



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CIVIL AND
ENVIRONMENTAL ENGINEERING

ASSESSMENT AND EVALUATION OF ADDIS ABABA LIGHT RAILWAY TRANSIT
TRACK STRUCTURES

A Thesis in Railway Engineering Program

By

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A Thesis

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ABSTRACT

To effectively solve the problem of urban transportation, especially that of the downtown area, the government of Ethiopia has planned and constructed light railway transit in the city of Addis Ababa. The AALRT railway tracks basically consists a flat framework made up of rails and sleepers which is supported on ballast. The ballast rest on a sub ballast layer which form the transition layer to the formation.

The significance of this research is to construct Phase-II AALRT project plan more reliable, efficient and esthetically attractive then the first phase AALRT project. This research would assess and evaluate lesson learned from first phase AALRT project. It focuses on external interactions that occur between the various components of a track structures and its supporting systems, integration with landscape, highway transportations and infra-structures. Besides, safety, future expansion, aesthetics and drainage system, wastage of materials and human power, the technology, knowledge and skill gained during construction and operation track structures.

The research were held through site investigations, desk studies and questionnaires response. The primary data for research gained from desk study through review detail design documents and literature from the Ethiopian railway corporation. The questionnaires are on the findings of the research analyzed using simple statistical approaches, Likert's scale and standard error deviation. Within this study it is possible to conclude assessment and evaluation the constructed AALRT project track structures.

The research identifying that providing light railway transit for resident of city has the effective solution for the immediate transportation problem. Besides, there is also lack of integration between the constructed railroad with existing buildings, pipes, wires and transportation situation. The commercial activities decrease due to cause of the laid railroad separate the city in two sides. The constructed AALRT project would not consider safety, future expansion and urban aesthetics. It also shows that there was wastage of properties, materials, labor force and lack of proper workmanship during construction of AALRT project.

Keywords; AALRT, Modal Integration, Interaction System, Aesthetics and Safety, Skill and experience.

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LIST OF ABBREVIATIONS

AACRA	Addis Ababa City road Authority
AAIT	Addis Ababa University institute of technology
AALRT	Addis Ababa Light Rail Transit
AASHTO	American Association of State Highway and Transportation Officials
AREMA	American Railway Engineering and Maintenance-of-Way Association
BRT	Bus Rapid Transit
BS	British Section
CRCC	China Railway Construction Company.
CWR	Continuously welded rail track
EEP	Ethiopian electric power
ERA	Ethiopian Road Authority
ERC	Ethiopian Railway Corporation
ETB	Ethiopian Birr
GB	Chinese Railway Manual
HSR	High-Speed Rail
JR –	Japan Railway
LRT	Light Rail transit
LRV	Light Rail Vehicle
TGV	Train Grande Vitesse (High Speed Train)
UIC	Union Internationale des Chemins (International Union of Railways)

CHAPTER 1 INTRODUCTION

1.1 General introduction

The transport of people and materials has a greater significance in world-wide than it had in the immediate past. The transport system and technology have undergone great changes in the past in which one system giving way and replaced by new developments: walking, riding, carts, cannels, railway, roads, shipping and flying.

The birth and evolution of railways during the last two centuries has had an enormous influence on industrial, social and economic development. This rail transport refers to the land transport of people or goods along guided paths called railways. It consist two parallel rail tracks at a fixed distance (gauge) apart, usually made of steel which called track and mounted upon cross beams called ties or sleepers". The track is a fundamental part of the railway infrastructure and represents the primary distinction from land transportation and it provides a fixed guidance system. The modern railway version is based on the steel wheel running on a steel rail. Other forms of guided vehicle technology exist; rubber-tyred trains, magnetic levitation and guided bus ways [1].

The main importance of providing modern railway infrastructure is basic for infrastructure of a country, artery of national economy and backbone of transport system. This rail transport mode is characterized by large transport capacity, environmentally friendly, low travel time and power consumption. It has also high level of passenger or cargo utilization over a limited space, most efficient energy consumer (1/3 of road transport and 1/7 to 1/5 of air transport), minimum friction and air resistance/guided movement/. Mostly electric powered, Safest and reliable mode of land transport with the lowest accident rate. It offers comfortable ride options such as meal, sleeping and entertainment, High degree of automation and management to develop urban transportation is a prerequisite element to accelerate the development of city economy. In the different ways to alleviate the pressure of urban public transportation, urban rail transportation is most effective methods. However, urban rail transit mostly runs through or is located down town. Therefore, vehicles, the wheel/rail impact, structure vibration and vibration source generate vibration and noise impact on the environment become

very prominent. The vibration and noise have direct effects on the people living, working or studying around the line [2].

The railway line have a continuous and long engineering structures, under the influence of rolling and long engineering structures. Some influences are load and natural conditions, with the gross vehicle weight of accumulated, increase in inevitable residual deformation, worsening the smoothness of lines, causing the damage of track structure and its components. Therefore, must timely ensure that the tracks are in good condition and in accordance with the technical standards to make trains running smoothly, safely and punctually

To effectively solve the problem of urban transportation, especially that of the downtown area, the government of Ethiopia decides to build a light rail in the city of Addis Ababa. Currently this project has construction completed and start works in September 2008 E.C. The grand estimated cost about \$475million through two lines, the east –west line and the south-north line. About 3km is the shared section, which has the greatest passenger flow [1].

For construction purpose, the railway track passes through different steps. began from desk investigation, site study, integrate with other infra-structure , cutting earth work, preparing subgrade ,selecting ballast materials, producing sleeper, and selecting durable, highly stress, corrosion, vibration resistance rail. Integrating materials with constructing railway line and introducing machine, equipment and construction methodology on each steps can analyzed and implemented for most efficient and economical way with different countries design manual. The Ethiopian government sign agreement with Chinese Railway Corporation and now they are under construction [1].

Recently, in Ethiopia through governments first phase five-year growth and transformation plan, Addis Ababa East-West & North-South (Phase I) Light Rail Transit Project constructed and began work. Meanwhile, the second phase project which passes through middle of town (from Piasa to Lebu through Africa union and Megenagna to Kality through bole brace) 32km railway line is already designed and contract are completed and begin implementation recently. All the AALRT project have Standard Gauge (1435 mm), Electric Traction, High capacity, speed (16-30 km/hr), and Concrete sleeper (160cm X20.5cmX22cm) [3]

1.2 Statement of a problem

Currently, in Addis Ababa capital city of Ethiopia population growth increasing progressively. This is due to migrant from rural and region area for search of better life. So due to this and other reason the user of transportation increase through time to time in a city. Because of this, Ethiopian government plan, execute and implement to construct light rail transit. Since Ethiopian government has no experience and skill human power to construct LRT previously, it need to sign agreement with experienced and user of technology. During introducing and construction of this system in our country were able to learn and transfer this technology. What do our government, client (ERC) and contractor learn from phase I project, In terms esthetics, future expansion, orientation, integration with land scape and nearby infra-structure... etc. Generally, this research deals with finding a solution for challenges happen during construction of phase I AALRT project. This leads us to construct phase II AALRT project within efficient and better than phase I AALRT project.

Therefore, the statement of a problem may rise some research questionnaires as follows

- Does the permanently laid track structure distort urban esthetics?
- Does the project consider future expansion and extension?
- Do our professionals gain experiences and skills?
- Is there wastage of materials and human labour power during construction?
- What about integration of project with landscapes and nearby infrastructures?
- How about quality of materials used for construction of AALRT project?

In addition, some other like questions was mentioned in this research.

1.3 Objectives of Research

Recently Ethiopian government plan and implement reduction of urban transport problem through providing light railway transit within support to urban bus transit. This research would assess and evaluate track structure constructed Phase-I Addis Ababa light rail transit from East-west line and North-south line.

1.3.1 The general objective

The general objective of this research is to make Phase-II AALRT plan, (passes at middle of town; from Piasa to Lebu through Africa union and Megenagna to Kality through bole brace which has total length 32km) more reliable, efficient and esthetically attractive than phase I AALRT line. This is done due to the skill and experience gain from first phase AALRT project. So by identifying main challenge and opportunity during construction phase and, confront challenge by providing solution before happening during construction design.

1.3.2 The specific objectives

Specific objective of this research are as follows

- To assess the factors concerned during construction, influencing with external interactions that occur between the various components of a track structure and its supporting systems
- To assess the designed track structures integration with landscape, other mode of transportation and infrastructure.
- To assessing the technology, knowledge and skill gained during construction of track structure
- To assess whether wastages of materials and labor humans power exist or not.
- To assess safety, future expansion, aesthetic and drainage system of track structure
- To evaluate the constructed railway track structures with developed countries metro or light railway transit.
- To evaluate property and quality of materials used for AALRT project.

This includes the development, evaluation and application of new and existing railway line constructed for purpose of better understanding of the performance of the system as a whole.

1.4 Significance of Research

The basic functions of railway infrastructure are movement of people and goods from place to place within safe, efficient and large capacity. The significance of this research is to construct the 32km second phase light railway transit in efficient way than first phase. Besides with preliminary and desk study consideration that possible to save

economic and time wastage through proper using human power, equipment and material from skill and experience adopt from phase I AALRT constructed railway track structure.

The researcher believe that some advantage of the research states are as follows

- It may help a client and stakeholder to revise their of design track alignment. To evaluate the experience gained from the construction held before. This may help both the consultant and contractor to minimize cost, to increase efficiency, to minimize wastage of human power and material.
- Shall be helping to consider future development of country infrastructures respect to railway line. This can help us to caution from redundant excavation of a lot and infrastructure.
- It may support increase its aesthetics, efficiency, construction methodology, machinery, materials type and quality during construction. And to minimize dis integration between new railway line constructed and existing infrastructures, and landscape.
- This research may also recommend by mentioning the main area of where the problem occur during construction of railway track; like safety, consideration of nearby infrastructure, methodology of construction in site, track noise and vibration reduction and so on.

So, analyzing the problem may leads to solution with some consideration. Because it helps to take a precaution during site construction and take a remedy for the problem happen.

1.5 The study scope and limitation

The main study scope of this research is to investigate about track structure constructed in case Addis Ababa light railway transit. Generally this study limited to only external factors that influences the construction of AALRT. This includes length, orientation, aesthetics, integration with nearby structure, comparison with other countries metro..etc

Since, the construction of light railway track structure new and for the first in our country. Assessment and evaluation for recently completed Addis Ababa light railway transit is a topic that has not been well covered by earlier researchers. Since lack of professional and new study area, unavailability of adequate documented information related to the subject matter has created inconveniency and has made it difficult for the

researcher to construct ideas easily based on the objective of this thesis. As a result, this research could be considered as a footstone for further similar future studies.

The major limitations of the study were lack of professionals and the skilled human resource in the railway construction industry. It took to time complete and return the questionnaires by the respondent. Furthermore, a series of motivational briefings and clarifications of the questionnaires had to be conducted by the researcher to the respondents in order to enable them complete and return the questionnaires in time. Other similar related problems were some of the limiting factors that has impeded the work of the research.

1.6 Overview of the Research Process and Study

This thesis constitutes of five chapters and a brief description of the content of each chapter is discussed here under as follows:

Chapter I: This part briefly discusses the research overview, purpose and initiation of the research, as well as significance of research.

Chapter II: In the literature review part, deals with all about from railway transport development up to modern railway track transport. Besides, deals with different countries development of railway technology and construction experience. Components of modern railway track form structure elements, rail, sleeper, ballast, and subgrade according to different countries manuals and data are more literature coverage in this thesis. Construction material and machinery use for track construction purpose are also described.

Chapter III: This part covers the research methodology consisting of the overall research strategy, the research design, the analysis of the data and writing up of the research paper.

Chapter IV: This chapter contains the discussion and analysis deals with use of evaluation and assessment the track structure constructed AALRT according to the result gained from research questionnaire, desk study and site investigation. Chapter V: This part mainly deals with the final output research conclusion and recommendations. .

CHAPTER 2 LITERATURE REVIEW

2.1 General introduction of railway

According to Merriam Webster dictionary definitions, Rail transport is a means of conveyance of passengers and goods on wheeled vehicles running on rails. It is also commonly referred as train transport. In contrast to road transport, where vehicles run on a prepared flat surface, rail vehicles or rolling stock are directionally guided by the tracks on which they run. Track usually consists of steel rails, installed on ties (sleepers) and ballast, on which the rolling stock, usually fitted with metal wheels, moves. Other variations are also possible, such as slab track, where the rails are fastened to a concrete foundation resting on a prepared subsurface.

Rolling stock in railway transport systems generally suffers lower frictional resistance than road vehicles, and the passenger and freight cars (carriages and wagons) can be coupled into longer trains. The operation is carried out by a railway company, providing transport between train stations or freight customer facilities. Power is provided by locomotives which either draw electric power from a railway electrification system or produce their own power, usually by diesel engines. Most tracks are accompanied by a signaling system. Railways are a safe land transport system when compared to other forms of transport. Railway transport is capable of high levels of passenger and cargo utilization and energy efficiency, but is often less flexible and more capital-intensive than road transport, when lower traffic levels are considered [4].

2.2 Historic development and Time line Evolution of railway

The earliest evidence found that there is 6 to 8.5 km long wagon way, which use for transporting boats in Greece from around 600 BC. Vehicles pulled by men and animals ran in grooves in limestone, which provided the track element, preventing the wagons from leaving the intended route. The first horse-drawn wagon ways also appeared in ancient Greece using cut-stone tracks. In 1515, the line originally used wooden rails and a hemp haulage rope, and was operated by human or animal power, through a tread

wheel as shown in Figure 2.1. The line still exists and is probably the oldest railway still to operate [4].



Figure 2-1 the first timber track a 16th-century gold mine [4]

Wagon ways or tramways are thought to have developed in Germany in to facilitate the transport of ore tubs to and from mines, using primitive wooden rails [5]. As the work became more wearing on the horses, a vehicle known as a dandy wagon was introduced, in which the horse could rest on downhill stretch as shown in Figure 2.2 [6].

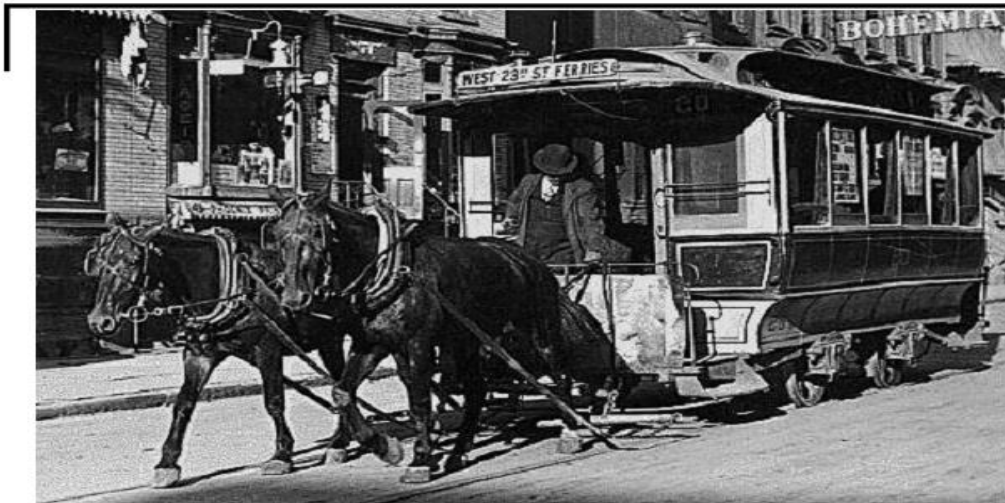


Figure 2-2 Wagon ways, horse drawn rail in Germany in 18 century [6].

According to Bianculli, Anthony J.(2003). in medieval times people mostly travelled by foot or horseback and any form of transportation was mainly for moving goods. Wagon ways were relatively common in Europe (typically in mining) from about 1500 through 1800. Mechanized rail transport systems first appeared in England in the 1820s. These systems, which made use of the steam locomotive, were critical to the Industrial

Revolution and to the development of export economies across the world. They have remained the primary form of land transport ever since for most of the world.

2.2.1 Development of Rails

A stiff wheel rolling on a rigid rail requires less energy per ton-mile moved than road transport, railroads are highly suitable for the movement of dense, bulk goods such as coal and other minerals. This was an incentive to experiment with many configurations and shapes of wheels and rails. They began to fix plates of cast iron to the upper surface of the wooden rails. The flanged wheel eventually proved its superiority due to its performance on curves, and the composite iron/wood rail was replaced by an all-metal rail, with its vastly superior stiffness, durability, and safety [7].

Cast iron proved unsatisfactory because it was brittle and broke under heavy loads. Wrought iron was a ductile material that could undergo considerable deformation before breaking; but iron was expensive. The rolling processes greatly lowered the cost of producing iron and rails. The next important development is which considerably reduced the amount of fuel needed to produce pig iron. Wrought iron was a soft material that contained included slag or dross. The softness and dross tended to make iron rails distort and delaminate, and they lasted less than 10 years under high traffic [6].

The open hearth furnace began to replace the Bessemer process improving the quality of steel and further reducing costs [8]. Besides development rails in size and shape leads further expansion of railway transport as shown in Figure 2.3.

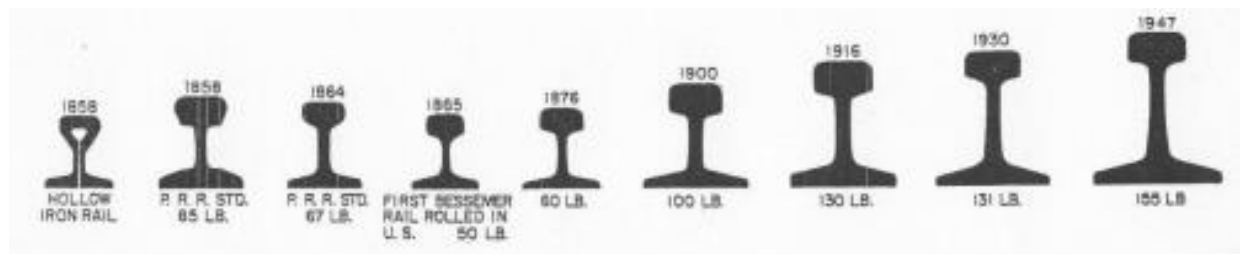


Figure 2-3 Rail developments with time, shape and size [7].

2.2.2 History of Development of Ethiopian railway

It was in 1917, during the reign of Emperor Menilik, that the first ever train service was provided to the people of Addis Ababa. The railway was stretched from the Capital city of, Addis Ababa, up to the neighboring country Djibouti through Dire Dawa. The idea of

connecting the capital of Ethiopia to the neighboring countries, especially Djibouti, was apprehended by the late Emperors advisor from Switzerland, Alfred Ilg. Rails from Dire Dawa to Addis Ababa, started to be laid in May, 1912, after the rail way was completely done and stretched between Djibouti and Dire Dawa in 1904. The construction work took three years and in 1915 the line reached Akaki, a small town 23 kilo Meters from Addis Ababa. Then after the project got completed and the line reached the Capital, the first trains arrived in it in 1917. After this, the capital, Addis Ababa, experienced major effects like an increase in its economic activities and a huge growth of population [8].

It is then almost a century later in which the city is undertaking the relatively more modern Light Rail Transit network project in its history of transport infrastructure, i.e. under the rule of the EPRDF. Starting this project in the capital was not an easy task to the current government. As it is explained in chapter two, one of the main targets set by the city's administration was the development of the LRT network system so as to strengthen the transport infrastructure. According to the AACPPO (2012), the Addis Ababa LRT network and the national railway system are governed and controlled by the Ethiopian railway corporation (ERC) which was established by the federal government in 2008. This company is responsible for the development of the railway systems [9]. The LRTN technology was chosen after a study was conducted in 2007 by a private consultant called G. Menckhoff. His study mainly focused on three major factors that are the implementation strategies, operating costs and the institutional set-up. The first railway line connects the northern and eastern economic and traffic corridors of Ethiopia, and provides a link to Addis Ababa and the Djibouti Port, the main import and export terminal for the region. The Project contributes to the economic development of the entire country [9].

According to Ethiopian Railway history are listed as follows.

- In 1897 the Construction began from Djibouti
- 1901- first commercial service from Djibouti to Dire Dawa
- 1906- firm went bankrupt and construction halted
- 1908- Compagnie de Chemin de Fer Franco-Ethiopien Djibouti Addis Ababa take over and begin reconstruction
- 1917- the line reach at Addis Ababa.

- 1000 mm gauge and diesel traction with steel sleeper and rail
- Owned and administered by the governments of Djibouti and Ethiopia
- Total length 781km – 681km in Ethiopia and 100km in Djibouti.
- 2006- Agreement with Italian company consta to rehabilitate the line
- 2007- National Railway development launched by CoM Regulation No. 141/2007 and ERC established [1]
- Suffers from old-age, lack of spares high operating cost, worn out track, no Locomotives, very low capacity [8].



(a)



(b)

Figure 2-4 The first Ethiopian to Djibouti railway track and locomotive (a) Steel sleeper and rail track (b) The oldest locomotive [8].

Ethiopia government purpose and design to build national railway and light rail transit first phase of a project construction is completed and second phase on way to start projects. Addis Ababa light rail transit first phase project completed start works on September 2015.

The designed characters of the LRT are

- Total length of 34.25 km (North-South line 16.9 km and East-West line 17.35 km)
- Electrified light rail transit
- Two lines (i.e. North-South and East-West lines) use common track of about 2.7km.
- Standard Gauge (1.435 meters) and Double track for the whole route
- Capacity of 80,000 PPH (Passenger/hr)
- Special Features of the Project, Performs on steep gradient and sharp curves.

The Ethiopian government proposed national railway network as follows; The Ethiopian Railways Corporation has identified eight railway corridors for study, design and subsequent implementation, the total estimated length with buffer of which is some 5060km [3].

The official website of ERC lists the National Railway Network (NRN) as follows [1]. There are eight railway routes. These are

- Addis Ababa-Modjo-Awash-Dire Dawa-Dewanle – 656km (mean while the construction of project completed and began work recently.)
- Modjo- Shashemene-Arbaminch-Konso-Moyale Including Shashemene-Hawasa and Konso-Weyto – 905km
- Addis Ababa-Ijaji-Jimma-Guraferda-Dima including Jimma-Bedele (direct to Boma with further extension – 740km
- Ijaji-Nekemet-Assosa-Kumruk – 460km
- Awash-Kombolcha-Mekele-Shire - 757
- Fenoteselam-Bahirdar-Wereta-Weldia-Semera-Elidar – 734km
- Wereta-Azezo-metema – 244km
- Adama-indeto-Gasera – 248km [1].

ERC design and propose total length 4744km Side by side with strengthening its institutional capacity. ERC has undertaken a prefeasibility study and LiDAR surveying using Air Born Laser Scanning for the entire proposed railway network [3].

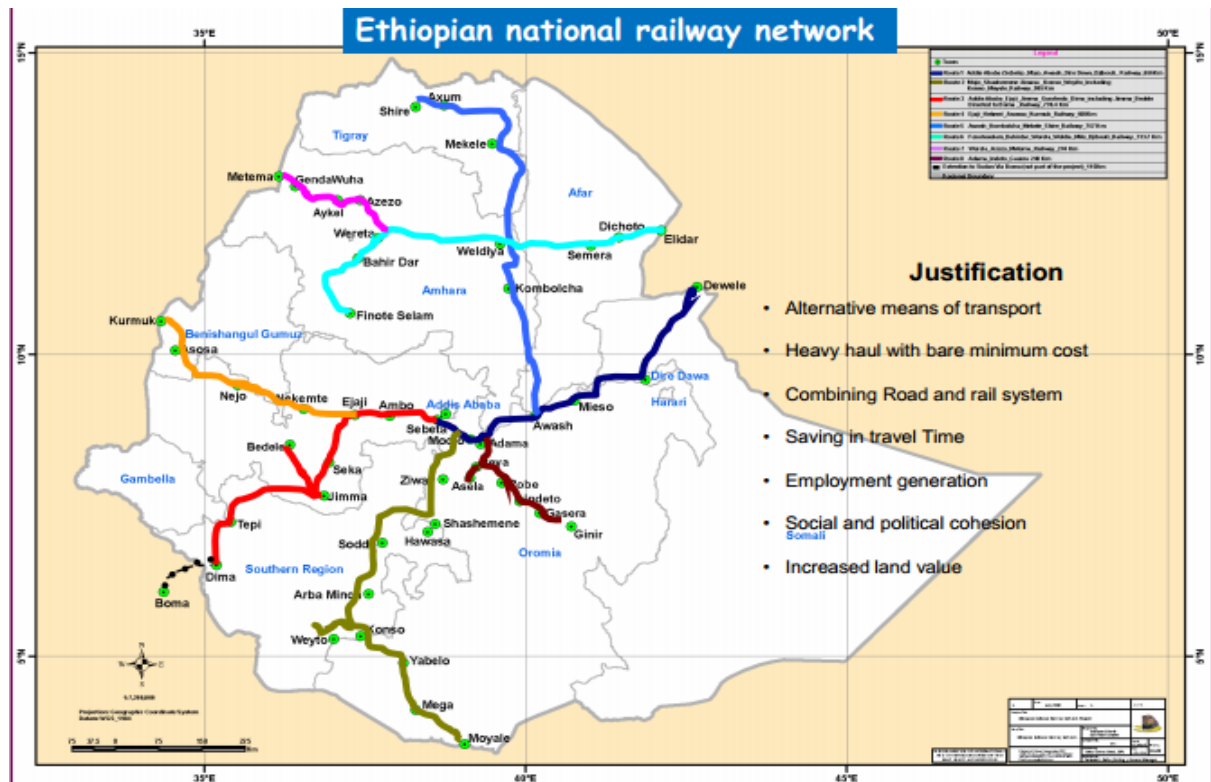


Figure 2-5 proposed and under construction Ethiopian national railway network [1].

2.2.3 General development of Railway technology

Reduction in friction was one of the major reasons for the success of railroads compared to wagons. This was demonstrated on an iron plate-covered wooden tramway in 1805 in England. At a time good horse on an ordinary turnpike road can draw two thousand pounds, or one ton for six miles in two hours, having stopped four times, in order to show he had the power of starting, as well as drawing his great load [10].

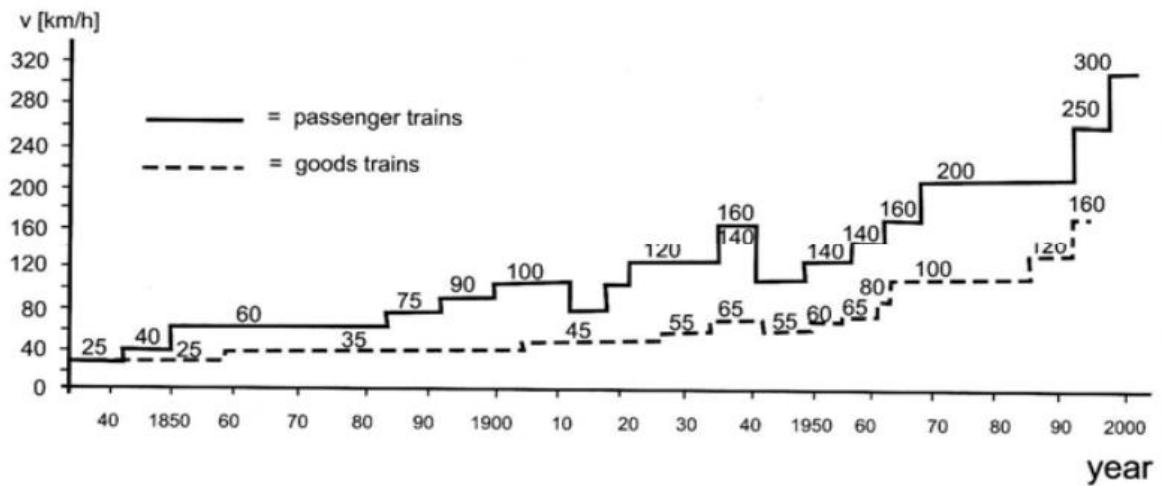


Figure 2-6 Development of train speeds (in km/h) for passenger and goods trains [11]

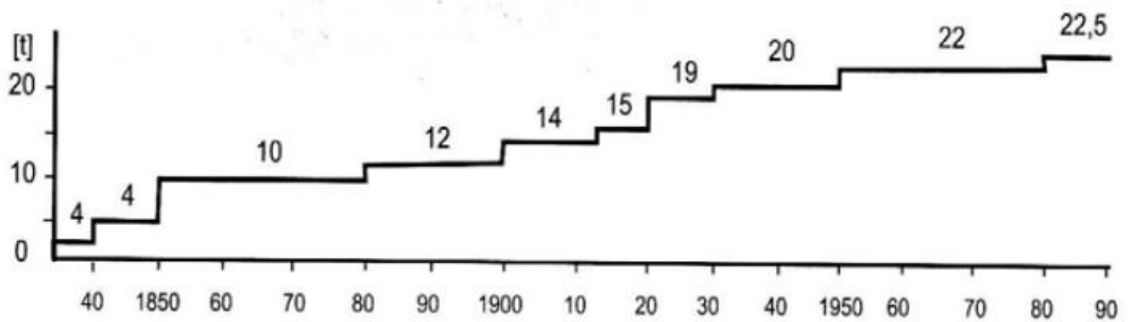


Figure 2-7 Development of wheel set axle loads in tons for passenger and goods trains

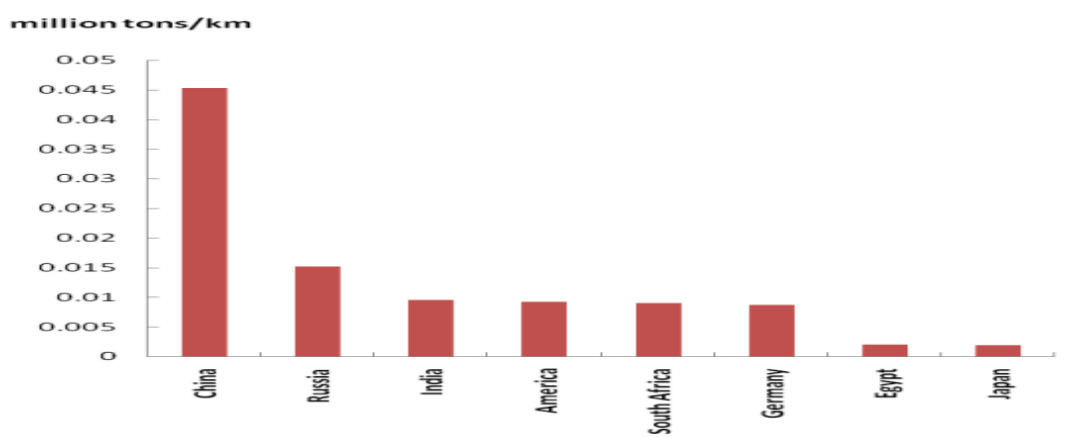


Figure 2-8 Rail transport density by million ton per km in different countries [11]



Figure 2-9 Future railway technology development (a) Underwater track construction and (b) Maglev train expansion

2.3 Railway track structures

2.3.1 General introduction

According to AREMA Track is the most obvious part of a railway route. But, there is a sub-structure supporting the track which is equally as important in ensuring a safe and comfortable ride for the train and its passengers or freight. There are now a range of modern track forms using a concrete base. They are generally used in special locations such as tunnels or bridges where a rigid base is required to ensure track stability in relation to the surrounding structures [12].

The standard track gauge in different countries railway manuals provided the clear distance between the two rails is 1435 mm. but many other gauges, wider and narrower than this. Gauge is often intentionally widened slightly on curved track (Track standard Manual, Dec 1998). The line of route has to be checked from time to time to ensure that the structures are not interfering with the gauge. A line is always gauged when a new type of rolling stock is to be introduced. It is important to see that the small variations in track position, platform edge, and cable duct location and signal equipment hasn't been allowed to creep inwards during maintenance and renewal programmer. Along the line of route various locations are marked by a fixed post in the track or a plate on a nearby structure to indicate the correct level or position of the track. These are called

monuments or datum plates. Measurements are taken from these to confirm the correct position of the track [13].

Curves in the track are almost a science on their own. Careful calculations are required to ensure that curves are designed and maintained properly and that train speeds are allowed to reach a reasonable level without causing too much lateral stress on the track or inducing a derailment [14]. There are both vertical curves and horizontal curves. There is also a section of track on either side of a curve known as the transition, where the track is changing from straight to a curve or from a curve of one radius to one of another radius. In addition it needs cant. The name used to describe the cross level angle of track on a curve, which is used to compensate for lateral forces generated by the train as it passes through the curve. In effect, the sleepers are laid at an angle so that the outer rail on the curve is at a higher level than the inner rail. In the US, it is known as super elevation. In practice, faster trains are allowed to travel round the curve at a speed greater than the equilibrium level offered by the cant setting [15]. Passengers will therefore feel a lateral acceleration similar to what they would feel if there was no cant and the train was travelling at a lower speed round the curve. The difference between the equilibrium cant required by the higher speed and the actual cant is known as the cant deficiency. Cant is measured either in degrees or in linear dimensions. On standard gauge track 1435 mm 150 mm of cant is equal to 6 degrees. This is the normal maximum in the United Kingdom [14]

2.3.2 The basic standard of a railway

The grade of a railway classified according to its role in railway network, properties, volume of passenger traffic, goods traffic volume, maximum allowable axle load, design speed, etc. The basic standard of a railway system, which is the basis to determine the technical standards and equipment types are depend on the list below [2].

- Axle load of rolling stock; - Axle load is one of major basis to determine the design load standard. Besides, Axle load of locomotives affect the power of locomotive, and car's axle load affect the train's load per meter. Car's axle loads control the bridge load and track type.
- Maximum running speed: - The maximum speed is one of the most important markers of railway transportation quality. It affects the travelling time of passenger and freight trains, traffic capacity and the using condition of rolling stock. It also affects construction cost, expenditure for buying rolling stock, locomotive energy consumption transportation cost, etc. It is the main base for designing transport

capacity and evaluation of economic effectiveness, determination of route alternatives [2].

- Volume of passenger and goods traffic affects the track-train interaction track deformation, residual life of structures.
- Designed speed, and significance of railway construction.

2.3.3 Basic classification of railway

The basic Classification of railway based on traction, number of track line of line, purpose of track and design speed of railway lists as follows even they vary according to countries code. But, According to Chinese Railway manual [16] the classification of Railways Based On as the following lists. Based on Kind of traction locomotive Diesel traction, Steam traction and Electric traction. Based on numbers of main lines Double track railway and Single-track railway. Besides, based on importance of a railway line Railway line for passenger traffic , railway line for mixed passenger and freight traffic Railway Line for goods traffic. Based on designed speed it classified as High speed line, Rapid speed line , Classes I - IV and Heavy haul railway [16].

2.4 Components of basic railway Track structure

According to American Railway Engineering and Maintenance-of-Way Association generally a railway infrastructure of track structure consists three major parts as shown in Figure 2.18.

1. Superstructure; consists Rails, Sleepers, Fasteners, Ballast and Sub ballast
2. Substructure; consists Frost protective layer, Subgrade and Drainage facilities.
3. Special structures; Bridges, Tunnels, Culverts, and Retaining walls [12].

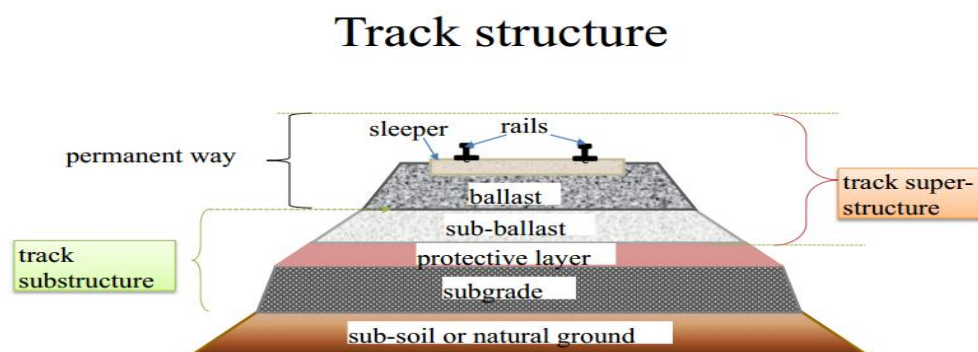


Figure 2-10 Modern track structure transverse section layouts [10].

In addition, Catenary masts (if the line is electrified on the overhead system) are located outside the drains and, beyond them, there is a walkway area. This may just be a cleared path for staff to walk safely, avoiding passing trains on modernized routes, a properly constructed path. Next to this path will be a cable trough. These were originally concrete but are nowadays often made of plastic. Cables crossing the track are protected by a plastic tube. Proper cable protection is essential to prevent damage by animals, track maintenance tools, weather and fire.

Usually, the edge of the railway property is outside the pathway or cable runs. If the line is built through an area requiring an embankment or cutting, the slopes will be carefully designed to ensure that the angle of slope will not take an excessive width of land and allow proper drainage but without risking an earth slip. The slope angle depends on the type of soil available, the exposure, the climate and the vegetation in the area. Drainage ditches are often added along the edges of cuttings and embankments. In the UK, fences are always provided along the boundary line of the railway to protect the public from wandering onto the track. Even so, there are a few accidents every year when trespassers are killed or injured by trains or electric conductor rails. Many countries around the world don't fence their railways, assuming people will treat them like roads and look both ways before crossing. Some components of railway materials property and requirement of track structure are listed as following based on reviewed literature.

2.4.1 Rails

2.4.1.1 General about Rails

According to Bianculli, the Rail is the most expensive material in the track. Rail is steel that has been rolled into an inverted "T" shape. The standard form of rail used around the world is the "flat bottom" rail. It has a wide base or "foot" and narrower top or "head" as shown in Figure 2.19. But bullhead rail introduced in United Kingdom only. Bullhead rail was originally designed with reuse in mind. It was intended that it would be turned over when the top had worn but this proved impossible because the underside also wore where it had been secured to the sleeper [10].

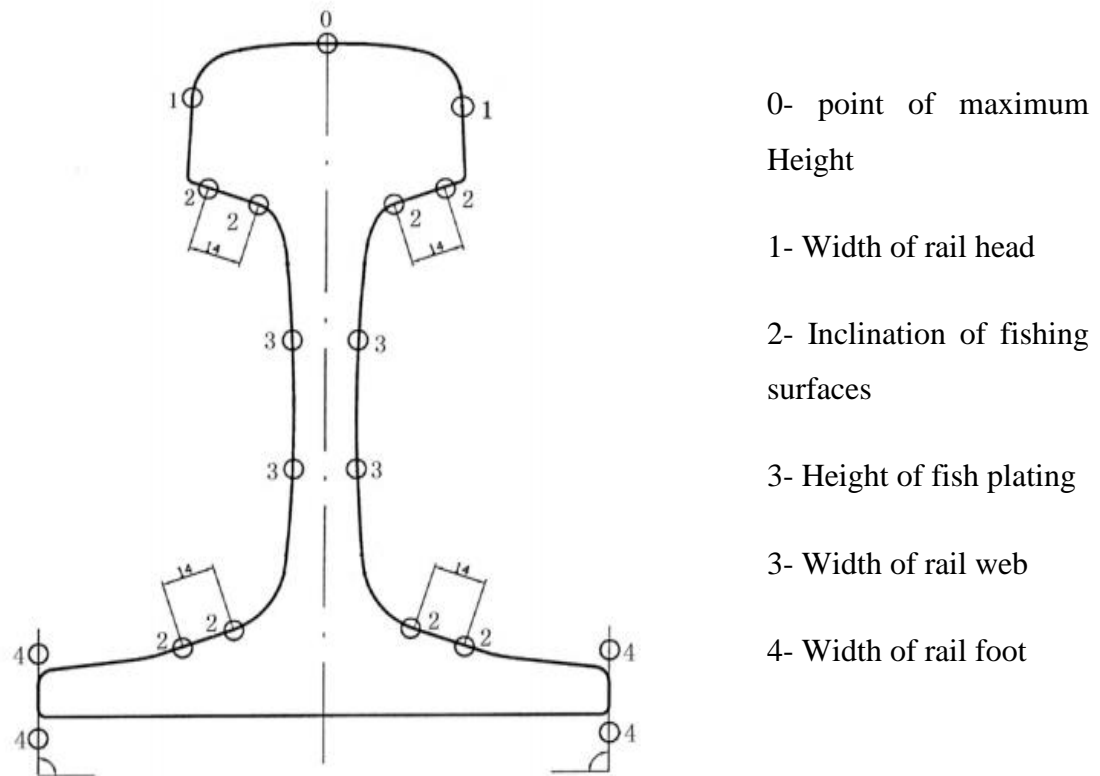


Figure 2-11 the standard form of Rail and Datum references for decision [16].

These Flat bottom rails can be spiked directly to the sleepers. A wide headed nail is driven into the sleeper on each side of the rail. So, the heads of the spikes hold the foot of the rail. Nowadays, heavier loads and faster trains require systems that are more sophisticated. Provided the tension is adjusted to the correct level, equivalent to a suitable rail temperature level, expansion joints are not normally needed. Special joints to allow rail adjustment are provided at suitable locations. Rail tends to creep in the main direction of travel so rail anchors are installed at intervals along the track. They are fitted under the rail against a base plate to act as a stop against movement [7].

2.4.1.2 Functions and requirements of rails

The purpose of the rail is to distribute accelerating and braking forces by means of adhesion. Act as an electric conductor on an electrified line, Conduct signal currents, Provide a smooth running surface, Transfer wheel loads to sleepers without large deflection, Resist tension failure from longitudinal tensile force caused by rail temperature reduction. Resist buckling from longitudinal compression force caused by rail temperature increase, Resist fatigue cracking from repeated wheel loads, Switches

and crossings /turnouts/set of points permit tracks to cross over each other and permit trains to switch from one track to another [2].

To fulfill these functions the selection and requirement of rails are based on the following conditions. Firstly the provided rails have high yield strength, tensile strength and hardness, high resistance to wear, compression and fatigue, high resistance to brittle fracture, good weld ability, and high degree of purity, good surface quality, and low residual stress after manufacturing to withstand temperature variations and other climatic conditions [10].

2.4.1.3 Weight, size and section of rails

The weight of rail is based on how much the rail weighs in kilogram per meter. Over the past 200 years, increasingly heavier rail was required to handle the increased weight of locomotives and rolling stock and traffic volume increases [14]. The largest rail commonly used today is 70kg/m., although 75kg/m. AREMA has recently recommended a new rail section to maximize available head wear and minimize stress related failures [12].

A rail's weight, along with its section and other information, is rolled as a raised character onto the web of the rail. The rail section refers to the shape of the cross-section of a rail. For example, there are several sections of 45kg rail. Rail mills identify the different shapes and types of rails by codes rolled onto the rail's web. The section code appears right after the weight. The section codes signify different dimension and shape as shown in the Table 2.1.

In general, rail sections smaller than 43kg/m. should not be utilized for new construction, but is available second-hand for replacing rail in track age utilizing the given section. 43kg/m and 50kg/m sections are adequate for many transit and light tonnage industrial park track age. New track age, exposed to 100-ton or heavier cars, should not utilize rail sections smaller than 43kg/m [10]. According to china railway manual 50kg/m rail section profiles are as shown in Fig. 2.20.

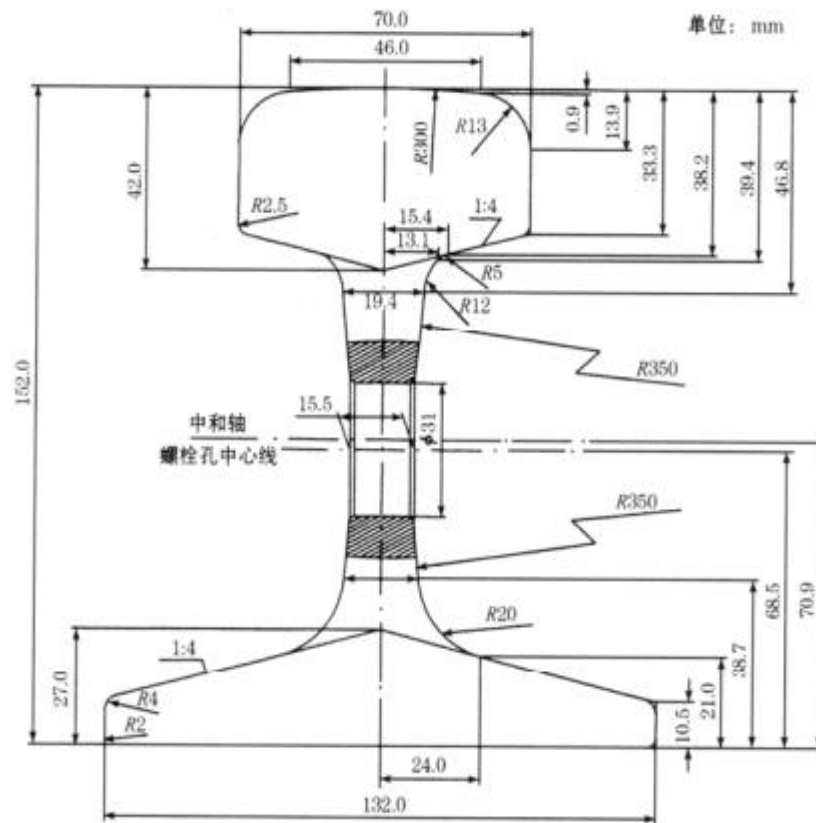


Figure 2-12 Section of Rail profile 50kg/m according to GB [16].

Good rail in these sections is becoming increasingly more difficult to find and the engineer may wish to give serious thought about the possibility of securing usable replacement rail in for maintenance purposes in later years.

The engineer wishing to utilize second-hand rail must take into consideration the amount of tread (top of rail) and gage wear present on the rail. Rail ends bent, kinked or badly battered may not be suitable for jointed rail relay use. The AREMA Manual for Railway Engineering has recommended maximum wear and alignment tolerances that are designated by the category of track usage [12]. The height of the rail and the width of the head of the rail are important to determine the selection of joint bars Avoidance of rail joints

Modern track work uses long welded rail lengths to provide a better ride, reduce wear, reduce damage to trains and eliminate the noise associated with rail joints. Rail welding is a complex art (or science) depending on how you feel about it. There are two main types of welding used for rails: Thermite welding and Flash Butt welding. Whenever

possible, the engineer should specify the use of welded rail. The elimination of the joint will reduce future maintenance costs by exponential factors. New rail is rolled in common lengths of either 12.5m or 25m in length. Construction is presently under way to roll rail in even longer lengths. These rails are then welded in a controlled environment into individual strings of up to 487m length for delivery to the field [17].



**Figure 2-13 (a) shows that one end rail join to other by bolts and shows jointed rail track
(b) Shows that the rail should be welded that to create smooth riding between rails.**

2.4.2 Sleeper (Ties)

2.4.2.1 General introduction about sleeper

Traditionally, sleepers, known as ties in the US, are wooden. They can be softwood or hardwood. Most in the UK are softwood, although London Underground uses a hardwood called Jarrah wood [18]. Wooden Sleepers are normally impregnated with preservative and, under good conditions, will last up to 25 years. They are easy to cut and drill and used to be cheap and plentiful. Nowadays, they are becoming more expensive and other types of materials have appeared notably concrete and steel. It used to be up to \$35-\$40 per tie in the late 1980's. They can last up to 20 years. Concrete ties are currently \$80-100 dollars. Recently, composite ties have come on the market. They are made of something like old tires and recycled plastic. They can be used and spiked like regular ties, cost about 50% less and save on trees [5].

2.4.2.2 Main purpose of sleepers or ties

The purpose of the tie is to cushion and transmit the load of the train to the ballast section as well as to maintain gage (Thomas P., 2001). Wood and even steel ties provide resiliency and absorption of some impact through the tie itself. Concrete ties require pads



between the rail bases and tie to provide a cushioning effect. If the amount of forces is quite large then the sleepers will come out of their position and will be moving either along with the rail sections or they will just loose this strength which they are going to impart to the overall track structure. So due to this aspect of stability both directional stability should be maintained [14].

Figure 2-14 Longitudinal reinforced concrete sleepers with rail [2].

Additionally, some advantages of sleepers are to establish and maintain track gauge, to distribute and transmit forces to the ballast bed or slab track. In addition, hold the rails, Secure the track, Dampen rail vibration, Reduce the influence of sound and impact waves on the environment, Mounting of the rails on the sleepers at an inclination of 1/20 or 1/40, Adequate mechanical strength both in the vertical and in the horizontal direction, Electrical insulation (along electrified lines) of each rail from the other. The number of sleepers per kilometer varies between 1500 and 2000, according to axle loads, The choice is usually economic, In tunnels, viaducts and bridges it is common to use sleepers with continuous slabs of either ordinary or Prestressed concrete [19].

2.4.2.3 Requirements for selection of sleepers

The very first requirement is always remains with respect to the cost. The cost, initial cost as well as the maintenance cost of the sleeper should be minimum. Besides they should be moderate weight, they should be easy to handle. If the weight is quite low then obviously, that is the easiest condition to handle the sleepers but then in that case the stability or the stiffness of the track will not be bear. Therefore at least they should be of moderate weight or they should be heavy weight but at the same time the structure

should be such that they are easy to handle. They should be able to resist shocks as well as the vibrations. If they are not in a position to resist shock and vibrations then obviously they will get crushed and if they are going to get crushed the maintenance requirements will increase, the periodical maintenance will increase, the cost will also increase [16]. The track circuiting must be possible. At the same time they should be anti-sabotage type or anti-theft qualities should be there, this is important as far as those locations are concerned which are removed or which are inaccessible or where the vision cannot be maintained thorough out the time period. So if they are anti-sabotage or anti-theft type then the safety of the track will be maintained or the safety of the operation will also be maintained. Fixing and removing of fastenings should also be easy. This is again related to the type of the material being used at the same time the type of the design being used. so that, if we have to remove or if we have to fix the fastenings that should not be difficult job. Sufficient bearing area should be there to all the sleepers so that they can transfer to the load to the wider area of the ballast cushion. The maintenance should be easy and the gauge adjustment should be possible using the sleepers [18].

2.4.2.4 Types of sleeper or Ties

Depending upon the position in a railway track, sleepers may be classified as longitudinal sleeper and transverse sleeper. The first Longitudinal Sleepers are the early form of sleepers which are not commonly used nowadays. It consists of slabs of stones or pieces of woods placed parallel to and underneath the rails. To maintain correct gauge of the track, cross pieces are provided at regular intervals. At present this type of sleepers are discarded mainly because of the following reasons. Running of the train is not smooth when this type of sleepers is used, Noise created by the track is considerable, and Cost is high.

Secondly, Transverse Sleepers Transverse sleepers introduced in 1835 and since then they are universally used. They remove the drawbacks of longitudinal sleepers i.e. the transverse sleepers are economical, silent in operation and running of the train over these sleepers is smooth [12].

Depending upon the material, the transverse sleepers may be classified as Timber/wooden sleepers, Steel sleepers, Cast Iron Sleepers and Concrete Sleepers.

2.4.2.4.1 Timber /wooden sleepers

The timber sleepers nearly fulfilled all the requirements of ideal sleepers and hence they are universally used. The wood used may be like teak, Sal etc. or it may be coniferous like pine. It is recommended that all timber ties be pressure-treated with preservatives to protect from insect and fungal attack. Hardwood ties are the predominate favorites for track and switch ties. Bridge ties are often sawn from the softwood species. Hardwood ties are designated as either track or switch ties. Factors of first importance in the design and use of ties include durability and resistance to crushing and abrasion. These depend, in turn, upon the type of wood, adequate seasoning, treatment with chemical preservatives, and protection [20].

Advantages of Timber Sleepers They are much useful for heavy loads and high speeds, Good insulators and hence good for track circuited railway tracks, they are able to accommodate any gauge, suitable for salty regions and coastal areas, can be used with any section of rail, Can be handled and placed easily, They are not badly damaged in case of derailment, they are not corroded, Cheaper than any other types of sleepers [13].

In reverse some of disadvantages of Timber Sleepers are liable to be attacked by vermin so, they must be properly treated before use, liable to catch fire, they do not resist creep they are affected by dry and wet rot, become expensive day by day, and life is shorter when compare to others [5].



Figure 2-15 Timber transverse sleepers for railway track [5].

2.4.2.4.2 Concrete sleepers

According to track standard manual, Reinforced concrete and pre-stressed concrete sleepers are now replacing all other types of sleepers except to some special circumstances such as crossing bridges etc. here timber sleepers are used. They were first used in France round about in 1914. But they are common since 1950 [13]. Concrete sleepers are much heavier than wooden ones, so they resist movement better. They work well under most conditions but there are some railways, which have found that they do not perform well under the loads of heavy haul freight trains. They offer less flexibility and are alleged to crack more easily under heavy loads with stiff ballast. They also have the disadvantage that they cannot be cut to size for turnouts and special track work. A concrete sleeper can weigh up to 320 kg compared with a wooden sleeper, which weighs about 100 kg. The spacing of concrete sleepers is about 25% greater than wooden sleepers. Sleepers at crossovers and turnouts vary in size according to their position in the layout. Concrete ties are rapidly gaining acceptance for heavy haul mainline use, (both track and turnouts), as well as for curvature greater than two [12].

They may be a twin block sleepers joined by an angle iron. It may be a single block pre-stressed type. Some advantages Concrete Sleepers Durable with life range from 40-50

years. They can be produced on large quantities locally by installing a plant and heavier than all other types. Thus, giving better lateral stability to the track, good insulators and thus suitable for use in track circuited lines and Efficient in controlling creep. They are not attacked by corrosion, Free from attacks of vermin and decay, suitable for all types of soils, Most suitable for welded tracks, Prevent buckling more efficiently, Initial cost is high but proves to be economical in long run, Effectively and strongly hold the track to gauge, Inflammable and fire resistant.

In reverse some disadvantages Concrete sleepers are difficult to be handled and to be manufactured in different sizes thus cannot be used in bridges and crossing, can be damaged easily while loading and unloading [14].

There are different types of concrete sleeper. The first is Reinforced twin-block sleepers. This type sleeper consists of two concrete blocks joined by a steel bar as shown in Figure 2.23. It is 30% lighter than a regular concrete sleeper, allowing it to be moved manually. It is popular in France and used for some lighter track forms like those used for tramway systems. Its advantages is Satisfactory transverse track resistance, allows high speeds and Long lifetime and Keeps track gauge within satisfactory tolerances. Its disadvantages are behavior less satisfactory if ballast thickness is not proper, load distribution and flexibility less satisfactory, Require elastic fastenings and difficult to handle and need Special attention required for the connecting bar.

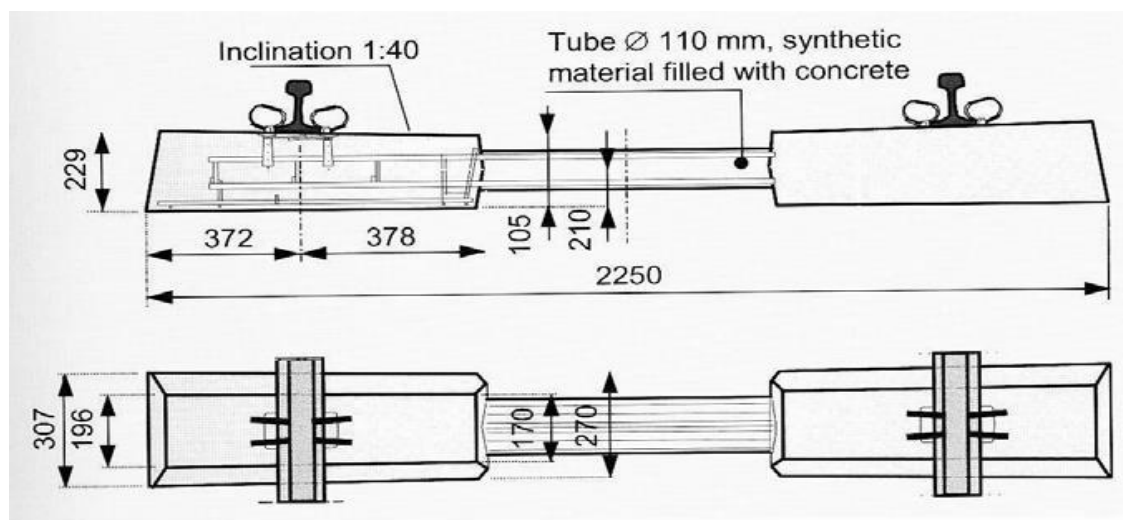


Figure 2-16 Reinforced twin-block sleepers [21]

The second type reinforced concrete is pre stressed mono block concrete. They can be supplied as crossties (i.e. track ties) or as switch ties. They are made of Prestressed concrete containing reinforcing steel wires. Advantages are maintaining track gauge, Long lifetime, distribute loads better than twin-blocks and Provide good surface for maintenance inspection staff. Disadvantages are Require elastic fastenings and special accessories for signaling and transverse resistance lower than twin-blocks.

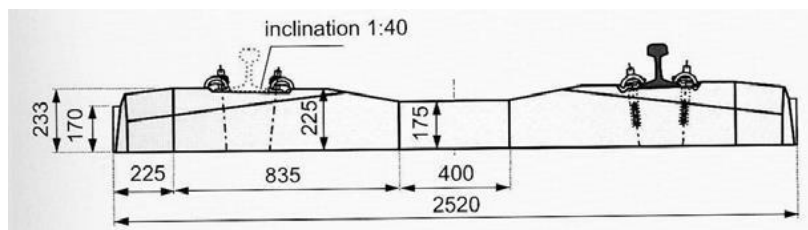
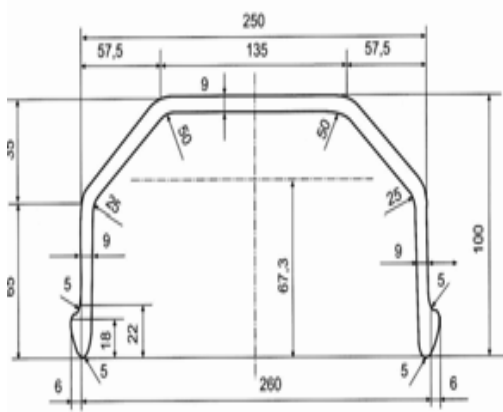


Figure 2-17 Prestressed mono block sleepers [19]

2.4.2.4.3 Steel sleepers

Steel sleepers are also now used on more lightly used roads, but they are regarded as suitable only where speeds are 160 km/h or less [10]. Some Properties of steel sleepers are it is industrial product of simple construction. Consists of a profile in the form of \cap and ends are forged to provide anchoring in the ballast, the rail is mounted on the steel sleeper by rail spikes (crampons) and Out of production today. Some advantages of steel sleepers are easily manufactured, installed and maintained. keep track gauge adequately constant for a long time, relatively long lifetime, life expectancy 35 years, after replacement, have a certain value as scrap iron [22]. In reverse some disadvantage steel sleepers are low transverse resistance, their form makes longitudinal and transverse track positioning difficult, noisy, Special insulating device required for signaling, Maintenance is difficult, Sensitive to chemical attacks [12].



(a)

(b)

Figure 2-18 (a) Steel sleeper section and (b) with steel sleeper track [18]

2.4.3 Fasteners and additional components

There are many different types of fasteners commonly used. Fasteners can be grouped by use as either connecting rail or track components together or to fasten rails to ties [10]. Fastenings and hold-down devices, with modern tie plate design, are aimed primarily at reducing movement between the tie plate and the tie, both vertically and laterally. As the track deflects under a wheel load, a reverse curve with upward bending is formed immediately in front of and behind the wheel. Lateral restraint is necessary to prevent wide gauge and plate cutting. Vertical restraint also reduces plate cutting [16].

The rail should be restrained within the tie plate shoulders, its own weight is usually sufficient, without unduly restricting the wave action in the rail. The plate must be held firmly to the tie by plate holding spikes to prevent any differential movement between plate and tie. The AREMA Manual for Railway Engineering gives a recommended spiking procedure. However, the Engineer should check to make sure that the railway has adopted the AREMA spiking standard [12].

Track Spikes are also a component. The purpose of the track spike is to first maintain gauge between the running rails and to secondly secure the rail to the tie. The underside of spike head is sloped to fit the top surface of the rail base. Spikes come in different lengths to ensure an adequate length of spike penetrates into the tie. The most common

track spikes used are for smaller rail sections. Spikes can be commonly secured in either 90kg [14].

Track bolts are also determined by the section of rail in use. Check the applicable railway standard to determine the proper bolt diameter and length. Track bolts are normally supplied as oval neck to prevent the bolt from turning when torqued. Track bolts are heat-treated and will stretch a little, thus they must be tightened after initial application. Track bolts are used with square nuts and spring washers. Over torquing track bolts creates frozen joints, which in most cases, is undesirable [2].

The other is tie Plates. It use of single or double shoulder tie plates make a more stable track and greatly lengthen the life of ties. Punched and sheared from hot-rolled steel sections, tie plates provide proper cant, uniform bearing surface for the rail and better load distribution to the ties. They hold the rail to gauge, providing more uniform wear to rail head and protect against undue wear to ties. Tie plates are designed with a long end or field end to be located outside of the rails. In the case of single shoulder tie plates, the shoulder is placed on the field end of the plate. The gauge end or short end of the plate is located inside of the rails. When ordering, identification of the rail section or the width of the rail base should be specified. Quality relaying tie plates are also available from our stocks which offer appreciable savings on railroad track age and industrial sidings [16].

Besides Gauge Rods are its own purposes. The purpose of a gauge rod is to maintain track gauge. They are often used to supplement the tie in preventing lateral movement of the rail in sharp curvature locations. They can also be used as a temporary means of maintaining traffic in defective tie conditions. They are not a permanent alternative to replacing a defective tie. Most gauge rods are adjustable with a nut on one end. Gauge rods are provided as either insulated for signaled territory or non-insulated, where track circuits are not used [12].

Sliding Joints also used for the purpose to accommodate the longitudinal expansion and contraction of the rail on long open decked bridges. Rail anchors are not typically used on open decked bridges because of the damage done to the softwood bridge ties. The sliding joint accommodates the thermal expansion produced by enabling the beveled rail ends to move but yet still maintain the continuity of the running rail. Besides a turnout is a combination of a switch, a frog, the rails necessary to connect the switch and the frog,

two guard rails, unless the frog is self-guarded, and a switch stand or switch machine for operating the switch. A turnout begins with the switch and ends with the frog. The purpose of a turnout is to permit engines and cars to pass from one track to another [22].

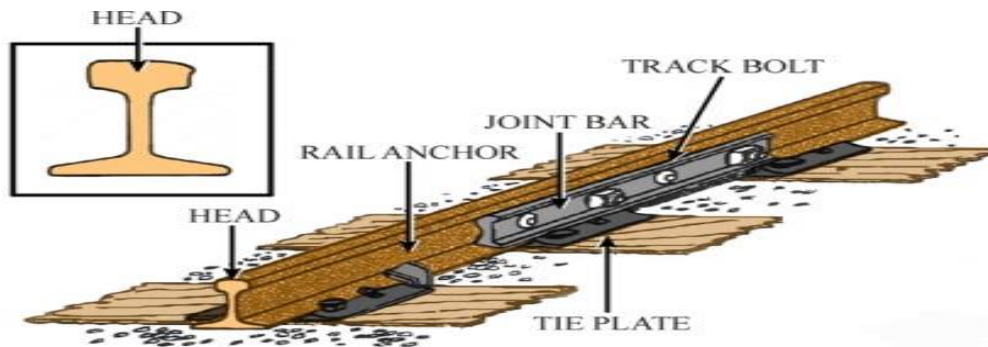


Figure 2-19 Railway fasteners; track bolts, track spikes and tie plat [23].

2.4.4 Ballast and sub ballast

2.4.4.1 General introduction

According to Australian rail track construction, Ballast by weight and by volume is the largest component of the track, and the cost of buying and distributing ballast forms a significant part of the entire civil engineering budget of the railways. In spite of the fact that ballast is the most important component of the permanent way, most attention has been focused on the track superstructure of rails, fasteners and sleepers, and not much consideration has been given to understanding the behavior of ballast in detail [18]. It is now universally accepted that good-quality hard angular stone, free from dust and dirt and not prone to cementing action, is the best material for ballast. However, historically track has been for longer on non-stone ballast than on stone ballast, as the first passenger train in the UK was run in 1821 and stone ballast was not adopted on all tracks until the 1930s [6].

The material used to support the cross ties and rail, is an important component in the track structure. It is the integral part of the track structure in the roadbed, and the quality of the ballast material has a direct relationship to the track support system. A principal purpose of the ballast section is to anchor the track and provide resistance against lateral, longitudinal and vertical movement of ties and rail, i.e., stability [19].

Ballast is provided to give support, load transfer and drainage to the track and thereby keep water away from the rails and sleepers. Ballast must support the weight of the track and the considerable cyclic loading of passing trains. Ballast is made up of stones of granite or a similar material and should be rough in shape to improve the locking of stones. In this way they will better resist movement. Ballast stones with smooth edges do not work so well. Ballast weighs about 1,600 to 1,800kg/cu/m. [12].

Additionally, the ballast section bears and distributes the applied load with diminished unit pressure to the subgrade beneath, gives immediate drainage to the track, facilitates maintenance, and provides a necessary degree of elasticity and resilience. Good drainage is of utmost importance to assure required stability.

2.4.4.2 Requirements of an ideal material for ballast

Ideal qualities in ballast materials are hardness and toughness, i.e., freedom from shattering under impact, durability or resistance to abrasion and weathering, freedom from deleterious particles (dirt), workability, compatibility, clean ability, availability, and low first cost. The principal desired characteristic is maximum stability at minimum over-all economic cost, including frequency of maintenance cycle, life of rails, ties and fastenings, and the labor costs [23].

Quality maintenance requires that more attention be given to the quality and characteristics of ballast. The practice of buying ballast purely because of low first cost or accessibility is clearly suspect. The ballast sizes recommended in the AREMA Manual for Railway Engineering are time-proven and acceptable. However, a number of AASHTO and ASTM gradations are similar to AREMA's and may be acceptable for use in some situations. This may be more cost effective in locales where AREMA gradations are not readily available but highway rock gradations are available. The comparison chart found at the back of this chapter cross-references various gradations. More important factors, probably, are the shape of the ballast particle, its degree of sharpness, angularity, and surface texture or roughness. These factors have been shown to have a significant effect upon the stability and compact ability of aggregates in general [12].

The ballast types most nearly meeting the ideal requirements, in order of preference, are granite trap rock, hard limestone, open hearth and blast furnace slags, other limestone's, prepared gravels, chat, volcanic ash, pit-run gravel and coarse sand (as a last resort).

There are other materials of local deposition that may be usefully considered, especially for light-traffic and industrial switching tracks [15].

Keeping ballast in a clean, free-draining condition begins with the selection of a ballast material that is tough, durable, not subject to abrasion, and free of clays, silts, and soft and friable pieces. Beyond that, maintaining adequate drainage and cleaning or renewal should be performed as needed. Shoulder and inter track cleaning are satisfactory until the ballast becomes cemented, too finely a braided, or until mud and dirt have collected under the ties and in the cribs. At this point, undercutting and cleaning, or undercutting, wasting and replacing with new ballast is in order. Undercutting may also be a necessary alternative to raising track during the surfacing and re-ballasting program where overhead clearances are restrictive. The depth of ballast required is a function of the supporting capacity of the subgrade. It should be sufficient to distribute the pressures to within the bearing capacity of the subgrade. Uniform distribution of pressures is another factor that varies with depth. Usually, a minimum depth of 40 to 60 centimeter is necessary to achieve uniform distribution. This depth may be distributed between ballast and sub-ballast. The greater the height of ballast around the tie, the greater is the resistance to vertical displacement. The same holds true for shoulder and lateral displacement [18].

2.4.4.3 Types of Ballast

They different types of ballast depend on materials availability and resistance. According to ASTM some types of ballast used on Railways are described in the following. The first one is Sand ballast. Sand ballast is used primarily for cast iron (CI) pots. It is also used with wooden and steel trough sleepers in areas where traffic density is very low. Coarse and is preferred in comparison to fine sand. It has good drainage properties, but has the drawback of blowing off because of being light. It also causes excessive wear of the rail top and the moving parts of the rolling stock. Secondly, Moorum ballast the decomposition of laterite results in the formation of moorum. It is red, and sometimes yellow, in colour. The moorum ballast is normally used as the initial ballast in new constructions and also as sub-ballast. As it prevents water from percolating into the formation, it is also used as a blanketing material for black cotton soil. The Third types of ballast are Coal ash or cinder. This type of ballast is normally used in meters and sidings or as the initial ballast in new constructions since it is very cheap and easily

available. It is harmful for steel sleepers and fittings because of its corrosive action. Finally, broken stone ballast. This type of ballast is used the most on Indian Railways. Good stone ballast is generally procured from hard stones such as granite, quartzite, and hard trap. The quality of stone should not be such that is it porous nor does it flake off due to the vagaries of weather. Good quality hard stone is normally used for high-speed tracks. This type of ballast works out to be economical in the long run. Other types of ballast such as the brickbat ballast, gravel ballast, stone ballast, and even earth ballast. These types of ballast are used only in special circumstances [20].



Figure 2-20 Rail ballast crushed stone aggregate on track

[Dec 2015 captured around Global hotel].

2.4.5 Sub ballast

It is a layer of material between the top ballast and sub grade with a gradation finer than the top ballast and coarser than the sub grade. The Function Used to reduce total ballast cost, Provide a filter layer between the top ballast and a fine grained sub grade. Application of A sub ballast layer is recommended for most new construction. In addition to providing filter to keep sub grade particle from working up in to and fouling the ballast, it provides a good mat to distribute loads from the ballast and prevents ballast particles from being pushed in to the sub grade [20].

A sub ballast layer is required whenever the sub grade contains 85% or more (by weight) of silt and clay sized particles or, the sub grade material has a liquid limit greater 50 and a plasticity index greater than 20. Material used for Sub ballast should be hard, angular,

non-cementing material, primarily of sand sized particles to function as a filter layer, the sub ballast particles should range in size from the smallest ballast particles to the largest sub grade particles [2]

2.4.6 Subgrade and Formation

It is the prepared earth on which the railroad ballast section and track structure are built. A sub grade is an earth structure, which is formed through excavating or filling and can bear the track structure directly, including section sub grade and sub grade of station and yard. Railway sub grade is the foundation of the track, it inherit and pass on the weight of track and the moving load of train. The formation is the ground upon which the track will be laid. It can be the natural ground level or grade or it can be an embankment or cutting. It is important that the formation is made of the right materials and is properly compacted to carry the loads of passing trains [20].

The formation under the track has a camber rather like that seen on a roadway. This is to ensure ease of water run-off to the drains provided on each side of the line. The track itself is supported on "ballast", made up of stones - usually granite or, in the US, basalt - below which is a layer of sand, which separates it from the formation. For new or renewed formations, the sand is normally laid over some sort of geotechnical screen or mesh to separate it from the foundation material below. In the past, asphalt or plastic sheeting has been used to prevent water seepage [15].

Subgrade is the naturally occurring soil which is prepared to receive the ballast. The prepared flat surface, which is ready to receive the ballast, sleepers, and rails, is called the formation. The formation is an important constituent of the track, as it supports the entire track structure. It has the following functions. To provide a smooth and uniform bed for laying the track, to bear the load transmitted to it from the moving load through the ballast, to facilitate drainage, to provide stability to the track. The formation can be in the shape of an embankment or a cutting. When the formation is in the shape of a raised bank constructed above the natural ground, it is called an embankment. The formation at a level below the natural ground is called a cutting. Normally a cutting or excavation is made through a hilly or natural ground for providing the railway line at the required level below the ground level as shown a Figure 2.30

The formation is prepared either by providing additional earthwork over the existing ground to make an embankment or by excavating the existing ground surface to make a cutting. The formation can thus be in the shape of either an embankment or a cutting. The height of the formation depends upon the ground contours and the gradients adopted. The side slope of the embankment depends upon the shearing strength of the soil and its angle of repose. The width of the formation depends upon the number of tracks to be laid, the gauge, and such other factors [6].

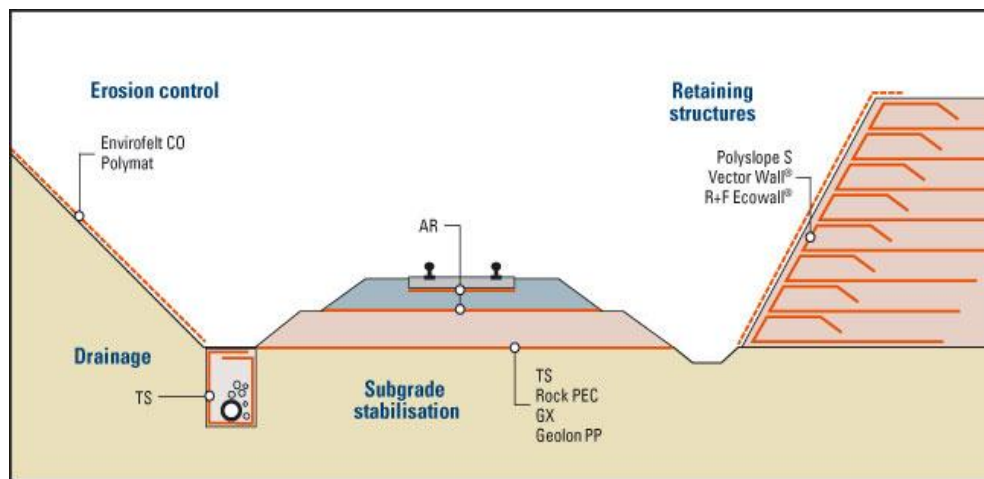


Figure 2-21 Railway Subgrade and its formation [14].

2.5 Special Railway structure components

2.5.1 Bridge or Elevated structure

A railway bridge is completed with a track structure, which is composed of rail, sleeper and track (concrete or ballast). A track structure can change the stiffness and the mass of the entire bridge structure. As a result, track structure can also change the critical speed of the train that gives rise to the resonance behavior [24].

The dynamic behavior of the railway bridge begins with the relationships between the dynamic properties of the bridge and the vibration characteristics of the moving train. A precise application of the dynamic properties of a structure, which are the first bending frequency and assumed damping ratio, will lead to a precise expectation of the dynamic behavior of a structure, with the relationship of the vibration frequencies of moving train loads [15].

There are different type's railroad bridges. Railroad bridges are nearly always simple-span structures. Listed below in groupings by span length are the more common types of bridges and materials used by the railroad industry for those span lengths. Short spans bridge length up to 25m. It may timber stringers, concrete slabs and rolled steel beams. The railway bridge lengthen up to 10 m is Conventional and Prestressed concrete box girders and rolled steel beams. The second type of railway bridge Medium spans which lengthen 25 m to 40 m Prestressed concrete beams deck and through plate girder.

The third type Railway Bridge long spans which lengthen more than 40m. Deck and trusses are simple, cantilever, and arches. Suspension bridges are not used by freight railroads due to excessive deflection [25].



Figure 2-22 Bridge or elevated structure of railway [24].

2.5.2 Tunnel structure

Tunneling is unique when compared to other types of civil construction. In non-tunnel projects like a large building or treatment plant there are usually many places to work at the same time, so the work can continue even if there is a problem holding up work at one location. Tunnels are long linear undertakings with few opportunities to perform the work at more than one location. Tunnels are also a series of repetitive operations each of which usually must be finished before the next can be started [26].

The planners and builders of tunnel projects to control and manage the project to a successful conclusion must understand this uniqueness and the linear and repetitive nature of the work. Perhaps the most significant factor influencing tunnel cost and schedule is the type of geologic material that the tunnel will be mined through and the amount of ground and surface water that will be encountered or crossed. Tunnels are mined through rock, soil or a combination of both. The geology encountered determines the tunneling methods that will be used, the speed that the tunnel can be constructed and the types of specialized equipment that are required [20].

The geologic material can also present some unique health and safety concerns that must be accounted for in the planning and construction of underground projects. Gas, petroleum, contamination, voids in the ground, hot water or large quantities of groundwater all pose safety concerns that must be addresses so that the workers building the tunnels are provided an environment free of hazards. Of similar importance to the tunneling methods and hours of operation are the communities that the tunnel will pass under, the locations of the major works hafts or portals from which the work will be serviced and the streets through which the equipment, personnel and material will get to and from the worksite as well as how the much removed from the tunnel is disposed of [2].

All of these factors will have impacts on the cost and schedule of underground projects and in fact represent risks to the project. These risks must be acknowledged, allocated and mitigated. Dealing with these risks can be accomplished through the contractual language between the parties to a tunnel project, or if not dealt with or if dealt with inappropriately, contractor claims or lawsuits [27].



Figure 2-23 New Australian tunneling methods for Railway [22].

2.6 Track construction machinery and equipment

They are different machine and equipment used for construction of railroad within efficient, accurate and limited time through advancement of the importance and development of technology. Some special machinery's are listed as follows.

2.6.1 New Rail's track construction machine

It installs new track on a previously prepared roadbed in a continuous operation. As self-propelled gantry, requiring one operator, keeps the ties supplied to the conveyor systems [23]. After being deposited by the gantry, the ties move via the conveyor system to the tie drop area. Rail, which has been previously distributed along the roadbed, is threaded through guides located at the rear of the tow unit. It is then guided inward to a gauging station. An operator who guides the rail onto the tie seat controls final placement of the rail on the new ties. He is also responsible for the proper alignment of the track. A "nipper-clipper" automatically engages and drives the clips onto their working position on the rail base as shown in Figure 2.31. This machine system installs an average of 500 ties per hour [28].



(a) Nipper Clipper



(b) Self propelled machine

Figure 2-24 Harsco Rail's new track construction machine [28]

2.6.2 Switch tamper/ Production /

Dominant characteristics of the Harsco Rail TM Mark VI production / switch tamper are high production rates, accuracy, fast travel speeds, versatility and component reliability. Major North American railroads have achieved unprecedented results and a high quality of track work completed by surfacing gangs equipped with these machines. Laterally traversing work heads and vibrators provide uniform tamping depth under production or switch tamping conditions.

The Mark VI design is versatile. It can be configured in various gauge widths (914mm to 1,676mm) and in single axle, bogie, or combination configurations as required to meet a specific railway's axle loading and curve radius requirements. Dual cabin and coupler configurations are also optionally available [10].

2.6.3 Production rail grinder

The RMS Series from Harsco Rail TM are 96-120 stone production rail grinders with dust collection. It is made up of nine specialized railway cars to make up a completely self-contained grinding train. All grinding functions (including grinding pressures, motor horsepower, and grinding angles) are controlled from inside the grind control car. Motors are individually controlled by hydraulics to provide the instantaneous response required for high speed grinding. An on-board computer allows monitoring, selection and maintaining up to 99 individual rail grinding patterns. The computer also accepts and stores up to 10 obstacles while working [29].

2.6.4 Track renewal system –TRT

Track Renewal System, Model TRT-909 removes old sleepers and rails, prepares the track bed for new sleepers, lays new sleepers and threads in new rail in one continuous operation and in one pass. It can be ready to begin work within minutes of arriving at a properly prepared work site. This machine also removes and collects the spikes and rail anchors, heats the rail with optionally available rail heater, and can apply various types of rail fastenings depending on customer requirements [14].

2.6.5 Transit / switch and crossing rail grinder/

Rail's transit / switch and crossing rail grinder (Model RGHC) is a self-contained machine consisting of main cabin, auxiliary cabin, engine and systems enclosure, main frame, running gear and grinding carriage. Machines can be utilized individually as eight or ten-stone machines or in multiple unit configurations as 8, 16, 20, 24, 30, 32 and 40 stone machines. In any configuration, the entire machine can be controlled by a single operator [30].

Features include integral dust collectors on each grinding car; low noise levels; towable in train formation; adaptable to fit various track gauges and easy operation via a touch screen control panel. In addition, investigating resource which can produce vibration and noise are vehicle, compact between rail and wheel, vibration of structures. On the elevated rail system, noise source identification, explore the distribution of the main noise sources, research analysis of the rail and bridge vibration in the surrounding environment, the spread and impact, are one of the hot rail traffic study [10].

2.7 Railway track Construction stages

According to Mareton bay rail Track Construction in Australia New railway line track construction is completed over six major stages which include The first phases are Embankment and earth work construction. Much of the Moreton Bay Rail alignment will be built on earth embankment which will form the rail foundation like on Figure 2.34. Bridges and culverts are needed to carry the rail line over existing roads and water courses and station facilities [18].

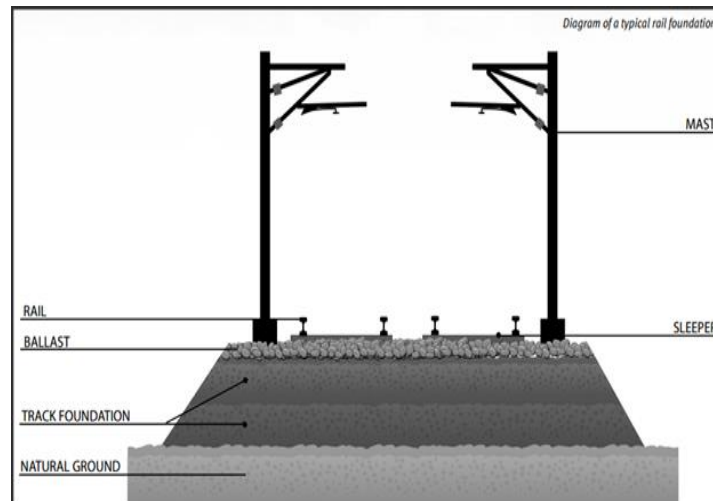


Figure 2-25 Embankment construction section

The second stage are Laying concrete sleepers over prepared road bed. Concrete rail sleepers are placed along the rail alignment as a base support for the rail. Sleepers are positioned by a front end loader with a sleeper 'grab' attachment which picks up a set of sleepers and lays them in the configuration for the rail tracks to then be attached. In stage three, laying the rail tracks over the sleepers. The steel rail is placed on top of the concrete sleepers and clipped into place by either a track mountable machine or by hand. The rail is then welded together using 'flash butt-welding' which melts two rail pieces together forming a seamless rail track. In the next stage by selecting spesfic type of rock used for supporting the sleepers and rail track, keeping them in place while trains run. A ballast machine rides the new tracks and places the ballast over the sleepers and between the tracks. After that, settling the rail. A track mountable machine called a tamping machine rides along the new track, lifting the tracks, to then vibrate the ballast into place. It then sets the track into its final position. This method is repeated numerous times to ensure the rail line settles and is ready for operation. At the end by Installing over-head equipment Masts are installed along the rail alignment to support the equipment which provides electricity to operate trains. Signaling structures are also installed along the rail route.

2.8 Light rail or light rail transit (LRT)

2.8.1 Definition of LRT

According to Encyclopedia Britannica LRT is urban public transport using rolling stock similar to a tramway, but operating at a higher capacity, and often on an exclusive right-of-way.

There is no standard definition, light rail operates primarily along exclusive rights-of-way and uses either individual tramcars or multiple units coupled to form a train. Few light rail networks tend to have characteristics closer to rapid transit or even commuter rail; some of these heavier rapid transit-like systems are referred to as light metros. Other light rail networks are tram-like in nature and partially operate on streets. A light rail system is found throughout the world, on all inhabited continents. They have been especially popular in recent years due to their lower capital costs and increased reliability compared to heavy rail systems [31].

According to Indian urban transportation definition Light rail transit (Modern tram way) is a medium capacity mode of mass rapid transport which straddles between the heavy capacity Metro rail and the low capacity bus services. It is a form of rail transit that utilizes equipment and infrastructure, typically less massive used for heavy rail modes. LRT may be at grade, partially grade-separated or completely elevated [32].

Besides, According to Transportation Systems Center defined light rail in as a mode of urban transportation utilizing predominantly reserved but not necessarily grade-separated rights-of-way. Electrically propelled rail vehicles operate singly or in trains. LRT provides a wide range of passenger's capabilities and performance characteristics at moderate costs [33]. Others defines light rail as a mode of transit service operating passenger rail cars singly, usually two-car or three-car, trains on fixed rails in right-of-way that is often separated from other traffic for part or much of the way. Light rail vehicles are typically driven electrically with power being drawn from an overhead electric line via pantograph. Driven by an operator on board the vehicle; and may have either high platform loading or low level boarding using steps [31].

Due to varying definitions, it is hard to distinguish between light rail, and other forms of urban and commuter rail. A system described as light rail in one city may be considered

to be a streetcar or tram system in another. Conversely, some lines that are called, light rail are in fact very similar to rapid transit in recent years. New terms such as light metro have been used to describe these medium-capacity systems. There is a significant difference in cost between these different classes of light rail transit. Tram-like systems are often less expensive than metro-like systems by a factor of two or more. The most difficult distinction to draw is that between light rail and streetcar or tram systems. The two versions LRT are as follows. The first are the traditional type, where tracks and trains run along the streets and share space with road traffic. Stops tend to be very frequent, but little effort is made to set up special stations. Because space is shared, the tracks are usually visually unobtrusive. The second version is more modern variation, where the trains tend to run along their own right-of-way and are often separated from road traffic. Stops are generally less frequent, and the vehicles are often boarded from a platform. Tracks are highly visible, and in some cases significant effort are expended to keep traffic away with special signaling, level crossings with gate arms, or even a complete separation with non-level crossings [33]. .

2.8.2 Characteristics of Light rail transit

LRT is a low cost, low axle load, eco-friendly, electrically propelled system with no local pollution and low noise and vibrations. Light rail vehicles (LRV) generally have a top speed of around 100km/h though mostly operating at much lower speeds, more kind to road vehicles [33]. Some LRT features include:

- Steel wheel vehicles operating on steel rails and are almost universally operated by electricity delivered through overhead lines. Electric power provides greater acceleration, making it suitable for operation with closely-spaced stations.
- Grooved steel rails laid flush with road surface or ballasted like normal railway track, making light rail the only system which can operate on both city roads and jointly with conventional rail services.
- Sharp road bends up to 25m radius, minimizing need for property acquisition and hence ideal for urban environment.
- Steeper inclines than heavy rail
- Shares its operational space with other road vehicles (e.g. automobiles) and often runs on, across or down the center of city roads.
- Grade separation only in exceptional circumstances.

- Light rail may also refer to any rail line with low speeds or many stops in a short distance [32].

Besides According Urban Corridor Facilities, 1962 Quinby distinguished this new concept in rail transportation from tram systems as having the capacity to carry more passengers, appearing like a train, with more than one car connected together, having more doors to facilitate full utilization of the space and faster and quieter in operation.

2.8.3 Comparisons light rail with other modes

There is a significant amount of overlap between the technologies, many of the same vehicles can be used for either, and it is common to classify streetcars or trams as a subcategory of light rail rather than as a distinct type of transportation. With its mix of right-of-way types and train control technologies, LRT offers the widest range of latitude of any rail system in the design, engineering, and operating practices. The challenge in designing light rail systems is to realize the potential of LRT to provide fast, comfortable service while avoiding the tendency to overdesign that result in excessive capital costs beyond what is necessary to meet the public's needs [31].

Some of the differences are listed according to international association public transport Light rail transit (LRT) are distinguished from rapid rail transit (RRT) vehicles by their capability for operation in mixed traffic, generally resulting in a narrower car body and articulation in order to operate in a street traffic environment. With their large size, large turning radius, and often an electrified third rail, RRT vehicles cannot operate in the street. Since LRT systems can operate in existing streets, they can often avoid the cost of expensive grade-separated subway and elevated segments that would be required with RRT.

Streetcars or trams Conversely, LRTs generally outperform traditional streetcars in terms of capacity and top-end speed, and almost all modern LRVs are capable of multiple-unit operation. The latest generation of LRVs is considerably larger and faster, typically 29 metres long with a maximum speed of around 105 kilometers per hour [20]. Heritage streetcars are to use historic cars on their streetcar systems instead of modern LRVs. A heritage streetcar may not have the capacity and speed of an LRV, but it will add to the ambiance and historic character of its location [34].

Light metro, A derivative of LRT is light rail rapid transit (LRRT), also referred to as Light Metro. Such railways are characterized by exclusive rights of way, advanced train control systems, short headway capability, and floor-level boarding. These systems approach the passenger capacity of full metro systems, but can be cheaper to construct due to LRVs generally being smaller in size, turning tighter curves and climbing steeper grades than standard RRT vehicles, and having a smaller station size [46].

Interurban rail as the term interurban mainly refers to rail cars that run through streets like ordinary streetcars (trams), but also between cities or towns, often through rural environments. In Europe interurban are making a comeback as tram-trains that operate on both railway and light rail tracks, often with different voltage.

Comparison LRT with bus can generally provide a high quality ride, and when segregated, regularity in service. Bus systems though highly flexible perform less well in these respects. Additionally the buses have a limitation of capacity, comfort, convenience and reliability of service. Most importantly the 'image' of bus services as a rule is poor and hence to get the user of the car and two-wheeler to shift to the use of the bus is not easy. LRT is capital intensive but cheaper than bus to operate for a given capacity at lower life-cycle cost, a higher commercial speed, reduced pollution. The preparatory time is relatively long and financing arrangements complex. Bus services, on the other hand, require much less funds and can be introduced quite quickly and plays a major role in city transport even when a popular rail transit mode operates in a city. While buses of various capacities may be used in a city, conservative approach is necessary when it comes to using rail transit technology [35].

2.8.4 Integration of light rail transit with nearby infrastructure

According to Transit cooperative research program, TCCR17 five basic principles should guide LRT system planning and selection of traffic control devices where LRTs operate on, adjacent to, or across city streets at low to moderate speeds. LRT system planning and traffic controls should [36].

- Respect the existing urban environment (unless a specific urban design change is desired)
- Comply with motorist, pedestrian, and LRV operator expectancy
- Strive to simplify decisions and minimize road-user confusion;

- Clearly transmit the level of risk associated with the surrounding environment; and
- Provide recovery opportunities for errant pedestrians and motorists.

Besides, according to transit corporative research program these planning principles translate into the following guidelines for railways geometry and traffic control devices [37]

- Unless a specific urban design change is desired (e.g., converting a street to a pedestrian mall), attempt to maintain existing traffic and travel patterns.
- If LRT operates within a street right-of-way, locate the LRT track way in the median of a two-way street where possible.
- If LRT is designed to operate on a one-way street, LRVs should operate in the direction of parallel motor vehicle traffic, and all not signalized midblock access points (such as driveways) should be closed. (It follows two-way LRT operations on one-way streets, especially contra flow, should be avoided wherever possible.) Further, where LRT is side-aligned, conflicting LRV and motor vehicle movements should be signalized to minimize motor vehicles stopping on the LRT alignment as well as general motorist confusion.
- If LRT operates within a street right-of-way, separate LRT operations from motor vehicles by a more substantial element (e.g., low-profile pavement bars, rumble strips, contrasting pavement texture, or mountable curbs) than paint or striping.
- Provide LRT signals that are clearly distinguishable from traffic signals in design and placement, and whose indications are meaningless to motorists and pedestrians without the provision of supplemental signs [36].

2.8.5 Safety and Aesthetics Light Rail Transit

According to Transit cooperative research program 1996, Safety can be improved by following the suggested guidelines and standards. Profoundly, for railway geometry and traffic control devices, the following additional actions should be taken through the early stages. The LRT planning, design, and environmental clearance process, consideration of potential LRV-motor vehicle-pedestrian conflicts should guide decisions regarding the types of alignment selected like separate versus shared right-of-way, median versus side

running, or contra-flow versus withflow operations. Secondly, Design and operating plans that focus on pedestrian and motorist flow and expectancy should be reviewed before new LRT systems and extensions of existing LRT systems are constructed. Thirdly, clear and consistent traffic control devices pertaining to light rail should be developed [37].

While many claim that light rail is safe. But according to analysis of data from the National Transportation Statistics report published by the US Department of Transportation [34]. shows that light rail fatalities is higher than all other forms of transportation. It states that Caution must be exercised in comparing fatalities across modes because significantly different definitions are used. In particular, Rail and Transit fatalities include incident-related (as distinct from accident-related) fatalities, such as fatalities from falls in transit stations or railroad employee fatalities from a fire in a work shed [34].

At grade modes offer the best aesthetics as they do not interfere with the skyline or the privacy of roadside premises. Elevated modes affect the skyline. Over elevated rail transit in aesthetics due to the slim guide beam needed overhead [38].

2.8.6 Construction and operation cost light railway transit

The cost of light rail construction varies widely, largely depending on the amount of tunneling and elevated structures required. According to survey of North American light rail a project [49]. show that costs of most LRT systems range from 2 billion ETB to over 15 billion per kilometer. In some cases is by far the most expensive in the US, at \$150 million per mile, since it includes extensive tunneling in poor soil conditions, elevated sections, and stations as deep as 55 m below ground level. These results in costs are more typical of subways or rapid transit systems than light rail . However, freeways are frequently built in suburbs or rural areas, whereas light rail tends to be concentrated in urban areas, where right of way and property acquisition is expensive [34].

Combining highway expansion with LRT construction can save costs by doing both highway improvements and rail construction at the same time. LRT cost efficiency improves dramatically as ridership increases. The same rail line, with similar capital and operating costs, is far more efficient, used many common light rail techniques to keep costs low, including minimizing underground and elevated track age, sharing transit

malls, leasing rights-of-way from freight railroads, and combining LRT construction with freeway expansion [39].

Compared to buses, costs can be lower due to lower labor costs per passenger in kilometer, higher ridership (observations show that light rail attracts more ridership than a comparable bus service) and faster average speed (reducing the amount of vehicles needed for the same service frequency). While light rail vehicles are more expensive to buy, they have a longer useful life than buses, sometimes making for lower life-cycle costs [40]

2.8.7 Specific Characteristics of a Railway Project construction

According to the Ethiopian Federal Environmental Protection Authority, FEPA 2012, the description and justification of a road or railway project shall cover at least the following elements [40].

- Spatial requirements (rights-of-way and other sites required for work).
- Project layout characteristics (including site location map).
- Land tenure and affected groups (directly or indirectly).
- Resettlement requirements and proposed transition and compensation means.
- Existing and proposed location of human settlements and public services such as health centres and accident and emergency units.
- Stakeholders' main uses, demands, modes of transport required, distance travelled, etc.
- Socio-cultural factors or constraints, such as customs and beliefs.
- Water requirements and potential sources and natural and human resources requirements.
- Construction activities (landclearing, burning, excavation, blasting, borrowing, extracting, filling, compacting, waterways crossing, paving, use of heavy machinery, etc.).
- Temporary (during construction) and permanent infrastructures.
- Surface water flows, culverts, and drainage.
- Anticipated liquid, solid (including waste) and gaseous emissions, and sources of nuisances (during the construction and operation phases).

- Construction schedules, costs, maintenance works, and associated costs.
- Anticipated traffic, products to be transported, and Intermodal transfer.
- Policing and traffic regulation and consultation approaches and participation mechanisms [33].

2.9 Case study the constructed Addis Ababa light rail transit Project

2.9.1 Introduction

The project is located in Addis Ababa, the capital city of Ethiopia, which was the location of the head office of African Union. The altitude of the plateau is 2,400m. The urban population cover over 3,400, 000. It takes 4% of the total population of Ethiopia. The urban area is 530.14 km², and the density reached 5,607.96/km [29].

General Condition of the Projects are The south-north and east-west line phase I project starts from Menelik-II Square and ends at Kality and from Torhayhoch to Ayat round square. The total length is 34km. Along south – North there are 22 stations, among which 9 are elevated stations (5 common stations at the common line), 2 underground station and 11 ground stations. The depot locates at the south end of the project. The control center (commonly used by both lines) is temporarily considered to be placed inside the parking yard [39].

To effectively solve the problem of urban transportation, especially that of the downtown area, the government of Ethiopia decides to build a light rail in the city of Addis Ababa. Currently this project has planned and implement two lines, the east –west line and the south-north line. About 3km is the shared section, which has the greatest passenger flow. The Basis for Design are mainly based on the following documents provided by ERC:

- East-West and North - south line topographic map (10 m contour line) ,
- plan position of the line,
- plan position of stations,
- the geographic report of some sections and the report of urban passenger flow study [1]

2.9.2 AALRT track structure components

The AALRT railway track consists of a flat framework made up of rails and sleepers, which is supported on ballast. The ballast rest on a sub ballast layer which form the transition layer to the formation. As the most important component, rail has the following functions. some are as follows. To accommodates the wheel loads and distributes over the sleepers or supports, guides the wheel in a lateral direction, any horizontal transverse forces. Besides, on the rail head being transferred to and distributed over the sleepers and supports, provides a smooth running surface and distributes accelerating and braking forces by means of adhesion, acts as an electrical conductor on an electrified line and conducts signal currents.

Addis Ababa Light rail transit evolved from streetcar technology. It defined as An electric railway system characterized by its ability to operate single or multiple car consists along exclusive rights-of-way at ground level, on aerial structures, in subways or in streets, able to board and discharge passengers at station platforms or at street and normally powered by overhead electrical wires [41].

2.9.3 Rail used for AALRT

According China railway group design drawing shows that the design and construction, of AALRT rail laid weighs 50kg/m. These is based on the requirement that total annual weight from single direction travelling should be no more than 800 billion tons (according to china Code for Metro Design GB50157-2003) and relative regulation in Code for Design of Rail Track (TB10082-2005), mainlines and auxiliary lines adopt 50kg/m PD3 rails. Due to this reason, AALRT rail weighs 50kg/m [3].

The weight of 50kg/m rail is 15% heavier than that of 43kg/m. The type of 50kg/m rail can significantly promote track strength, reduce track deformation and stress. In the same operating condition the duration of 50kg/ m rail is 1.5-2 times of 43kg/m. Therefore the adoption of 50kg/m rail can extend the maintenance cycle of the rail track and reduce vibration, which can enhance the stability of the rail track and reduce daily work for maintenance. Furthermore rail can also play function as current return circuit for tractive power supply. Therefore rail of large section can enhance the conduction of electricity. Moreover Chinese rail manufacture have not produced 43kg/m rail as common product. The adoption of 43kg/m rail will make difficulties for material supply and rail placing. And rigid fastener 70 diameter or arched shrapnel fastener 76

diameter have to be adopted when 43kg/m rail is placed, which are difficult for procurement in China. And joint bars as well as other fittings for 43kg/m rail are also difficult for procurement [3].

As the operation interval of long-term LRT project in Addis Ababa is 2.5 minutes, it is recommended to use hot rolled rail PD3 with standard length of 25m. Jointed track and common joint bar are adopted. The maximum super elevation of outer rail in the curved section is 120mm. The centrifugal acceleration of 0.4m/s which is not counter acted is permitted. Curve super elevation is set in the way of increasing Super elevation in the outer rail, which is realized with linear transition in transition curve. If there is no transition curve, it can be realized with linear transition in the straight line of curve end [42].

2.9.4 AALRT Fastener and Sleeper

According to Addis Ababa LRT project study report the fastener should be in simple structure and be installed conveniently. It should also have enough clamping force, anti-creeping capacity, elasticity, electric insulation and can meet the requirements of adjusting distance and height, reducing vibration and noise and protecting current from straying. After analyzing the fastener type and practical operation, railway spring bar fastener I is recommended. The static stiffness of rubber cushion is 50 ~ 70kN/mm. Underground track and elevated track will adopt reinforced concrete short sleeper, railway spring bar fastener I and the rubber cushion is 50~70kN/mm. Outside depot the concrete sleeper II, railway spring bar fastener I and rubber cushion with 50~70kN/mm are adopted. Inside the depot the same concrete sleeper and railway spring bar fastener I are adopted [42].

According to the track condition AALRT project, every kilometer of the mainlines and auxiliary lines will use 1520 bars of sleepers this means at each 0.65m. Elevated support rail bed should use 1600 sleepers (0.625m spacing) each kilometer.

2.9.5 Ballast Bed

Ballast bed for underground track mainlines adopts monolithic track bed with reinforced concrete short sleepers. The solid track bed with reinforced concrete short sleepers maintains the characteristics of mature techniques, simple structure, long duration,

simple construction and can ensure good quality, convenient operation and maintenance [30].

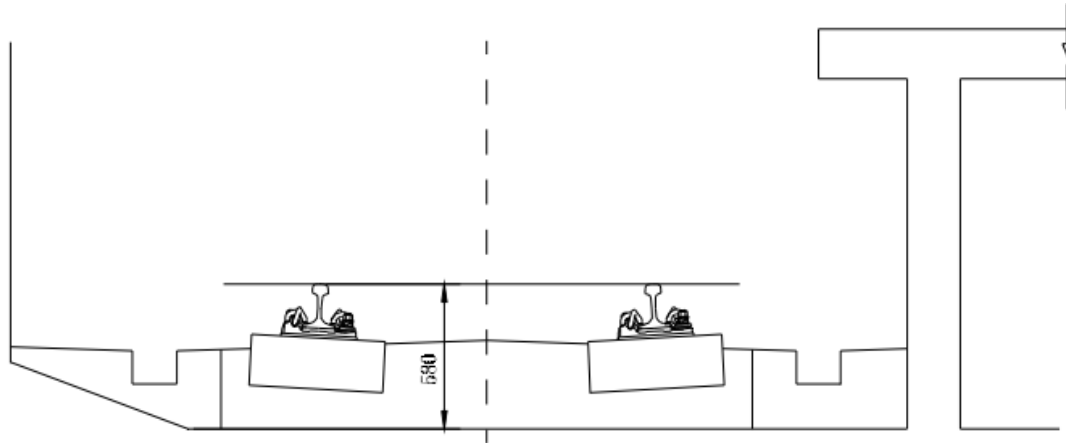


Figure 2-26 Underground Solid bed with Reinforced Concrete Short Sleeper AALRT project [42]

Ballast bed for grade track with prestressed reinforced concrete sleeper will be adopted for grade track. The double-layered gravel ballast bed has a thickness of 450mm. The layer of top ballast has thickness of 25cm, and the layer of sub-ballast has a thickness of 20cm. The material for sub-ballast layer should be mixed asphalt ballast with a certain compaction. This layer can protect the surface of sub-grade from the gravel disturbing drain rainwater easily and distribute the load further [20].

2.9.6 Construction Scheme of AALRT

The structure of the track should ensure the safe operation, smooth travelling and comfortable ride and have enough strength, stiffness, stability, durability and properly stable in order to reduce maintenance. Track structure should be as simple as possible, whose components should be effective, general and interchangeable. Therefore it would be better to adopt standard components which will be easy to load and unload and convenient for construction and maintenance. Based on other countries experiences of municipal rail transport projects home and other projects intends to adopt reliable and economical scheme for track structure [24]. Major Technique Standards used during construction of AALRT For the construction of AALRT project basics techniques used for route are the constructed route have two main lines and the ability of travelling highest average speed is 80km/hr. but due to limitation of urban area and other reason average travelling Speed is 18km/h. Minimum Curve radius at the main

line interval is 50 meters. In general, 30 meters is also applied in difficult sections and auxiliary line used is 30 meters. The Vertical Curve Radius use for AALRT project is 1000 meters within the standard gauge track 1435mm. The axis weight of the tramcar is not more than 11tons .The total length of one unit marshaling of the train is 28.4 meters [42].

According to Light Rail transit construction drawing design, Volume III Route Longitudinal Gradients are as follows The Greatest longitudinal Gradient in Mainline Section 50‰, The Greatest Longitudinal Gradient in Auxiliary Line is 50‰ The longitudinal gradient for elevated station is level grade or 0% [5]. When the gradient algebraic difference between two adjacent slopes is not less than 2‰, vertical curve should be placed in the shape of circular curve to connect the two slopes. The surface of ballast bed should be 30-40mm lower than the supporting rail surface of the sleepers. The transverse gradient for drainage in the ballast bed should not be less than 1.5% [41]. The longitudinal gradient for drainage in the ballast should be consistent with the gradient of the line. The gradient of level gradient the section should not be less than 3‰. The widening value should decrease by degrees within transition curve. If there is no transition curve, the widening value should decrease by degrees the straight line. The decrease rate should be no more than 2‰. The maximum super elevation is 120mm. If the super elevation is not enough, a transverse acceleration of 0.4 m/s², which is not counteracted, is permitted. The curve Super elevation should be set in the way of increasing the Super elevation in outer rail. The Super elevation should make linear transit by degrees within transition curve. If there is no transition curve, it should decrease by degrees the straight line [42].

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

3.1 The study approach

In evaluation and assessment of Addis Ababa light railway transit track structure they are a lot of factor that influence the development of urban infra-structure and solving transportation problem in the capital city of Ethiopia Addis Ababa. The study approach would conducted through detail questionnaire, site investigation and analyze practical problem which appear during construction of AALRT Therefore, in so doing, the research would need to consider different aspects of the problem such as aesthetics, efficiency, strength, future expansion, satisfaction, orientation, integration with nearby structure...etc.

3.2 Research type

The research is a practical problem that developed from an observation the Addis Ababa light railway transit project. It supplemented by research questionnaires designed to assess the knowledge and skill gain during construction track structure. In addition to evaluate and assess future expansion, quality of material supplied for track components, feasibility of planting manufacturer for track structure components, safety and aesthetic of track structure, integration with nearby structure, satisfaction of customers, evaluating the constructed railway track structure with developed countries metro or light railway transit.

The research is applied and exploratory in its nature because the research was initiated from practical problems and aims to find out in methodology and short cut to construct phase two AALRT project in better and efficient than phase I AALRT.

3.3 Data Source and Collection

The data collection approach adopted for conducting this research includes site observation, by assess basic documents, AALRT design reports, respondents and archival documents. Besides desk study as the primary data source for this research,

the research was conducted by disseminating two types of questionnaires open ended and closed ended to a large number of contractor, governmental, professional institution and consulting companies that undertake and related organization with railway corporation.

Data collection part of the research is the most challenging and hectic part of the research where delay in meeting deadline with respondents and vague & unclear responses have been encountered. This and similar problems made the research stressful for the period of data collection. The questionnaires were carefully designed with intent of acquiring high response rate from respondents. The answers of the structured part of the questionnaire were based on Likert's scale of five ordinal measures of agreement towards each statement (from 1 to 5) as shown in the following [43].

The two reasons given why this simple scale approach is adopted [44]:

- To provide simplicity for the respondent to answer, and
- To make evaluation of collected data easier

Likert's- scale helps to know respondents' feelings or attitudes about an opinion. The respondents must indicate how closely their feelings match with the question or statement on a rating scale. Respondents are then asked about AALRT railway on these variables in affecting accordingly the respondents would choose one of the following based on their outlook.

1. strongly disagree
2. Dis agree
3. Neutral
4. Agree
5. strongly agree

After expressing their agreement and/or disagreement on variable of questioners on railway track structure, respondents result was analyzed the chances of variables respondents were evaluated about the impacts based their choices [43].

- 1- No significance

- 2- Minor significance
- 3- Average significance
- 4- High significance
- 5- Extreme significance

Upon the completion of data gathered from the desk investigation and questionnaire respondents on constructed railway track assessment. Ethiopian Railway Corporation has to be identifying the problem and recommend taking remedy for next project. The questionnaires are then prepared in such a way that detailed information can be gathered in a systematically prepared in table.

3.4 The Research Population

The research samples will be gathered from organization and companies that works together with the clients' Ethiopian railway corporation. The respondents were selected based on their direct and indirect involvement on railway construction activities. For the purpose of the research ERC and consultant's high level were selected. Lists were taken according to direct involvement of in railway construction and the research samples were selected randomly from the organizations.

Sample size for the research study is calculated using the following formula,

$$n = \frac{p*(1-p)z^2}{E^2} \dots\dots\dots [\text{Eq-3.1}]$$

Where; n - Necessary Sample Size. Z - Z-score from Z-score table within 95% confidence level Z=1.96. P - proportion of the population with professionals exceeding 10% of engineers estimate and E- Margin of error (Confidence Interval). With confidence level 95%, marginal error + or - 5% and proportion of the population to be 0.10 which is the most forgiving number ensuring that the sample will be large enough and the sample size is found to be 139. The variables were determined on the basis of the time available for conducting the research work, available fund for the study (project), and the reliability of the respondents [43].

In order to get a thorough representation of the sample size, the dissemination of the questionnaires was conducted to organization encompassing of experience and reputational diversities within the construction industry.

3.5 Research Instruments

The survey instrument for this research is developed in such a way that the data collection approach is adopted for conducting this research from both primary and secondary sources. Site investigation, questionnaire and desk study provide the primary data for this thesis while the secondary data sources include renowned civil engineering journals on railway transport system, internet sources, and related archival documents. These different methods of data collection system have been used in order that the data or information obtained from one would supplement the other source where information gaps have been exhibited and enforcement of evidences is required.

3.6 Method of Analysis

Both descriptive and inferential statistics are employed in the data analysis. In the analysis the Mean Score, Mode, standard deviation method is taken as a tool to establish the relative importance of the railway track structure constructed in Ethiopia. In accordance to Likert's scale of five ordinal measures of agreement towards each statement (1, 2, 3, 4 and 5), the mean score is calculated for each factor that is used to determine the relative ranking. The mean score (MS) for each variables attribute overrun is computed by using the following Formula [43].

$$MS = \frac{(f*n)}{N} \dots\dots\dots [Eq-3.2]$$

Where: MS – Mean Score

- f – Frequency of responses for each score
- n – Scores given to each factor (from 1 to 5)
- N – Total number of responses concerning each factor

Standard deviation, mode and mean score for each questions developed analyzed us a summary. The mode is the value that occurs most frequently in a sample. when multiple values occur with the highest frequency the sample is said to be bi-modal or multi-modal. Standard deviation (σ) is a measure of the dispersion of a collection of numbers. It indicates how widely spread the values in a dataset are with respect to their mean

$$\sigma = \sqrt{\frac{\sum (x-X)^2}{(n-1)}} \dots \dots \dots \text{[Eq-3.3]}$$

Because the mean of the population is usually unknown, it is important to estimate the error between the sample mean and the population means [51].

The SEM Standard Error of the Mean is an unbiased estimate of expected error in the sample estimate of a population mean.

$$\text{SEM} = \frac{\sigma}{\sqrt{n}} \dots \dots \dots \text{[Eq -3.4]}$$

Ranks of variables based on cumulative mean score as perceived by different parties should be tested for correlation. The purpose of a correlation test is to verify whether there is a great deal of difference in ranking respondents and as well in order to be able avoids from being deceived by chance of occurrences and significance as view standard error of mean [45].

CHAPTER 4 DATA ANALYSIS AND DISCUSSIONS

4.1 Introduction

This part of the research deals with the analysis and discussion of the data compiled from the questionnaire, site investigation and desk study. It includes camera shoots, interviews and videos that recorded in news and social Medias.

The procedure used in analyzing the results was aimed at establishing the relative importance of the various factors that cause problem during construction AALRT track structure and for purpose of caution during construction of phase two AALRT project.

The questionnaire were intended to give each respondent an opportunity to identify satisfaction level and recommendation with the respondent's response strongly disagree, disagree, agree or very low, low, high, very high ...etc. For each variable, the percentages of respondents' were rank for the analysis purpose. It was possible to identify the most important factors in assessment of construction of AALRT.

From the desk study, a variety design documents, structural drawings of Addis Ababa railway track structure components, design report of AALRT and additional documents ERC were surveyed. During the desk study, all relevant documents such as standards of different countries manual, case study Addis Ababa light railway design documents were thoroughly investigated. These has enabled the research understand the problematic area and forecasting for efficient way of constructing phase II AALRT in efficient and wise manner.

4.2 Questionnaire Response Rate

Detailed questionnaires were designed and disseminated for the assessment of professional opinion about the constructed Addis Ababa light rail transit track structure. In line with this purpose, questionnaires were distributed to owner of a project (ERC) and organization that directly and indirectly involved in construction of a project. Since there is only one owner and contractor during construction of AALRT project no need to form groups of respondents. We need only general assessment that focus on

professional's knowledge and information about railway construction. Not need focus on individuals or organizations performance or duty.

A total of 139 questionnaires were distributed to different organization and companies out of this, 71 questionnaires were filled and returned. Three questionnaires were rejected due to incompleteness. Hence, out of the 71 questionnaires 68 were found to be suitable for data analysis. The overall response rate was 49% as shown in table below.

Table 4-1 Summary of number and percentage of questionnaires distributed and returned.

Respondents category	Questionnaire		Percentage returned	Valid response	Percentage of response
	distributed	returned			
Directly involved organization in construction					
Client (ERC)	11	6	54%	6	54%
Contractors(CRCC) and Site engineers	13	5	38%	5	38%
Consultants of ERC	8	3	37%	3	37%
Supervisors(AACRA)	15	8	53%	8	40%
Suppliers(sleeper producer)	7	3	43%	3	43%
ERA(Ethiopian road authority)	18	10	61%	9	50%
UDM (urban development ministries)	9	5	55%	5	55%
EPP(Ethiopia electric power)	12	5	41%	5	41%
ERCC	9	5	66%	4	44%
ERC professional institution	21	14	67%	14	67%
Others (customer of ERC, drivers, workers, site foreman ...)	19	8	42%	8	42%
Total	139	68	49%	71	51%

4.3 Quality of Respondents

Various experienced professional levels were targeted to fill the questionnaire survey. Out of the total questionnaire disseminated, 90% of professionals were from governmental organizations of more than 20 years of establishment and employee has from 1 to 15 years work experience. Only 10% have individuals and self-business workers from respondents. In regard, of educational background, M.Sc. 21%, B.Sc. 69% degree and others 10% (technicians, skilled labour) holders' valid respondents number respectively as shown Table 4.2.

The reliability and accuracy of the survey is believed satisfactorily accurate. Because 100% selected organization professionals are directly and indirectly involved in construction of Addis Ababa light railway transit track structure. Besides, as a society they use or meet users of a transportation system during perform their day to day activity. Due to this reason they have immediate and accurate information was responded. Since the constructed Addis Ababa light rail transit are laid and erected at center of town everyone would comment and discusses on track structure of railroad. Generally, since this project is new for generation and citizens of our country it expected and tolerated to create awareness and deal with transportation system. Therefore, relevant pertinent professionals and owners information are believed and would be compiled for the analysis in order to draw reliable conclusions and recommendations.

Table 4-2 Summary of the status, Respondents education background

Respondents category	Respondents education background						
	BSC	MSC	other	Total	%B.sc	%M.sc	%Other
Client (ERC)	4	2	0	6	66	34	
Contractors(CRCC) and Site engineers	4	0	1	5	80	0	20
Consultants of ERC	0	3	0	3	0	100	0
Supervisors(AACRA)	4	1	1	6	66	17	17
Suppliers(sleeper producer)	3	0	0	3	100	0	0
ERA(Ethiopian road	8	1	0	9	88	12	0

authority)							
UDM(urban development ministries)	5	0	0	5	100	0	0
EEP(Ethiopia electric power)	4	0	1	5	80	0	20
ERCC	3	1	0	4	75	25	0
ERC professional institution	10	4	0	14	71	29	0
Others (drivers, skilled laborer , site foreman)	2	2	4	8	25	25	50
Total	47	14	7	68	69%	21%	10%

4.4 Desk Study and Questionnaire Response on Assessment and Evaluation on track structure constructed in AALRT

The research has made us to survey the general assessment began from importance of providing railway , satisfaction of resident through provided railway line alignment, service provided ... up to production of components of materials need for construction of phase II AALRT and national railway network.

4.4.1 Satisfaction level due to GTP-1 implementation plan in terms of LRT

According to our governments first growth and transformation plans phase I light railway transit construction was made and implemented recently. According to the research, as shown in the Figure 4.1, professionals and planner are satisfied. Because they suggest that, in Ethiopia and East Africa the constructed AALRT is the first electric traction and light rail. Even if the project is high cost by considering growth of urban resident citizens providing long term and efficient transportation is one of main success for government due to the planned and implemented light rail transit in initiating and appreciating other railway project for construction.

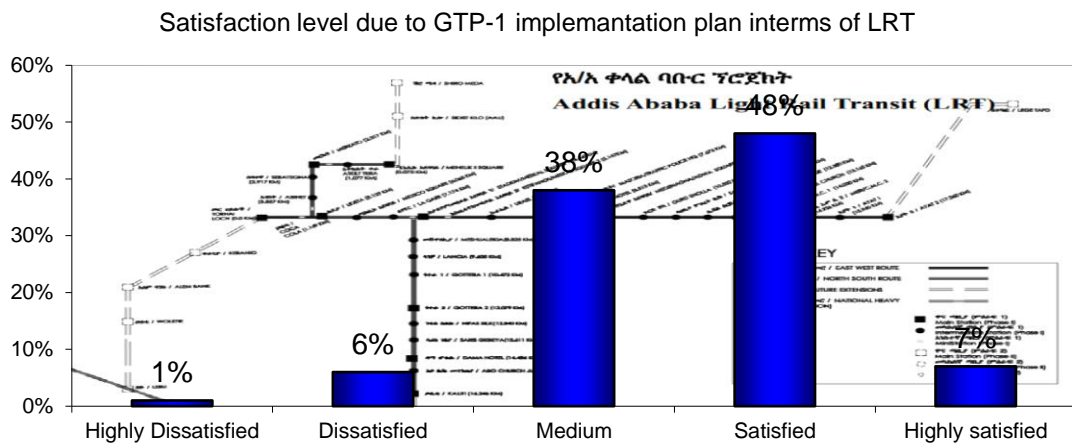


Figure 4-1 Satisfaction level due to GTP-1 implementation plan in terms of LRT adopted by respondents

Based on the survey conducted in this research, most respondents agree on the opinion that government plan and implementation satisfies professionals and citizens as the first project constructed in east Africa and encourage for extension and development of new railway line.

4.4.2 Importance of providing LRT for capital city, Addis Ababa

Some professionals ask, is that necessary to provide LRT for Addis Ababa town? Since providing fixed permanent structure inside the town may limit flexibility transportation and traffic system in the town. They quote development of Brazilian metros and trams [46]. They suffer for demolishing old existing railway line and replacing with modern system of traction. Since, they replace with bus rapid transit with optimum cost and flexible system. They use railway transport for freight and national railway transport. Currently according to the research conducted, there are very high demand of transportation and impossible to alleviate this transportation problem within providing highway transport. Addis Ababa's Transport problems are diverse like aged Fleet, chaotic movement of mini-bus taxis, environmentally unacceptable emission, unsafe, Hazardous to life and property. Even if it is also possible to provide large amount of highway transport, there are inadequate land and create traffic congestion. Due to this us a Figure 4.2 shows 78% our professionals strongly agree that providing LRT is currently the solution for the transportation problem.

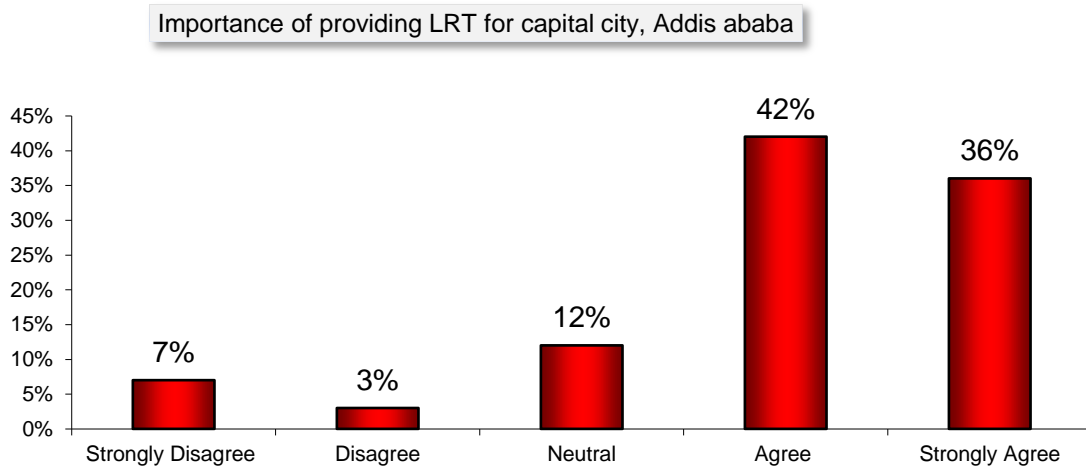


Figure 4-2 Importance of providing LRT for town of Addis Ababa

4.4.3 Considerations need of customer in selection of route, orientation and service

This research also study about satisfaction level due to the provided track structure route, orientation and length. According to site plan of Addis Ababa city most residential and apartment building is constructed at the side of town or outlet to the national corridor (like Lega Tafo, Summit, Akaki, Tuledimtu, Jemoo, Galan...). Besides many work place and offices is under construction at center of town (Behrawi, Mexico, piasa...) where they need high transportation demand for movement from home to work place. So, the constructed railway track structure laid from Gumeruk, Kality to Menilk round square and Torhyloch to Ayat round square.

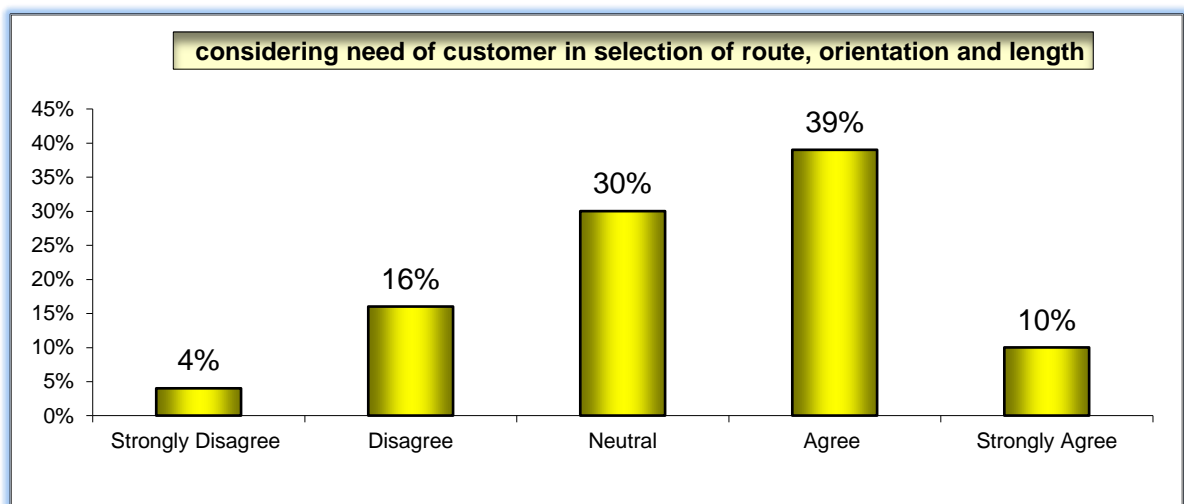


Figure 4-3 Consideration need of customer in selection of route, orientation and length adopted by respondents

As the Figure 4.3 shows all most professionals, agree that the constructed track line consider the need of customer since highly populated resident where live at the end of the track line as governments plan. This helps resident to transport at work places.

According to this research the questionnaire response and site investigation the alignments constructed from North- South and East-West, consider some part need of customer in selection of route, orientation and length. Highway user also complains due to lack of proper turning place to another direction. Besides even if there is road crossing at railway line it has high traffic congestion for both pedestrian and vehicle driver. Additionally, the speed, some route trip cost and rotation of alignment(from stadium to Lideta then Merkato and end at Minilik round square) railway line and cost are not integrated. Since directly the cost form stadium to paisa is reduced by half when compared to railway trip cost. According to their response this is result happened due to lack of proper design and lack of consideration of road crossing at high volume of traffic congestion. So that as the Figure 4.3 shows customer satisfaction level is nearly neutral. This shows that if extension line track construction is held and traffic congestion problem is solved satisfaction level of customer is increases as the questionnaire response rate shows.

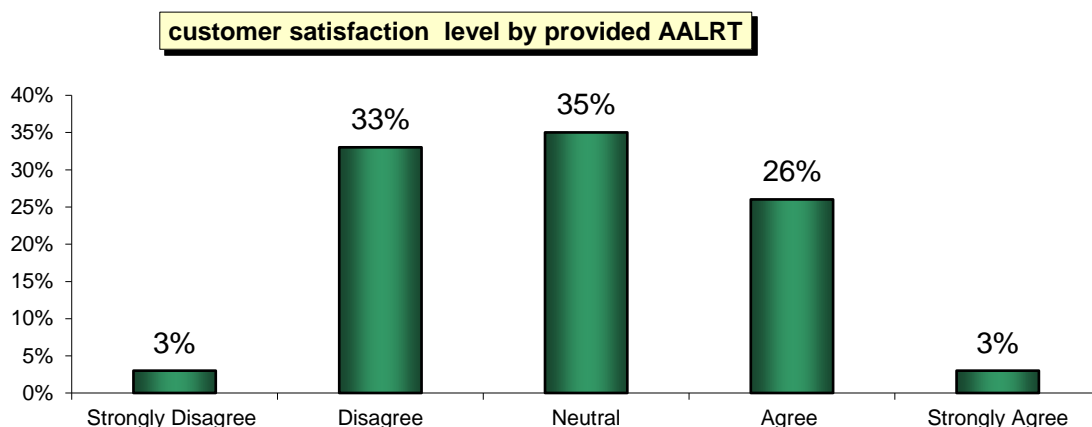


Figure 4-4 Customer satisfaction level by provided AALRT project adopted by respondents

4.4.4 Consideration Safety, Future expansion and Aesthetics on AALRT project

According to LRT project study report guidelines safety, reliability, economic and effectiveness are carried out in order to save energy, resource and endeavor to meet the requirements of saving investment and enhancing efficiency [3].

According to this research when we say aesthetics' it consider beauty, formal ordering principle like unity, proportion, Variety and harmony. As a famous Architect Le-courbiouser define aesthetics it is sensitive to art and beauty that showing good taste & appreciative or deals with the nature and expression of beauty. Besides, it must establishing spiritual harmony between people and their environment [47]. For better visualization of the new Light Rail Transit System with the city environment, aesthetics is one factor to be considered in the planning stage. In different literatures, it is indicated that the installation of the LRT infrastructure which includes the track way, overhead Catenary wires and support masts, signal support poles, grade crossing control measures, fencing, stations, and other ancillary structures, including the LRT train moving through the community, may be considered by some community residents as being visually displeasing.

Architectural elevation and general layout must be in compliance with requirement of urban planning. Architectural elevation shall be elegant and scientific, and match with surrounding environment and sceneries. The construction of elevated structure should take the impact on city transportation into consideration and try to reduce the impact. When the elevated structure crosses critical sections (junctions, it should conform to the requirement of grade transportation and choose proper construction method and structure [41]

According to this professionals questionnaire response 42% of respondents are disagree with constructed AALRT project that would not consider safety, reliability, future expansion and urban aesthetics. They mention the reason the constructed permanent laid and elevated track structure should create phobia to nearby activity's and if trains accidents happens, it creates sever damage. Since, all most track routes passed between road ways restrict future expansions of railway track structure. Specially, these 42% professionals suggests, from Lideta to Stadium this huge elevated track structure (jungle of huge, long columns, deck, station overpass) structure distorts urban aesthetics and prone to severe accident if happens. On another hand 32% of questionnaire respondents

agree that AALRT project would consider safety, reliability, future expansion and urban aesthetics. Besides according to their suggestion ends of phase one root is ready for extension and expansion to all corridors. Generally, about 25% of out of 68 respondents have neutral idea. This means the project considers somewhat safety, future expansion like parking, greenery and aesthetic as our economy and technology.

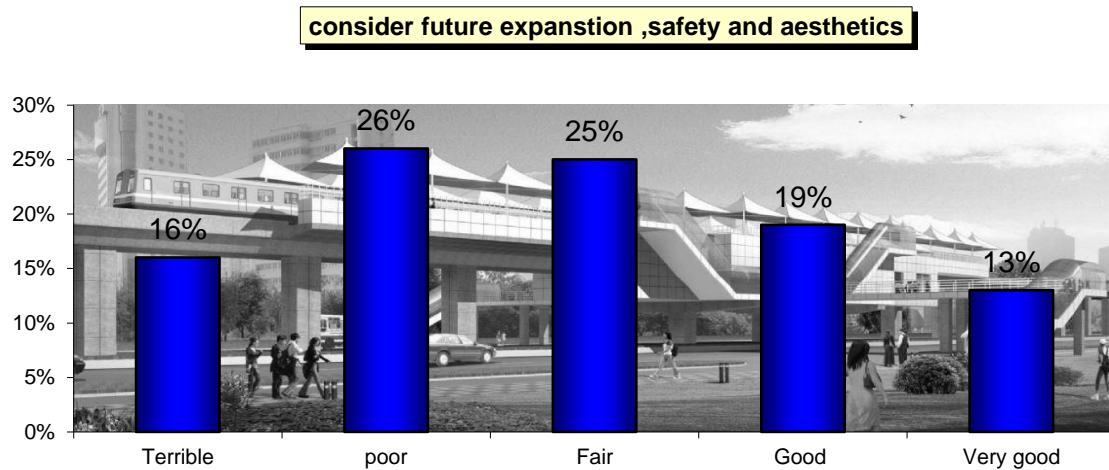


Figure 4-5 Consideration safety, future expansion and aesthetics of AALRT project adopted by respondents

4.4.5 Integration AALRT with nearby infrastructure and landscape

One of the objectives of this research is to assess the integration of the constructed railroad with nearby infrastructure (like road, ditch, telecom tower, power pole and buildings) and landscape. According to LRT project study report the line for LRT should be coordinated with the existing roads and planning roads in the future. And the project should try to reduce the demolition of existing structures and the effect to the city transportation. the design of structure should consider about underground existing buildings, pipes and wires. Besides, try to reduce negative impact on buildings, pipes and wires. The elevated structure should not only meet the requirement of marshaling, but also consider about the electric supporting equipment, communication supporting system and anti-beam falling system. According to the requirements of different section geologic situation and master plan of the city and integrated with existing buildings, pipes, wires and transportation situation, reasonable construction method and structure should be adopted after comprehensive comparison among different technical aspect , economical aspect, construction techniques, environmental protections and functions.

Based on these guidelines the LRT project fitting with Ethiopian domestic situation should be constructed. The location of station should meet the requirements of Addis Ababa city plan and transportation, especially railway transportation network plan Integrated with the surrounding areas and land usage to realize the integration of public transportation.

The selection of station location should well deal with the relationship among city traffic, ground architectures, underground lines and pipes and underground structures. The selection of station location should try to reduce building demolition, pipes and lines relocating and the effects to ground architecture, traffic and residents.

According to this research site investigation, desk study, professional's questionnaire response rate there is lack of integration with the nearby infrastructure. As a Figure 4.6 shows, more than 75% of responds agree there is disintegration with the landscape, telecom tower, electric pole, drainage system...etc.

Besides they suggests the cause of disintegration may be

- There is lack of master plan that shows infrastructure and landscape to design properly by considering future development and utilization of infrastructure.
- There is lack of discussion and corporation with concerned organization during construction
- Lack of immediate restoration and maintenance after demolished nearby infrastructure with concern organization.
- They cannot consider nearby existing structure and future expansions plan during design phase. This leads for redundant works and additional cost.
- They modify their design and construction without consulting Concern Company.

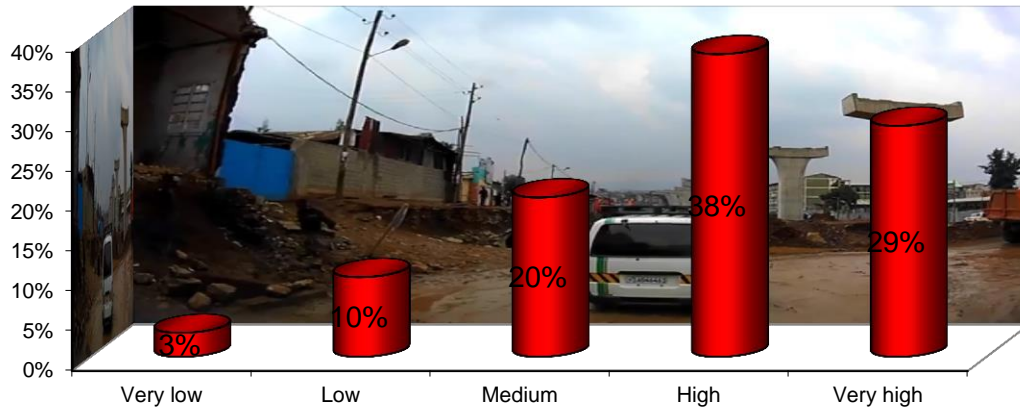
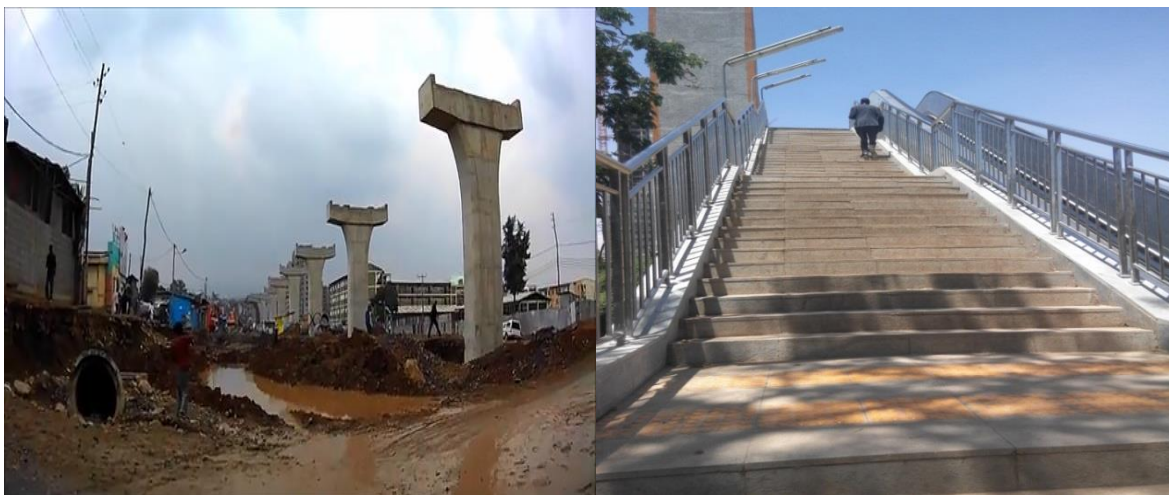


Figure 4-6 Degree of disintegration with the nearby infrastructure and landscape adopted by respondents

To explain this disintegration some professionals locate to see the station around Lideta that station landing enter in the building, sewerage line at Merkato and demolished building around Leghar. They suggest that this examples show there is problem of discussions and integrations with the concerns legitimate organization.



a)Disintegrate with drainage

(b)Highly elevated stair at stadium



(C) Lideta station disintegrate with building around Supreme Court

Figure 4-7 Camera shoots shows disintegration with nearby infrastructure

According to desk study data the first Turnkey tender issued by Ethiopian Railway Corporation on April 2008. During tendering period three tenderers submitted proposals. The first Pre-contract negotiations failed because of high cost, failure to available cost break down and unconfirmed finance source. According to concern professionals 53% respondents out of 33 valid response they have neutral idea. This means contract agreement were fair, open, inclusive and attractive.

Desk investigation reveal LRT project study report shows that the selected route for NRN and LRT have been surveyed (500m band) by the latest technology that found in the world using Light Detection and Ranging (LiDAR) technology. Based on the city planning, street network and geographic, geological, engineering, hydrogeological conditions both on the ground and underground as well as the traffic condition, the alignment should be effectively designed. The location and placing method of the alignment should be reasonably selected.

According to site visit and design the studies for route selection, topography and survey data collected are highly integrated with actual sites during construction. Accordingly Figure 2.8 shows professionals questionnaire respond, 36% of respondents are agree,

28% of respondent disagree and 36% respondent's neutral idea out of 68 valid responses which suggest that railway track structure construction attempt to consider topographic and geological data. Professionals reason out to their responses, elevated structure constructed at a place where high traffic volume (stadium to Lideta, see on appendix) and tunnel structure at elevated area near saint gorges (Minilik round square).

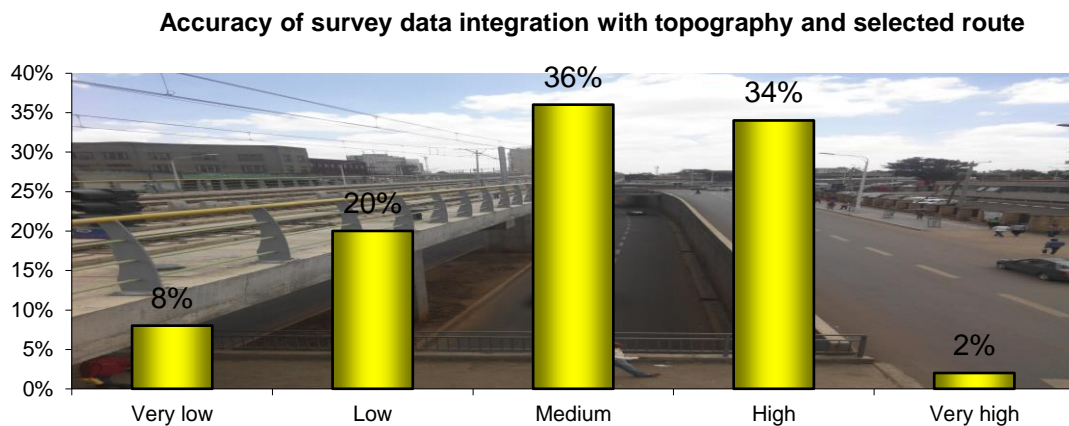


Figure 4-8 Accuracy of survey data integration with actual site topography and landscape

4.4.6 Wastage of properties, materials and human labor and lack of proper workmanship

Ethiopian government have long-term plan to construct light rail transit before implementation. At a time, due to situation invites and large involvement of political commitments, construction of AALRT project began and completed work within limited time. During this time for completion and construction of AALRT project they are a lot of buildings, roads, wires, underground utilities are damaged and demolished. As the Figure 2.9, shows 54% professionals agree with there are wastage of properties, materials, human labour and lack of proper workmanship during construction of AALRT project.

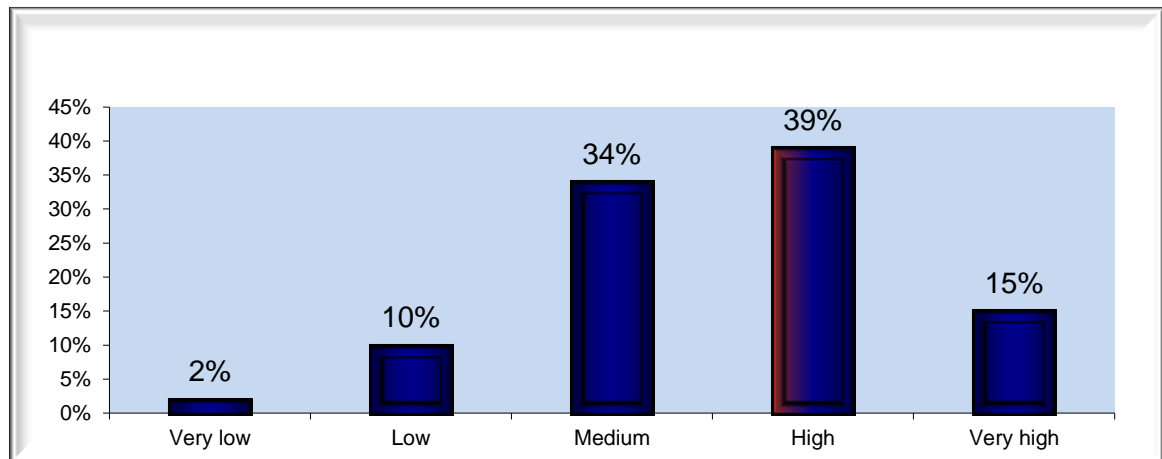


Figure 4-9 Wastage of properties, materials and human labour during construction of AALRT project adopted by respondents questionnaire response

Desk studies also reveal that the road constructed from Stadium to Kality was demolished for railway purpose without serving more than 10years. The road costs more than 32million ETB. Besides, buildings and bridges around Meganagna demolished within few years' service. This shows that there is wastage of property, material and costs.

So according to the research output professionals recommend during construction phase II AALRT project they must use properly planned and approved design drawings to avoid redundant excavation and construction works. Additionally, future expansion and extension plan considered before implementation and construction. This reduces wastage and improper disposal of properties.

4.4.7 Strength of quality of materials supplied for railway track structures component in AALRT project

For construction of railway track structure, some basics components are listed below. Those are rail, fasteners, sleepers, ballasts, sub ballast and subgrade. Some auxiliaries are tie rods, safety rail (buffer) ...etc. This AALRT project designed for minimum 30 years [3]. So we are not only considering construction of track structure but also quality of materials with comparing previously constructed light rail transit in other countries not on laboratory investigation. According to professional questionnaire response there is quality of material in rail track, which is used 50kg/m best, and optimum for light transit. However, most professionals disagree on ballasts, sleepers and buffer materials quality. Especially the main functions of ballast track are providing resistance forces, resiliency,

void storage, drainage, and facilitating maintenance. But on some parts the ballasts used are lack purity and consistency of aggregate size. This results void filled by fine particle and dust. So, drainage and vibration controlling system through providing ballasts are disturbed and affects durability of tracks. Besides, buffer provided for AALRT project is low strength and esthetics. According to Figure 2.10 about 45% disagree, 25% neutral and 30% agrees out of 68 respondents with the general provided quality of materials supplied for AALRT project construction. So according to respondent's response and site investigation it must need to revise ballasts and buffers (safety rail) quality.

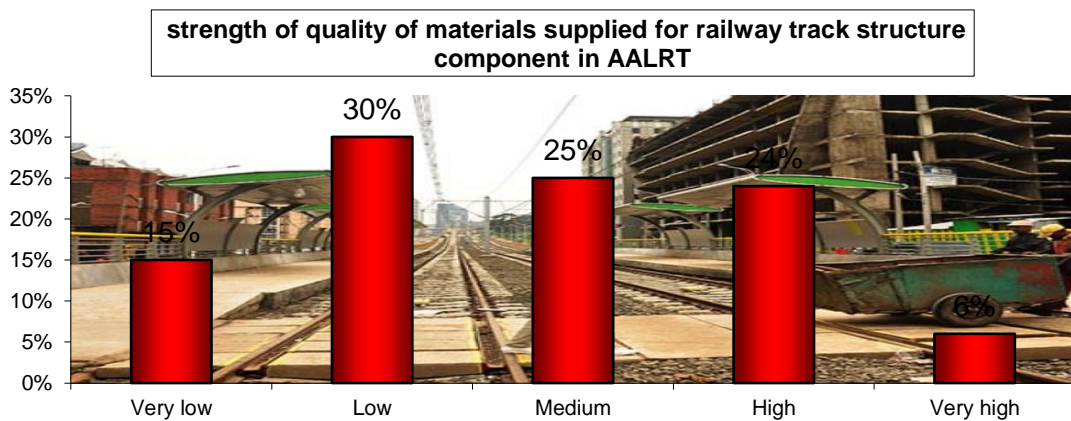


Figure 4-10 Strength of quality of materials used for track structure construction according to professionals response

4.4.8 Feasibility and beneficiary if a new railway tracks component material production and supply

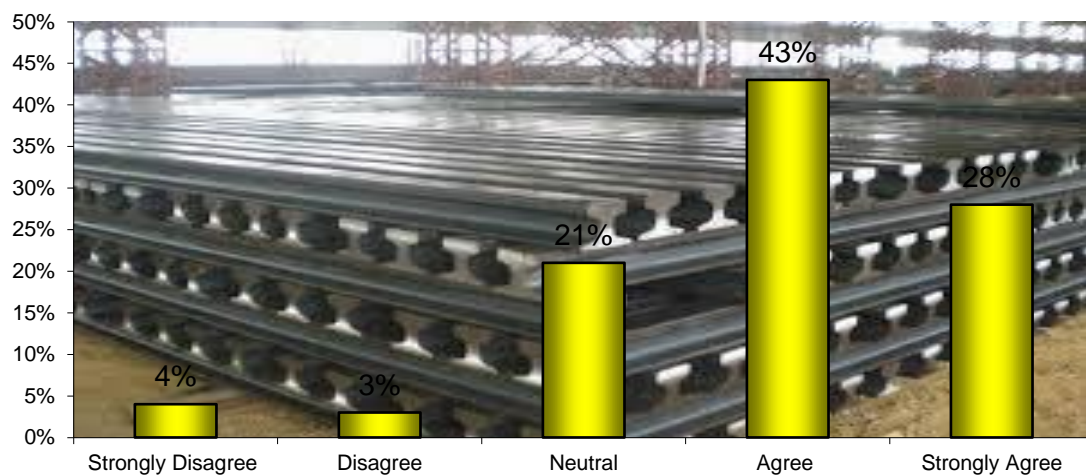


Figure 4-11 Feasibility and beneficiary if a new railway tracks component material production and supply adopted by respondents

According to questionnaire response and desk investigation production of railway track structure components like ballast, sleeper, and cable production are highly beneficial and advantageous. In assumption for construction of LRT and NRN for 5000km we need more than 7.5 million sleepers if we use minimum 1500 sleeper/kilometer. Additionally ballast and cable production factory have highly profitable and advantageous. For example in AALRT track structure for only providing underground cable costs more than 1billion ETB. But only three companies exists for production include METEC. Even if, Australian Sleeper production company, Austrak, a world leader in sleeper design and production technology for more than 30 years has provided for clients with safety, certainty and engineering excellence. Currently, they produce in excess 18 million sleepers and built 12 factories [18]. Likewise, if our country entrepreneur, investors and government plant production factories and companies they are highly beneficial and advantageous. This leads production of sleeper, ballast and cable for best quality, amount and create computation between suppliers. Currently some foreigners only (like turkey, china...) would produce and manufacture sleepers and cable. Therefore, our investors need further research and prepare proposals for production and supply of railway track structures components.

4.4.9 Skill and technology transfer during machine operation and construction of railway track

Since the constructed railway track structures are the first for this generation they are no experience and skill. During construction of AALRT project began from survey to operation, they need a lot of technology product, machinery and skill of construction. According to questionnaire response rate as a Figure 2.12 shows 54% of professional respondents agree and 30% have neutral idea. As number shows that there is technology and skill transfer between our professionals and foreign contractors, manufacturers and suppliers. This helps our citizens professionals get experience with construction and operation for newly designed and planned track structure in more efficient and economical ways. Besides, during site investigation observation and interview with supervisor, foreman and labors are highly skilled and got experience on operation machinery, foundation works, reinforcing steel works, and masonry works.

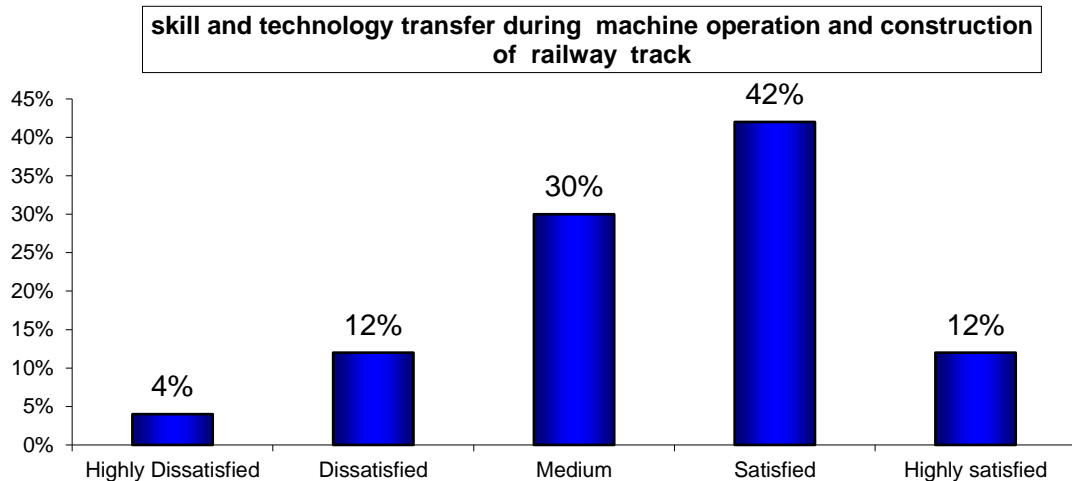


Figure 4-12 skill and technology transfer during machine operation and construction of railway track adopted by respondents

4.4.10 Influence of laid AALRT track structure on road user, highway traffic and commercial activity

All most all constructed AALRT project laid between road centers used like as median. According to Figure 4.13, about 72% of professionals agree that the constructed AALRT project creates very high traffic congestion on both road user driver and pedestrian. They suggest the cause would be lack of road crossing and the position of placement of railway track structure.

Road from Torhayiloch to Ayat round square previously commercial activity is very high. Especially around Hayahulet before construction of LRT track structure commercial activity are high. Currently since the lane is separated by LRT line and need long journey to cross with automobile. Besides, decreases commercial activity and efficient movement of traffic. The extreme result will be congested system of traffic which has a negative impact on the development of a city. An extreme focus given to mobility will result in a decrease in accessibility, which limits surrounding land use development. Retailing centers, cafeterias, commercial centers deny roadside corridors through which high-speed traffic passes. This affects directly or indirectly development of the inter-urban centers. On other hand, planning of accessibility by compromising mobility can create benefits by expanding small-scale retail development in residential areas, thereby bringing shops within walking distance that could be accessed by circulator bus route that links residential areas to commercial areas. Therefore, a

trade-off between accessibility and mobility shall come into play by transport planners and designers for better development of a city.

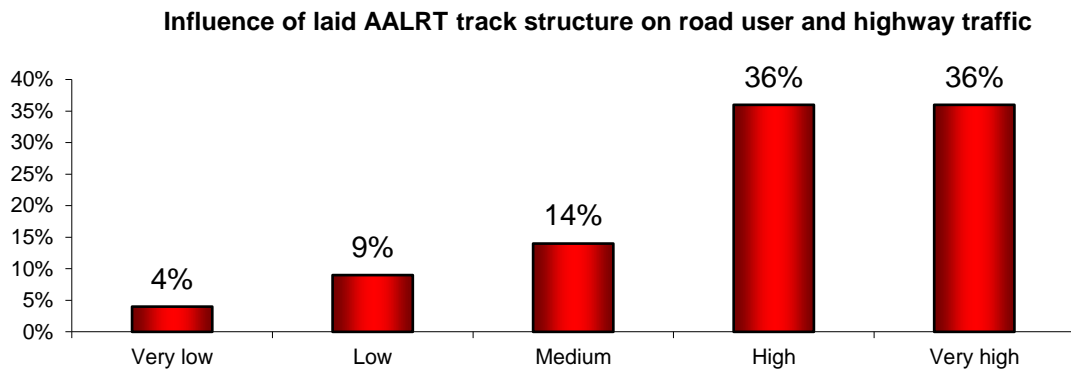


Figure 4-13 Influence of AALRT track structure on road and traffic adopted by respondents

4.5 Summary of the assessment AALRT project according to respondents' response

A number of respondents have given their opinion on general assessment and construction of Addis Ababa light rail transit. From the questionnaires returned, factors chosen from each respondents are rated based on mean score method (MS), mode and standard mean error. In this research the variables of having a mean score of >3 is considered to be the most significant cause while a mean score of < 3 means the respondents do not agree that the variable will be need to amend or modify for phase II AALRT track construction. In accordance to Likert's scale of five ordinal measures of agreement towards each statement (1, 2, 3, 4 and 5), the mean score is calculated for each factor that is used to determine the relative ranking. The mean score (MS) for each variables attribute overrun is computed by using the following Formula;

$$MS \cong \frac{(f*n)}{N} \dots\dots\dots [\text{Eq 3.2}]$$

Where: MS – Mean Score, f – Frequency of responses for each score, n – Scores given to each factor (from 1 to 5), N – Total number of responses concerning each factor

The mode is the value that occurs most frequently in a sample. When multiple values occur with the highest frequency, the sample is said to be bi-modal or multi-modal. In this research when questionnaire response Mode value is >3 it is best and having need to proceed within this variable. But when mode value <3 it may need to revise the variable while designing and constructing. When just mode value is =3 respondent opinion is neutral and need to improve by revising variables.

In this research, Standard deviation (σ) is a measure of the dispersion of a collection of respondents. It indicates how all professionals give the values in a dataset are with respect to their mean.

$$\sigma = \sqrt{\frac{\sum (x-X)^2}{(n-1)}} \dots \dots \dots \text{[Eq. 3.3]}$$

Because the mean of the population is usually unknown, it is important to estimate the error between the sample mean and the population mean. The SEM Standard Error of the

Mean is an unbiased estimate of expected error in the sample estimate of a population mean.

$$SEM = \frac{\sigma}{\sqrt{n}} \dots \dots \dots \text{[Eq. 3.4]}$$

Ranks of variables based on cumulative mean score as perceived by different parties should be tested for correlation. The purpose of a correlation test is to verify whether there is a great deal of difference in ranking respondents and as well in order to be able avoid from being deceived by chance of occurrences and significance as view standard error of mean. So in this research if standard error deviation is <0.2 chance being deceived is minimum and acceptable. The summary Table 4.5 shows all values are output excel according to input values from questionnaire response to compare and show results of assessment.

Table 4-3 summary of questionnaire adopted by respondents shows the Standard error deviation, mode and mean score for each variable.

Evaluation Survey	Very low= 1	Low = 2	Neut = 3	High = 4	Very high = 5	n	Mean	Mode	SEM
1. Satisfaction level due to GTP-1 implementation plan in terms of LRT	1%	6%	38%	48%	7%	68	3.53	4	<u>0.1</u>
2. Significance of providing LRT for capital city of Addis Ababa	7%	3%	12%	42%	36%	68	3.96	4	<u>0.1</u>
3. Customer satisfaction by provided AALRT	3%	33%	35%	26%	3%	68	2.91	3	<u>0.1</u>
4. Consideration need of customer in selection of route, orientation and length	4%	16%	30%	39%	10%	68	3.34	4	<u>0.1</u>
5. Consider future expansion and aesthetics	16%	26%	25%	19%	13%	68	2.10	2	<u>0.1</u>
6. Disintegrate with nearby structure and landscape	3%	10%	20%	38%	29%	68	3.79	4	<u>0.1</u>
7. Contract agreement were fair, open, inclusive and attractive	9%	21%	53%	18%	0%	33	2.79	3	<u>0.1</u>
8. Accuracy of survey data integration with topography and selected route	8%	20%	36%	34%	2%	49	3.00	3	<u>0.1</u>
9. wastage of materials and human labour due revised design and lack of proper workmanship	2%	10%	34%	39%	15%	58	3.53	4	<u>0.1</u>
10. quality of materials supplied for railway track structure component in AALRT	6%	24%	25%	30%	15%	66	2.76	2	<u>0.1</u>
11. effects of lack of professional and skilled human power for supervision and construction of AALRT project	6%	12%	24%	38%	21%	67	3.54	4	<u>0.1</u>

12. Influence of laid AALRT track structure on road user and highway traffic	4%	9%	14%	36%	36%	68	3.91	5	<u>0.1</u>
13. implementation of initial design plan with actual constructed AALRT project	3%	13%	34%	36%	13%	60	3.42	3	<u>0.1</u>
14. sufficient compensation paid for land acquisition and property	0%	7%	30%	38%	26%	60	3.87	4	<u>0.1</u>
15. Corporation between your organization and construction company of AALRT project	3%	3%	25%	49%	19%	58	3.74	4	<u>0.1</u>
16. Influence of AALRT on your organization in terms of cost, wastage of materials and service disruption	11%	42%	33%	13%	0%	44	2.45	2	<u>0.1</u>
17. Foreign and local suppliers of track structure components production quality and amount of output	3%	21%	26%	44%	5%	60	3.25	4	<u>0.1</u>
18. Feasibility and beneficiary if a new railway track component production and supply like ballast, sleeper, buffer,...etc.	4%	3%	21%	43%	28%	66	3.86	4	<u>0.1</u>
19. Skill and knowledge transferred for machine operation and construction of new railway track	4%	12%	30%	42%	12%	66	3.42	3	<u>0.1</u>
20. Providing subsurface or underground instead of elevated track structure on high volume traffic congestion	10%	6%	22%	39%	23%	68	3.63	4	<u>0.1</u>

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The researcher believes that through the finding and study of this research and conclusion result is applicable and reasonable. Assessment and evaluation light railway transit constructed in Addis Ababa held up through site investigation, desk study and questionnaire response. In accordance and in line with the analysis result drawn up from the desk study, site investigation and questionnaires respondents the research hereby summarizes the following under listed core points adopted as conclusions to the study of the research.

- I. Providing light railway transit for resident of city has the effective solution for the immediate transportation problem. The research affirms that about 55% respondents highly satisfied with governments plan and implementation of GTP-I in terms the constructed light railway transit in Addis Ababa.
- II. The respondent about 78% are satisfied by the provided AALRT project selection of orientation, route and length. However, in other case, about 36% of respondents did not satisfy by the service provided. The speed, the cost of short distance trip and headway time is discouraged the user of transportation system.
- III. There is lack of integration between the constructed railroad with existing buildings, pipes, wires and transportation situation. More than 67% of questionnaire respondent's agree there is disintegration with the landscape and the nearby infrastructure.
- IV. The constructed AALRT project would not consider safety, future expansion and urban aesthetics. The questionnaire respondents agree with the statement. Besides, as site investigation and interview, the constructed permanent laid and elevated track structure should create phobia to nearby persons and barrier to road user. If trains accidents happens, it will creates sever damage. Specially, professionals suggest, the route from Lideta to Stadium congested with many, huge, long, and massive columns, and long overpass around station. These structures are prone to vehicle collision and distort urban aesthetics.
- V. During construction of AALRT project many our professionals and laborers operate new machinery and develop a new railway track line with foreign contractors, manufacturers and suppliers. According to interview and questionnaire respondents 54% are agree with, there is technology, knowledge and skill transfer would be held.
- VI. There are wastage of properties, materials, labour force and lack of proper workmanship during construction of AALRT project. About 54% questionnaire

respondents agree with the statement. Additionally, as site investigation and desk study findings they reason out this problem happen due to lack of skill, lack of coordination between organization and redundant revise of the design.

- VII. According to desk study and site investigation the rail track which is used 50kg/m best and optimum for light transit. Even though there is lack of quality on materials like ballasts, sleepers and buffer. Especially, the ballasts used are lack purity and consistency of aggregate size, and the safety guard or buffer provided are low strength and esthetics.
- VIII. The production of railway track structures components like ballast, sleeper, and cable production are highly beneficial and advantageous. According to 71% questionnaire respondent and desk investigation result if local suppliers involve on production material's they create competition between suppliers and encourage for high quality production.
- IX. All most all constructed AALRT project laid between road centers used like as median. As 72%, respondent and site investigation reveal that the constructed AALRT project creates very high traffic congestion on road user, driver and pedestrian. Because lack of road crossing and the position of placement of railway track structures.
- X. There is lack of corporation and communication between organizations, which have common works. According to questionnaire, respondent and desk study the integration between the contractor organization and other urban infrastructure organization are very low.

5.2 Recommendations

In respect to this research, the following basic recommendation are expected to be exercise for phase-II AALRT project to construct in efficient, economical, aesthetically attractive, integrated with nearby infrastructure and to consider future expansion. Through the assessment and evaluation phase-I AALRT project track structure construction the client, contractor and consultant are expected to consider the following recommendations.

- I. Considering learned lesson from phase one AALRT and revising design plan of phase two AALRT project are used for more efficient, economical and better project completion through experience and skill gained.
- II. To reduce wastage of material and human labour force, the contractor must have held proper site investigation and used final approved design for construction to prohibit redundant excavation and many revised designed plan.
- III. During preliminary site study and investigation, the government must consider free areas, parking area, future expansion and extension due to fast growing

population and construction building. As experienced from phase I AALRT, applying vast and free area can help to reduce congestion of massive structure and to construct attractive, comfortable, pleasant railway track structure and stations.

- IV. If government corporate enterprises and involves investor in the production of railway track structure components like ballast, sleeper, and cable production are highly beneficial and advantageous. Since connecting Africa through railway route are the visions of countries. While that time they need competitive supplier of materials. This benefits a citizen to create job opportunity and to decrease foreign currency.
- V. To solve highway traffic congestion created by railway route due lack of road crossing, they may have proper pre design and having enough free area to consider bridge crossing where the railway line and pedestrians intersects.
- VI. To decrease maintenance period the constructed railway track they may use high quality materials, built proper drainage and create awareness to society to preserve the constructed line from damage.
- VII. Researchers' recommend Constructing sub surface and underground LRT or metro may reduce traffic congestion and accidents, increase land use value and advantages on long term benefits.

5.3 Further study area

Since the constructed Addis Ababa light rail transit is the first and there is no experience held before and there is no research done in any aspect in Ethiopia within the title Assessment and evaluation of AALRT project in different aspects. In order to enforce further the finding of the thesis and for the sake of this research, the following core study areas that are further develop the concept of assessment and evaluation of the constructed AALRT track structure. Some are

- Assessment of prevention railway accident in AALRT
- Assessment of durability, Maintenance and preservation of constructed AALRT track structure
- Feasibility of production and manufacture railway track structure components material like sleeper, rail, ballast and buffer within local contractor.
- Development of model integration and interaction railroad with highway in AALRT project

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APPENDIX 1

Questionnaire

Dear Sir/Mr./Miss/Madam,

The purpose of this survey is to obtain data for the specified research being conducted as a partial fulfillment of M.Sc. Degree in Railway Engineering Program at Addis Ababa University.

The aim of this questionnaire is to obtain professional opinion, to assess and evaluate the constructed Addis Ababa light rail transit track structure. So that, the lessons can be used as a feedback to construct phase-II AALRT in efficient, economical, safe and durable,

The study is presumed;

- to assess the factors concerned during construction with both internal and external interactions that occur between the various components of a track structure and its supporting systems
- to evaluate construction methodology, equipment and construction materials of railway constructed
- to assess the designed track structure integration with landscape and other infrastructure
- to study the knowledge and skill gained during construction track structure
- to evaluate and assess future expansion, safety and aesthetic of track structure

The information supplied in this questionnaire will be used solely for broad research purposes (for academic purpose). All specific company and interview information will be kept confidential at all times.

Only generalized analysis of the information contained within this completed questionnaire will be utilized in the research process. Your response, in this regard therefore is highly valuable and contributory to the outcome of the research. Thank you for your invaluable time and cooperation in advance.

Post Graduate Student, Railway Engineering program

Addis Ababa university institute of technology

Tel: 0910415544

E-mail:-bwbenwon@gmail.com

Addis Ababa, Ethiopia

Regards; Biniam Shawul

Date; February – 2016

Instruction for completing the questionnaire

- ❖ Please put “X” mark on the space provided to indicate your response where applicable.
- ❖ In case where responses other than marks are required, please write your response in the space provided.
- ❖ Unknown, if you cannot answer the question according to your knowledge, skills or position within your organization
- ❖ You may mark more than one as the case may be or use additional paper where the space provided is not enough.

Part 1: General Information about Respondents

1.1 Organization /Company Name (optional):

1.2 On what discipline is your company engaged for the construction of railway track?

- Contractor client (project owner)
- Consultant Professional institutions

❖ If other, please specify.....

1.3 Type or origin of your organization

- Governmental
- Domestic Contractor

- Domestic Consultant
- Foreign Contractor
- Foreign Consultant
- Financer
- Others (please specify)

1.4 Your position in the organization/ title.....

1.5 Contact addresses (Optional):

Name (optional): E-mail: Tel:

1.6 Educational status?

- B.Sc.
- M.Sc.
- Ph.D.

❖ If others, please specify.....

1.7 Does your organization have been involved in Railway track construction?

- Directly involved throughout construction
- Directly involved in some part of construction
- Indirectly involved
- Not involved at all.

❖ If your company is not involved in construction, how do you rate, the degree of influence on your company works?

- 1 very high
- 2-High
- 3-Medium
- 4-Less
- 5 Very Low

Part II: General questionnaires on AALRT Project

2.1 The constructed modern railway transport is one of the part of first growth and transformation plan (GTP-I) in Ethiopia. Are you satisfied by implemented plan?

- 1– Highly dissatisfied. 3 - Neutral 5 - Highly satisfied
- 2- Not satisfied 4 – Satisfied

❖ If you are not satisfied please specify your reason?

.....

.....

.....

2.2 How you rate the significance of provided and newly coming light railway transit for Addis Ababa?

- 1- Very Low 3 – Average 5 – Extremely important
- 2- Low 4 – High

2.3 How do you rate, the service provided by the constructed AALRT in satisfying customers need?

- 1– Highly dissatisfied. 3 - Neutral 5 - Highly satisfied
- 2- Not satisfied 4 – Satisfied

❖ If you are not satisfied please specify your reason?

.....

.....

2.4 Do you agree that the constructed AALRT considered the need of customers in selection of route, orientation and length?

- 1- Strongly disagree 3 - Neutral 5 - Strongly agree

- 2- Disagree 4 - Agree

❖ If you disagree please specify your professional suggestion? (Location, orientation and length).

2.5 The constructed AALRT railway track structures, which placed and erected at center of town had considered future expansions, esthetics, comfort and safety. How do you rate the agreement level with the above statement?

- 1– Highly disagree 3 - Neutral 5 - Highly Agree
- 2- Disagree 4 – Agree

❖ If you disagree please select your reason from the following?

- It creates barrier to road transport and results traffic congestion.
- The elevated and lied structures distort urban aesthetic
- Setbacks to nearby buildings are small. (It creates vibration and noise pollution)
- It is exposed for accident

❖ If other please specify?

2.6 There is disintegration between constructed railway track structures and nearby infrastructure (like road, ditch, telecom tower, power pole and buildings). How do you agree with above statement?

- 1- Strongly disagree 3 - Neutral 5 - Strongly agree
- 2- Moderately disagree 4 - Agree

❖ If you agree, please select from the following that the cause of disintegration?

- They construct track way without proper desk and site investigation

- They cannot consider nearby existing structure and future expansions plan during design phase. This leads for redundant works and additional cost.
 - They modify their design and construction without consulting Concern Company.
 - ❖ If other please specify
-

Part III – Specific Questionnaire

(For engineers, consultant, project managers, experts and construction supervisors of ERC, CREC, LRT and SWEROAD)

3.1 Ethiopian government sign contract agreements and negotiation with local and international contractor and consultant to construct AALRT and national railway network (NRN). Do you agree that the contract agreement, bidding and evaluation were fair, open, inclusive and attractive?

- 1– Highly disagree 3 - Neutral 5 - Highly Agree
- 2- Disagree 4 – Agree Unknown

- ❖ If your answer is number 1, 2 and 3, what do you suggest?
-
-

3.2 According to ERC study data the selected route for NRN and LRT have been surveyed by the latest technology that found in the world using Light Detection and Ranging (LiDAR) technology . So the studies for route selection, topography and survey data collected are highly integrated with actual sites during construction. How do you rate the agreement level with the above statement?

- 1- Strongly disagree 3 - Neutral 5 - Strongly agree
- 2- Don't agree 4 - Agree Unknown

- ❖ If you disagree please specify your reason?

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3.3 There are wastage of materials and human labors due to revised design and lack of proper workmanship. How do you agree to the statement?

- 1- Strongly disagree 3 - Neutral 5 - Strongly agree
- 2- Don't agree 4 - Agree Unknown

❖ If you agree what do you recommend for minimize wastage?

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3.4 How do rate the quality of materials that supplied for railway track structure components in AALRT?

- 1- Very less 3 - Average 5 – Very high
- 2- Less 4 – Good quality Unknown

❖ If your answer number is 1, 2 and 3. In what type of material do you view low quality?

- Rail fastener sleeper
- Ballast Auxiliary structure Buffer (safety rail)

❖ If else please specify?

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3.5 In our country there are lack of professionals and skill human power for design, supervision and construction of railroads. How do you rate its effects on constructed AALRT?

- 1- Very low 3 - Medium 5 –Very high

- 2- Low 4 – High Unknown

❖ If your answer is 1, 2 and 3 please specify your view?

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3.6 Almost all AALRT track structure lied on existing road and some building structure. So during onsite excavation and construction work, there creates high traffic congestion. How do level degree of trouble on road user?

- 1 Very High 3- Medium 5-Very Less
- 2-High 4- Less

3.7 How do you rate the integration of the initial design plan of the project with the actual constructed line in AALRT?

- 1-Very low 3-Medium 5- Very High
- 2-Low 4- High Unknown

3.8 Since almost all AALRT railroad is lie on existing road way and on some building structure how do you rate, does sufficient compensation paid for land acquisition and property?

- 1-Very low 3-Medium 5- Very High
- 2-Low 4- High Unknown

❖ If your answer is 1, 2 and 3 what do you suggest?

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3.9 How you level degree of interaction between organizations that corporate on construction of AALRT (like between CRCC, ERC with ACCRA, telecom, water supply, electric power, sewerage, drainage, and buildings).

- 1-Very low 3 - Neutral 5 – Very high
 2-Low 4 - Good Unknown

3.10 Is there any organization you know that corporates urban infrastructures and development works?

- Yes NO

❖ If yes please specify it name?

3.11 During construction phase-I AALRT there is a lot of redundant excavation even if, after the works is completed and layered. How do you level the influence on your organization in terms of cost, wastage of material and labour force?

- 1- Very high 3 – Medium 5 – Very less
 2- High 4 – Not much Unknown

❖ Please specify a solution If they have influence your organization?

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3.12 There are foreign and local suppliers for railway track structures components like ballast, sleeper and rail. How do you level their production quality and amount of output?

- 1– Very low. 3 - Neutral 5 – Very high
 2- Low 4 – High Unknown

If you are not satisfied, please specify reason that cause less quality and output scarcity?

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3.13 How do you rate agreement level, are there feasible and beneficial if a new association or organization have built an Industry or manufacturer for supply of track structure components (like sleeper, rail, ballast.. etc.) in our country.

- 1- Strongly disagree 3 - Neutral 5 - Strongly agree
- 2- Don't agree 4 - Agree Unknown

❖ If you disagree please specify your reason?

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❖ If you agree please suggest, in what way or in what track component, they are advantageous to supply material?

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3.14 How do you rate, our professionals and employee gained skill and transferred knowledge of operating new machinery, construction and design of new railway track structure during construction of phase-I AALRT line?

- 1- Very low 3 – Medium 5 – Very High
- 2- Less 4 - High Unknown

❖ If your answer is number 1, 2 and 3 please specify what would do to improve?

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3.15 The constructed permanent railway infra-structure has long term plan and service. Besides the LRT line passes at center of town where high traffic congestion. How do

level your agreement, if the line were provided at subsurface or underground rather than elevated structure even if, it has high cost?

- 1- Strongly disagree 3 - Neutral 5 - Strongly agree
- 2- Don't agree 4 – Agree Unknown

❖ If your answer is number 1, 2 and 3 please specify the reason behind?

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3.16 If your organization were authorized to construct AALRT phase –II line (from Minilik to Lebu through Mexico and Meganagna to Kality through Bole brace,) what do you suggest, appreciate and modify to construct more economical, durable, safest, esthetically attractive and efficient than phase-I AALRT line?

Thank you!!!

APPENDIX 2

Interview guide question

My name is Biniam. I am a graduate student in Addis Ababa University and I am conducting a research here in Addis. The general objective of this research is to assess the Constructed light railway transit track structure in Addis Ababa. This is an interview guide prepared to collect data from people those have direct involvement in AALRT project construction.

Thank you for your Cooperation!

Personal information

1. Interviewee - _____
2. Age _____
3. Sex _____
4. Your duty in construction of a project-----

Interviewer: - Biniam Shawul, student

1. General overview of the AALRT?
2. Please list Source, distribution, Supply and production about components of AALRT track structure (like sleeper, rail, ballast,.)
3. Please discuss about route selection, distance, and orientation, service provided and construction methodology?
4. List any claim or disintegration of infrastructure with main railroad line during construction?
5. Esthetic, drainage, safety and durability of constructed AALRT?
6. Recommendations for future to construct in better, efficient and economical way? Operation of machinery, Construction methodology and material handling, Skill transfer and design of track structure, Future expansion, extension and aesthetics.
7. Anything that you want to suggest about the LRT construction, service ...?

Thank you

APPENDIX 3

List of Figures that Captured during Site investigation for Assessment and Evaluation of Addis Ababa Light railway transit project. On April 2016



(1) Slab track AALRT project with UG cable (2) pic shows Drainage Problem around Lideta



(3)Tele cable damaged during railway crossing (4) Under pass with low height around Merkato



(5) DarMar Station platform around Abinet
for highway around Mexico

(6) Overpass railway and underpass