance between tracks in stations is a difference in high speed rail and conventional rail this is due to engine, braking capability and aerodynamic effect.

According to *Ethiopia standard proposed by Russia* and *Chinese railway station design standard*, they consider similar factors to deciding the distance between centers of lines. These factors are rolling stock clearance limit, construction clearance limit, loading clearance limit of out-of-gauge freight, calculative width of related equipments arranged between two adjacent lines and properties of operation handled between two adjacent lines. [2] In addition, to ensure traffic and station staff safety at work, which is determine according to the line is overrun by loads of goods train, and the installation of signal channel unit and water crane and other equipment. Hence, the minimum distance between line and distance between two adjacent lines are listed in the following table.

Table 4.6: Ethiopia standard proposed by Russia and Chinese standards distance between tracks at stations [27][29]

No.	Types of tracks	Intervals between track centerlines at stations and passing loop (m)	
		Normal	Minimum
1	Mainline and adjacent tracks	5	5
2	On single-track and double track lines with the speed of no more than 120km/hr	5.5	5
3	On double track lines with the speed of more than 120km/hr	6	5.5
4	Receiving departure track, marshalling departure, marshalling tracks	5	5
5	Auxiliary station tracks: rolling stock holding tracks, freight yard tracks (excluding tracks for transshipment), etc.	4.6	4.6
6	Tracks in receiving and departure yards designed for cars inspection and repair (without uncoupling)	5.6 and 5.3	5.6 and 5.3
7	Between yards and groups of track	6.5	6.5
8	Draw-out and adjacent track	6.5	5
9	Tracks for passenger trains preparation: Without power and water supply Communications	6	6
10	With communications	7	7

On the other hand, according to *AREMA, 1982* railway design standard, the main track should be spaced not less than 4.5m center to center from any parallel track, and when such parallel track is another arrival departure track, they should be spaced not less than 5.5m center to center.[28]

Distance between tracks and platform

The distance between tracks and platforms is not as much affected by the high speed concept and is decided similarly in all regulations. The distance is based on the height of the platform, the curve radius and the inclination of the track. The resulting distances are also similar for both the national and international regulations. As an example the track-platform distances for a straight track with the recommended platform heights of countries are shown in the table.

Table 4.7: Requirements for distance between track and platform

Regulation	Track- Platform distance(m)
European	1.65
Norwegian	1.68
Swedish	1.70

According to AREMA and Chinese standards the distance between adjacent track and platform edge in a station is depend on the platform level.

Table 4.8: Track- platform distance (AREMA and Chinese standards)

<table>
<tr><th colspan="2" rowspan="2">Standard</th><th colspan="2">Track – platform distance</th></tr>
<tr><th>Ordinary level ATR</th><th>High Level ATR</th></tr>
<tr><td colspan="2">AREMA</td><td>1.67 m</td><td>1.702m</td></tr>
<tr><td rowspan="2">China</td><td>Edge of passenger platform</td><td>1.75 m</td><td>1.75 m</td></tr>
<tr><td>Edge of freight platform</td><td>1.75 m</td><td>1.85 m</td></tr>
</table>

5. Adaptation of Station Design Parameters

This chapter presents the adaptation of railway station design parameters for Ethiopian national railway network based on Ethiopia topography, climatic conditions, economy, and compatibility and interoperability factors. The adaptation of station design parameters is made by with comparison of different standards, such as AREMA, China and Ethiopian standard proposed by Russia based on the above factors that are considered. Therefore, by comparing standards of the above countries and the experiences obtained from literature review and relevant documents to be considered in design a railway station are used for the adaptation of Ethiopia national railway network.

5.1 Railway Station locations

Generally, locations of railway station along the route or line is needed in order to train load or unload passenger and goods. To serve those purposes the terrain would be convenient based on locomotive type, line speed, train length, traction power, etc. With regard to topography, Ethiopia has great diversity of terrain - a massive highland complex of mountains and dissected plateaus along the selected eight routs, this influence every new railway direction, rout selection and length and station locations. This diverse and difficult topography of the country has implications with the cost of construction affecting Ethiopia economy.

In this regard, steeper terrain would require a greater amount of either fill or cut and fill during rail line construction than flatter terrain, and would therefore have a greater impact on topography and economy. Normally, the steeper the terrain is, the greater the impact in station locations. The lesser the amount of fill and cut, the lower the construction cost.

Therefore, the recommended railway station location for Ethiopian national railway network to provide a safe, cost effective meaning avoid unnecessary and excessive replacement costs and reliable which would consider the following factors.

1. Availability of land uses that serves its purpose/ functions.
   In this regard, the station which will have locomotive maintenance, repair and servicing facilities, it would be reasonably closer to the terminus of the service being provided or this type of stations are located at the end point of service.

In addition, supporting facilities like maintenance yards, Electric substation, parking lots, station facilities, etc… and also for possibility of future expansion should be consider.

2. Accessibility is also another point to be considered in station locations selection.

   Accessible public transport or other mode of transportation refers to locating the station entry and infrastructure to allow for physical access for all passengers and convenient for transferring between rails to other mode, i.e. easy access to the corridor and connectivity with other modes of transportation is very important in selecting station locations.

3. Availability of adequate utility services such as existing electrical sources, water supply, commercial activities etc are also important.
4. Last but not least railway station location should avoid extensive communication pole, signal and other infrastructure relocation costs. The station site should respect the existing topographic conditions, including existing natural vegetation, with the goal of minimizing grading and the destruction of the existing natural conditions, as well as existing structures.

5.2 Track and platform Arrangement

According to operational requirement, determination of the type of platform best suited to a particular situation is dependent upon the character and volume of the various kinds of traffic handled, the type of station, the location and type of approaches to the platforms for the various kinds of traffic, the relation of the various approaches to each other, the relative lengths of platforms and trains, space available for station track and platform development, and the method of operation. Because there are so many variables involved, final conclusion as to the best arrangement can only be reached with a thorough study. [28][54]

However, according to Ethiopian topography, climatic condition and interoperability to other countries, Island (center) platform requires a greater degree of access to other platform via foot bridges or underpasses compared to a single faced platform. For instance, if the track is already in place it will have to be slewed to accommodate the island platform. This may not be possible due to difficult topography and tighter land constraints on the network and also the existing overhead structures may be expensive or not economical to relocate. Hence, for Ethiopia national

railway side platform is recommended as much as possible. Since side platform accommodates high volume of passengers and also has greater flexibility for future expansion.
In flow-through platforms are not typically used due to Ethiopian economy and operational considerations. However, Ethiopia can construct this type of platforms in junction stations (like Mojo, Awash, Sebeta, etc…). Because its advantage where very high passenger volumes and/or unique passenger characteristics (e.g., a high percentage of passengers with bags) require that the station designer minimize cross-flows on the platform and dwell times.

As it is know, most of Ethiopian national railway network is mixed traffic single line. Therefore, selecting platform arrangements, the railways customers' level of understanding/exposure to technology should be taken in to accounts. And therefore, the track arrangement should be interoperable to the other line designed by other different countries standards. Especially, for Ethiopian people they may climb over or through a fence by the side of the railway tracks, which can causes lots of accidents. Hence, before selecting platform arrangement, safety issues and construction costs needs to be addressed very well. Therefore, Ethiopia track and platform arrangement in a station should follow the following guideline.

1. Identify the through station tracks (from end to end), single/double track line and traffic demand, etc…
2. Identify the advantage and disadvantage of the platform type in each station, according to availability of land (including topography), interoperability to selected traffic, and economy with respect to safety and construction and maintenance cost.
3. To be safe and cost effective, platforms should be located on tangent track as much as possible.
4. Appropriate signage should be provided to be avoided boarding trains across active tracks.
5. Harmonization of track interoperability to the other countries standards.

5.3 Number of Parallel Tracks and platform

The design of a railway station depends strongly on operational factors such as time table, disturbance (delay) and occurrence of shunting movements etc. This affects the number of tracks needed at a station that is operated with a mix of stopping and passing trains arriving from independently operated lines.

As compared to AREMA with Chinese and Ethiopia railway station design standards and different countries station design experience for determining number of tracks and platform, general factors are considered as mentioned earlier. China and Ethiopia standard proposed by Russia follows basically the train traffic volume (number of pairs of train) for different types stations and its functions to add one or more track. Once number of station track decided then we can determine platform number and type based on station functions.

In general, to determine number of station tracks and platform the following factors should be considered

1. Frequency of train during peak time (train traffic volume)
2. Train technical inspection before long and steep down- slope,
3. Technical operation process in a station,
4. Organizing method of trains
5. Servicing performed in the station,
6. Type of operation used (stations to handle train order)
7. Allowances for delayed or special trains

As mentioned before, Ethiopia has no standardized guideline to determine number of tracks in stations. But, including the above factors many countries like China and Russia determine number of tracks in a station is through research, investigation and experience. Therefore, based on Ethiopia topography and economy the following table is recommended for Ethiopia national railway network based on station function and train frequency in a station.

Table 5.1: Adapted track number for Ethiopia national railway stations

Type of station	Number of arrival- departure tracks in bi directional (excluding main line)			
	Single track line with the capacity showed in pairs of trains with constant interval time table			Double line
	Less than 12	13 - 24	More than 24	
Passing station	1	1-2	2	-
Overtaking station	-	-	-	1-2
Intermediate station	2	2	2-3	2-3
Note: It is allowed to add one receiving departure track				

In District and Marshalling station number of arrival departure tracks Chines Standard is preferable than Ethiopia proposed by Russia. This is because numbers of arrival departure tracks are based on number of paired train in a station and function of station before terminal. To be economical safe, Ethiopia can use the following number of tracks in a railway station based on number of train and station functions.

Table 5.2: Adapted track number for marshalling and district stations of Ethiopia railway.

Converted number of pairs of trains	Number of arrival and departure tracks in bi-direction (tracks) (excluding main tracks and locomotive running tracks)
≤ 12	3
13~18	4
19~24	5
25~36	6
37~48	6~8
49~72	8~10
73~96	10~12
> 96	12~14

5.4 Effective length of arrival departure track and Gradient in station

Operation and maintenance cost of a railway project are very expansive tasks. These costs are needed throughout the life time of a railway. Because the geometry characteristics of a railway such as gradient and track length in a station may affect the operating and maintenance cost, these cost should be considered from the planning phases of a railway project.

5.4.1 Effective length of arrival- departure track

As mentioned before, the effective length of receiving-departure track or other station track is the length where trains and vehicle can stop without interfering near tracks to conduct traffic route.

As compared, effective length arrival departure track of different countries standards, AREMA one is more general than Chinese and Ethiopia standard proposed by Russia. Chinese Railway standard is well developed on the basis of international practices in railway design, construction and maintenance as well as on the basis of relevant scientific research or through investigation. Trains in Ethiopian railways will follow the system of locomotives (unlike the EMU's). Since the tractive effort is available only for the locomotive that hauls from the front, increasing the number of wagons will result in decreased acceleration and deceleration (arising from increased inertia).

Therefore, to adapt the effective length of receiving-departure tracks for freight and mixed traffic should be established according to the train length planned for the 10th year of operation with regard to unification of the effective train length on the connected routes. Hence, the values of the effective length of receiving-departure tracks for Ethiopian railway to design and construct and economical safe railway station track length, the following point should be considered to deciding the length of arrival departure track:

1. Identify station type (passenger, Freight, or Mixed)
2. train length planned for 10th year of operation
3. traffic capacity requirement
4. type of operation used

Including the above factors and Ethiopian economy and capacity the following table is recommended for national railway network.

Table 5.3: Adapted Effective length for Ethiopia national railway stations

Traffic Station	Effective Length (L_{ef})
Passenger (Freight passing though)	$L_{ef} \leq 650$ m
Freight(Passenger passing though)	650 m $\leq L_{ef} \leq$ 1050 m
Both passenger & Freight station	$L_{ef} \leq 1050$ m

5.4.2 Gradient in Station

Adapting the station gradient (including parking areas and areas for coupling and decoupling the rolling stock) is one of the important parameters to design a railway station to prevent additional expenses by adding locomotives and to use line capacity effectively by preventing weight of locomotive. Large gradients result, principally in heavier locomotives, increased locomotive power, and/or less freight train weight, and/or reduced speed and line capacity, and/or requirement of higher braking capacity, and/or larger signaling distances.

According to AREMA, Chinese, and Ethiopia standards proposed by Russia and other countries experience like Hindu and Japanese, except China all countries consider the rolling stock traction power as a factor to determine slope in a station. But the Chinese standard considers performance of the locomotive i.e traction power, braking device, topographic conditions, and effective length of arrival departure track. However, the maximum allowable gradient in AREMA standard is 0.35%, in all other countries is 0.25%. This implies how America uses high power locomotives to haul trains. Therefore, for Ethiopia railway stations, china's standard is recommended for determining gradient on stations based on the above mentioned facts.

Table 5.4: Adapted Gradient on station on the basis of effective length ($^0/_{00}$)

Terrain conditions	Effective length of arrival and departure track(m)			
	1050	850	750	650
Common section	8	10	12	15
Difficult section	10	12	15	18

5.5 .Platform Dimension

To adapt for Ethiopia national railway station platform design, two primary types of stations to be consider: terminal stations and intermediate stations. Several operating scenarios warrant consideration with each station type.

For example, there are intermediate stations where all trains will stop and intermediate stations where some trains stop and other trains will run through the station. In terminal station platforms shall be used for a single type of train operation (high-speed trains or conventional passenger trains) as the requirements are different for each type.

However, it is necessary to provide separate platform configurations for freight train and conventional passenger trains at stations along shared corridors since the criteria of the vehicles (length, floor height, location of the doors, etc.) vary according to the type of rolling stock operating within the corridor.

These considerations lead to the following design guidelines:

1. Limit train speed on tracks adjacent to platforms;
2. Provide physical access control to the platform (such as doors or barriers) or similar devices limiting access to areas near the tracks.
3. Provide audible and visual warning on platforms that provide advance notice of approaching trains (such systems will be provided at all stations whether platforms are adjacent to passing trains or not).

Generally, platforms have different functions and characteristics during departing and arriving peak conditions. For the arriving peak, the platform must have sufficient area and vertical access facilities for passengers to quickly move through it. During the departing peak, the platform acts as a storage area for passengers waiting for a train and as a movement space for passengers distributing themselves along the platform.[68]

For Ethiopia national railway it is necessary to give high priority for safety to passenger to design platform dimension. Hence, Ethiopia national railway platforms shall be located on straight track and track gradients not steeper than 1 in 500 wherever reasonably practicable**.** In addition a station platform is located not horizontal curves with radii less than 1000m.

5.5.1 Platform Length

Ethiopia national railway is conventional network whose maximum design speeds from 100km/hr- 120km/hrs for freight and passenger respectively and the passenger train length is 22-25m/car. Hence, station platform length depends on the longest train running on that section. It should accommodate the full length of a typical train consist and allow for maximum flexibility. While the minimum required platform length will vary depending on the type of rail service provided. Therefore, platform lengths should be standardized as much as possible both within the individual station, and across multiple stations serving a corridor.

When to adapt for Ethiopia national railway station design, platform length must accommodate design traffic demand with reasonable construction cost and provide maximum convenience for passengers. In this regard the Chinese standards indicate that platform length is to be determined according to factors such as station character, platform type, passenger flow density, safety distance, vertical circulation width etc. Hence, based on the above reasons Chinese standard is recommended for Ethiopia station design to determine passenger platform length based on passenger traffic flow in the near future and actual situation. Therefore, the recommended passenger platform length should be less than 550m and greater than 300m. But in the case of rear passenger traffic flow the platform length can be used less than 300m to be economical.

5.5.2 Platform Width

The platform width shall be sufficient to allow reception and movement for the maximum number of passengers. Platforms at terminal stations may require additional platform width because of higher passenger loads, the concurrent boarding and alighting of multiple trains, and operational requirements.

The dimension of the platform width will need to be ascertained to ensure that sufficient space is provided on platforms to allow:

a) Passenger circulation to, from and along the platform;

b) Operational and passenger facilities where provided;

c) Passengers to wait for trains in relative comfort and provide protection from the weather (including sun, wind, rain)

According to the experience of *South Florida, 2009*, the minimum platform width of side and island passenger platform is recommended to be 6.1m and 7.6m respectively. On the other hand, according to AREMA standard 3.05m and 4.6m platform width are used for side and island passenger platform respectively. Whereas, according to Chinese National Standard of Code for Design of Railway Station and Terminal *GB 50091-2006*, is reasonable for both passenger and freight boarding and alighting system for different platform width and it is preferable to adapt this for Ethiopia railway system. To prevent overcrowding with the maximum expected usage of the platform and permit the unscheduled detraining of passengers from a fully occupied train, and any passengers occupying the platform when the train arrives, without risk of injury to passengers.

Therefore, safe and cost effective passenger/freight platform width can be adapted for Ethiopia railway based on future passenger traffic demand, luggage carrying tools, platform type and section design speeds. Therefore, the Chinese platform width is recommended for Ethiopia national railway station.

Table 5.5: Adapted platform width for Ethiopia National Railway Station

Platform	Minimum width(m)
Center island	10.5
Side w/Baggage Loading	8.5
Side w/passenger service only	4
Freight platform	9

5.5.3 Platform Height

Station platform height, a raised structure or area within a station, can be recommended for station platforms of both passenger and freight boarding. For passenger safety, proper platform height should be selected without affecting loading gauge (the maximum size of train cars), and must conform to the structure gauge physical clearance specifications for the system. Tracks which are shared between freight and passenger service must have platforms which do not obstruct either type of train. To reduce station construction costs, many train systems use a low platform, and require passenger cars with internal stairs up to the train floor. For these reasons

Chinese code of standard is reasonable for both passenger and freight boarding system for different platform level. Hence, it is possible to recommend this Chinese standard for Ethiopia railway station platform height. Station platform shall be located on track gradients not steeper than 1 in 500 wherever reasonably practicable. Where this is no reasonably practicable, appropriate risk control measures shall be agreed with the station operator.

Table 5.6: Recommended platform height for Ethiopia railway station.

Boarding/ Alighting	Height of platform edge from top of rail(mm)			Offset distance from adjacent track(mm)		
	Low level	Ordinary	High level	Low level	Ordinary	High level
Passenger	300	500	1250	1000	1000	1000
Freight	-	1100	≤ 4800	-	1000	1100

5.6. Distance between tracks

The overall dimension of the station depends on the distances between the tracks and between tracks and platforms. There is a difference in how the distance is decided for high speed rail and conventional rail. In technical specification for interoperability (TSI) if the speed of track is less than 230km/hr and greater than 300km/hr the distance between parallel track are 4m and 4.5m respectively. To ensure traffic and station staff safety at work and to determine cost effective station dimension, the recommended parallel track spacing for Ethiopia railway station design, main track should be spaced not less than 4.5m center to center from any parallel track, and when such parallel track is another arrival departure track, they should be spaced not less than 5.5m center to center.

5.7 . Distance between tracks and platform.

The distance between tracks and platform is not as much affected by high speed concept and is decided similarly in all regulations. The distance is based on the height of the platform, the curve radius and inclination of the track.

As compared to AREMA and Chinese standard the distance between adjacent track and passenger/ freight platform edge in a station depends on the platform level. But for Ethiopia to be safe and cost effective distance between platform and track spacing china standard is better and acceptable because, it consider passenger and freight platform beside track level.

Table 5.7: Adapted platform edge and adjacent track spacing.

Standard		**Track – platform distance**	
		Ordinary level ATR	High Level ATR
China	Edge of passenger platform	1.75 m	1.75 m
	Edge of freight platform	1.75 m	1.85 m

6. Conclusion and Recommendation

6.1 Conclusion

This research attempted to adapt railway station design parameters for the Ethiopian railway system, and it basically focuses on station location, track and platform technical aspect and passenger safety on platform. The adaptation of the station design parameters for Ethiopia railway system was made focusing on topography, Climatic conditions, economy and Interoperability.

1. Railway station location is selection of places along a route or line at which a train stops for fuel or to pick up or let off passengers or goods. Proper station locations are fundamental for the success of the railway system in any country. Therefore, the selection of a proper site requires a study of all factors affecting costs of constructions and operations. This includes cost of preparing station site, soil and foundation condition, drainage, sewage disposal, labour supply, etc…Hence, when station locations are selected for the system more or equal attention should be given both to safety and costs, as it is also indicated in the feasibility study conducted by China.
2. Number of track in a station, train types and length, and traffic demand are basic factors to be considered in selecting/ determining the arrangement of track and platform in a station. Island, sided and flow through platforms have their own advantage from cost and safety perspectives. All those bench mark countries like China, Russia and America give high priority for safety i.e. safe movements of passengers, implies arrangement of platform should be integrated to the track as much as possible. Therefore, for the Ethiopia railway system, the intermediate stations, where they are supposed to be erected, platform position need to be tangent to the track, so as to ensure safe movements of passengers.
3. The number of parallel tracks and platforms and the way they arranged in a station, is paramount important to utilize maximize rout capacity i.e. to give safe movement of passengers and goods. Hence, in Ethiopia the number of tracks and platforms need to be designed based on train frequency in a station and station function which is vital for cost effective and safe movement of people and goods.
4. Effective length of arrival departure track in a station is the part of the total length where locomotive and car can park without hindering the traffic in adjacent line. To ensure the

highest possible degree of safety, all standards considered effective track length should take the maximum train length that uses the stations and type of operations to prevent collisions and derailments. Depending on each station own purpose and function, all stations along the line may or may not have the same effective length. Therefore, economically to be cost effective, identifying the station track access i.e. passing through track, only passenger track, freight track, mixed train track is very important for adapting effective length of arrival departure tracks for Ethiopia.

5. In designing a station considering gradient which is the result of the topography of that specific site is very important. Gradient on a station has both safety and economic implications, which are preventing movement of standing vehicle due to gravity and preventing additional resistance due to grade, especially freight stations, cost of cut and fill material and labor cost respectively. Therefore, to be economical and safe movement of passengers and goods, Ethiopia national railway stations gradient for mixed train should be flat.
6. Proper design of passenger station platforms enables passengers to board and alight from trains in safe and efficient manner. Station area especially platform has a chance of an accident for; it is a connector between the rail track and the station. Platform length is equal to the maximum train length that accommodates passenger train and it is not greater than 550m. The central platform width with luggage is not less than 10.5m and side platform with luggage is not less than 8.5m but for freight platform minimum width is 9m. For the safe movement of passengers, the height of platform edge from the top of rail for passenger station is 0.5m for ordinary level and for freight ordinary level height is 1.1m.
7. The required minimum distance between tracks varies between 4.5 to 5.5 meters. The distance between tracks and platform edge is not affected by the high speed. The distance is based on the height of the platform, structure gauge and out-of gauge for a mixed traffic. Hence, for safe movements of train and cost effective tracks; recommended distance between tracks in a mixed station should not be less than 4.5m. And to be safe and cost effective distance between platform and tracks china standard is better because, it consider passenger and freight platform separately beside track level.

6.2. Recommendation for Future Works

The present work has attempted to standardize guidelines for railway station design parameters (station locations, platform and track technical aspect and passenger service and comfort factors) based on topography, climatic condition, economy and interoperability adapting parameters for Ethiopia national railway stations. However, due to source constraints and time limitations the present research work did not cover several important aspects of station design parameters detail information on national railway station.

In view of this work, it would be desirable to consider the following recommendations for the future work for the development of national railway station in Ethiopia.

A. For distribution of intermediate station along the route based on train speed, train travel time between stations, locomotive type and rout gradient need further study for Ethiopia national railway system.

B. There are aspects of station design that are not cover in this thesis such as cost for construction and maintenance for different station alternatives.

C. The safety issues in a station related to mechanical problems such as signaling failure, equipment failure and train control failure should be taken as a critical issue in future studies. And in addition the contribution of track structure failures to safety problem in railway system needs a detail investigation.

D. Since many of the possible problems with the station substructure are connected to ground water, the drainage system (usually considered as a part of the substructure) should need a special concern and detailed study.

E. The standard issues related to station operation and maintenance should be taken as critical issue in future studies.

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8. Appendixes

Appendix A: **Definitions**

Platform Height is defined as the vertical distance separating the rail level and the top of the platform edge.

Platform Length is the actual platform edge distance running parallel to the track from one the end of a platform to its corresponding opposite platform end.

Platform Width is defined as the horizontal distance, square to the track, separating the platform edge and the corresponding opposite platform edge.

Single Faced Platforms are characterized by one side of the platform being adjacent to a section of track while the other usually comprising of a wall or fence.

Sustainable design means promote positive environmental, social, cultural and economic values; recurrent cost savings.

Rolling stock clearance limit is a cross contour (perpendicular to the track centerline), which is sufficient for the rolling stock set upon the straight horizontal track section (both empty and loaded). This must be relevant for both new rolling stock and the one having the maximum allowable wear condition.

Structure gauge is a limit cross contour (perpendicular to the track centerline), which is designed only for the rolling stock and must be free of any parts of buildings, constructions and facilities as well as any materials, parts and equipment located along the track.

Through track station is a special type of stations that through station which allows trains to enter from both sides as well as leave at either side.

Rout capacity is a maximum traffic flow per track i.e. number of train per day.

System safety: The application of engineering and management principles, criteria, and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost, throughout all phases of the system life cycle.

Structure gauge also called **the minimum clearance outline,** is the minimum height and width of tunnels and bridge as well as the minimum height and width of the doors that allow a rail siding access in to a warehouse.

The loading gauge represents the maximum width and height to which a vehicle may be built or loaded.

Appendix – B: Abbreviations

AREMA = American Railway Engineering and Maintenance-of-Way Association

CDE = Chemin de fer Djibouto-Ethiopien (Ethio-Djibouti Railway)

ERC = Ethiopia Railway Corporation

NRNE= Ethiopia National Railway Network.

TSI = Technical Specifications for Interoperability

RGS = railway Group Standard

NFPA-130 = National Fire Protection Association (Standard for Fixed Guide way Transit and Passenger Rail Systems)

ADA = Americans with Disabilities (persons with a disability)

GDP = Gross Domestic Product.

Amtrack = American Passenger railroad corporation (American track)

EMU = Electric Multiple Units