Modeling the Safety Conditions of a Railway Line: The Case of Ethio-Djibouti Railway

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Declaration

I, the undersigned, declared that this thesis work entitled “Modeling the Safety Conditions of a Railway Line: The Case of Ethio-Djibouti Railway” and submitted in partial fulfillment of the requirements of Degree of Masters of Science in Railway Engineering (Civil Infrastructure) complies with the regulations of the university and it is original work of my own and has not been presented for a degree of any other university. All sources of material used for this thesis have been properly acknowledged.

By

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ABSTRACT

The Ethio- Djibouti railway line run from Addis Ababa to the port city of Djibouti (Negad). The construction of this rail infrastructure is essential for the economic growth and development of both countries. However, after the operation start the Ethio- Djibouti railway line faced so many challenges due to different safety issues that challenge the train speed to travel at less than the designed speed.

This thesis concerns identifying and setting countermeasures for the major safety problem by developing a model. Safety problems are incidents that lead to accidents, collisions, and death. This is done by taking previous data, questionnaire results, and field data from video cameras that were installed on the train (CCTVs if any) and locating the major Land use accident analysis area by using QGIS and then developing a solution on the major accident locations. From other literature underpasses, overpasses, or providing fences on the railway crossing and implementing government laws are considered the major solution to prevent safety issues on railway property. So by considering the Ethiopian people's culture of living, developing new countermeasures are taken to solve the issues on the Ethio- Djibouti railway.

Finally from this thesis, the extra expense cost by the Ethiopian Railway Company is deducted and solved. Once safety problems are solved the Compensation cost, unplanned purchasing cost, and also maintenance costs will be reduced, especially the compensation cost for the mortality of animals and person will be reduced once the location is identified providing the possible measures for the find out problems.

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LIST OF ABBREVIATION

CCECC …… China Civil Engineering Construction Corporation

CDF……...Cumulative Distribution Function

CREC ……...China Railway Group

CS..... Consequence severity

EDR……...Ethio-Djibouti railway

ETA…….. Event tree analysis

FF..... Failure frequency

FHWA .....Federal Highway Administration

FMEA……....Failure mode and effect analysis

FRA…….…. Federal Railroad Administration

FTA …….....Federal Transit Administration

FTA……..... Fault tree analysis

K……Kilometer

MIL-STD ……..Military standard

RL..... Risk level

SPSS……. Statistical Package for Social Science

USC……...University of Southern California

WHMS ……..Workplace Health and Safety Management System

CHAPTER ONE

1. INTRODUCTION

1.1 Background

The history of the railway in Ethiopia began in 1894-1917 to connect the Ethiopian capital city to French Somaliland. After the closed of that line, railway development in Ethiopia again starts in 1917. This line opened on January 1, 2018, which connects Ethiopia with Djibouti via Dire Dawa.

Ethio-Djibouti railway line is the first modern electrified standard meter-gauge railway line in East Africa. One of the visions of the standard gauge railway is to develop fast and sustainable economic growth. The Ethio-Djibouti railway line covers a total of 759 km in length with 21 stations. On its way to cover the 21 stations, the train passes through a total of 61 bridges, 37 frame bridges, and 453 culverts along the route ('Ethiopia-Djibouti Railway Line Modernisation', 2022). These line is jointly owned by both the Djiboutian and Ethiopian governments and also the construction is undertaken by the Chinese state-owned companies, China Railway Group (CREC), and China Civil Engineering Construction Corporation (CCECC). This solves the landlocked country Ethiopia to cover 95% of its international trade through the Port of Djibouti (Adinew, 2021).

Currently, the Ethio-Djibouti railway line operates with multiple challenges like train collisions with animals, vehicles, and persons and facing illegal activities like robbery, train blocking, and vandalized railway facilities. Train collisions with animals are a major safety problem for the Ethiopian railway corporation and for the nomad people that live around there ('News: Ethio- Djibouti railway source from theft and vandalism, leading to heavy revenue loss', 2021) also the nomadic tribes led to rent-seeking practices, such as compensation for owners of cattle and camels killed by trains. The level of compensation is at the discretion of the operator and has no statutory basis. (Adinew, 2021)

Several culverts and underpasses were constructed for drainage purposes and livestock crossing but the people are still using the previous crossing path separated by the railway line. This trend is the major problem that increases the animal-train collision of the Ethio-

Djibouti railway line and also it's mentioned as a reason for its speed to go down from 120km/hr to 80km/hr ('News: Ethio- Djibouti railway source from theft and vandalism, leading to heavy revenue loss', 2021). This is if some problem or safety issues are faced the train stopping distance can be reduced during the operation period. Such kind of trend hinders the country's strategic goal of sustainable and stable economic development as a middle-income country. And it shows that if this is not solved very wisely and urgently, the loss is very high for one country that planned and construct this railway line to meet its goal.

To reduce major accidents increasing safety is mandatory. This needs to use planning methods to pass transportation corridors safely. So this thesis study is undertaken to solve the major safety challenge by developing countermeasures as a solution for the Ethio-Djibouti standard gauge railway line.

1.2 Statement of the problem

From (Nuru, 2022) the total length of this railway line is 759 km including the 5 kilometers of shunting operations. A total of 666 km of the railway line was constructed in Ethiopia and the remaining 93 km is in Djibouti. This railway line population territory is bisected and passes through thousands of farmers and different ethnic tribes with different weather conditions, side by side the living ways of people around the railway line also have different cultures and living ways from one city to the other. So the safety issues are different from place to place as different population sizes are in different places of nearby the railway line.

According to the reports, ('News: Ethio- Djibouti railway source from theft and vandalism, leading to heavy revenue loss', 2021) currently the Ethio- Djibouti railway are facing problems. As stated, because of the animal accident the railway is operating below the design speed. Even though railways have different safety problems they only mention animal accident as a factor. while 572 different type of accident occurred in the year of 2019 G.C upto 2022 G.C, (EDR safety department, 2022). The cause of the accident maybe human factor, natural factor or design problems so to find out the main cause this research conduct different safety issues on this railway company. For instance, see Fig 1 below, animal accident at K289+560m. So that before concluding this was the main issues, research have to be done on the area to understand causes and contributing factor of railway safety to eliminate the major barriers. So this research will find out the major safety problem in Ethio-

Djibouti railway by addressing different safety issues such as train blocking, trespassing activity, robbery, vandalism, and animal-train collision accidents in addition to the vehicle train collision accident. In addition Fig 1 below shows vehicle train collision at K62+257m this was on Bishoftu area and the accident happened on a level crossing as this section of the Ethio- Djibouti railway have a double track, once the accident happen the vehicle collide with the train it transferred to the other side of the track and the train pass by its own track line. In addition to that at K316+600 the pedestrian side walk way is totally stolen from the bridge side. This initiate the pedestrian to use sleepers below the track line to cross the bridge and this increase trespassing activity. Those cause high mortality rates, high safety risks for the train, passengers, livestock owners, and people living around the railway line area. So developing sustainable countermeasures as a recommendation for the major safety challenges by addressing different safety problems to enhance the safety condition that help to increase economic growth and sustainability for the company EDR and also for both countries.

Figure 1, Accident and robbery safety problem in EDR

1.3 Research question

1. What are the major safety challenges on the Ethio-Djibouti railway line?
2. How to identify major safety problem accident areas?
3. How the identified major safety problem affect the safety condition of the railway?

1.4 Objective of the research

1.4.1 General objective of the research

Assessing the major safety issue on the Ethio-Djibouti railway line and developing possible countermeasures for the problems. Developing models that can predict the safety issue on the Ethio-Djibouti railway line is the general objective of this thesis.

1.4.2 Specific objective

- Identifying major safety issues causes. Is it by nature condition, person activity, and design problem?
- Identifying main black spot locations.
- Develop Model and apply the model for safety prediction to know how the safety condition affect the Ethio-Dijibouti railway line

1.5 Significance of the research

As this research conducted on the existing Ethio- Djibouti Railway Company, which even didn't serve a decade but facing different challenges due to different safety issues. So the significant of the research are

Theoretical significance

As EDR line is a cross country railway line developing safety on the railway line help to increase the company economy by saving the compensation cost that spent for different accident and incident safety issues. In addition increasing the safe movement on the railway line farmers and owners of the livestock who live beside the railway line. Decreasing the accident rate on the black spot location are the theoretical benefit of this research.

Practical significance

Analyze the situation and impact of accidents from the predicted future value to assess the current condition of safety in the company, and the practical significant of this research is on the identified accident location a technical solution like constructing railway infrastructure and railway barriers have to be set. This reduce the risk of collisions and accidents on the railway line to increase the safety condition along the path.

1.6 Scope of the study

As railway is one of the safe and fast transportation system, avoiding the safety barrier is the mandatory work. So the scope of this thesis is to find out the major safety challenge in Ethio-Djibouti railway line to set possible countermeasure. When safety is at high risk accident will happen so that find out major location for accidents and relate them with their surrounding land use activity by covering the accident location of 759km of the railway line, starting from Addis Ababa Furi station up to Negad Djibouti port which is the end station for the Ethio-Djibouti railway. Use those accident data to find out the future prediction status and relate with there impact to set possible countermeasure. In addition to that, online questionnaires also used to assess the different types of the safety challenge face by the company.

1.7 Structure of the Research

The structure of the research are organized as follows: the first chapter contains introduction, with eight different subtopic Statement of the problem, Research question, objective of the research, significance of the research, scope of the study and structure of the research. The second chapter cover literature review from different articles different types of railway safety problems. The third chapter contains methodology, as well as data collecting and analysis method. The fourth chapter covers research result analysis, and discussion. Finally, the conclusion and recommendation, and direction of future study are included in chapter five.

CHAPTER TWO

2. LITERATURE REVIEW

Railway transportation uses trains to transport passengers and goods, which is characterized by large transport volume, fast speed, low cost, and protection against climate. As it has the most extended network infrastructure the safety of the railway is necessary to build trust from the customers, the employers, and also the people who live around the railway line network.

As rail transport is one of the safest transport modes rail safety management and measures are put in the first place. Different problems challenge the safety of the railway. That arise due to vandalism, trespassing, terrorism, natural disasters, passenger act, etc. This can interrupt the train function and damage the critical rail infrastructure. So, assessment of safety issues in railways helps identify the challenges to developing defense and protection (Setola, 2015). Studies show that safety is an important issue in railways. Since minor safety issues can lead to disastrous destructions and accidents on the trains, passengers, employees, road users, animals, and residents in the area of the railway. Some of the factors for train accidents are derailment, train speed, track class, traffic density in certain stations, carriages, and method of operation in the management of the railway's organizations. For this matter, the number of accidents and the level of safety need to have an inversely proportional relationship (Izyan *et al.*, 2019).

To assess the level of safety in railway transportation, the risk system has a quantitative characteristic (Science, 2021). When the safety level is at risk accidents happen. There are major categories of accident analysis models like the Swiss Cheese Model (SCM) and SCM-based models; sequential models. Sequential models include fault tree analysis (FTA), event tree analysis, (ETA), and failure mode and effect analysis (FMEA) (Zhang, 2021), (Macura, Laketić and Pamučar, 2022) FMEA is considered one of the most used tools for risk assessment of transportation project. This method was developed in the middle of the 1960s in the United States for the needs of the Apollo mission as a risk control tool. Based on this study the disadvantage of FMEA analysis is, that looks at individual failure modes rather than their combination similarly (Izyan *et al.*, 2019) use ETA (Event tree analysis) to

analyze the accidents and as described limitation of ETA only analysis one incident (or event) at a certain time also, many researchers (Matsika *et al.*, 2012), (Debbech, Bon and Collart-dutilleul, 2019) anticipate safety problem in the railway of European Railway Traffic Management System for this matter, safety analysis is executed through standard methods such as FTA, FMECA, and Model-Driven Engineering (MDE). Those are successfully adopted in many domains and industrial research projects for safety assurance and analysis. These quantitative techniques and methods need high-quality data and information. During assessment work based on the researcher, this data was obtained through, primary (questionnaire, interviews) and secondary data (previous documents) and analyzed by MS-Excel solver, SPSS, and other tools (Ayub Nassr', 2017).

According to (Debbech, Bon, and Collart-dutilleul, 2019) and (Bäckman, 2002), FTA is a deductive methodology, it is a graphic model that displays the various logical combinations of events or conditions that can result in an accident. This tree starts with the so-called event" which is a specific undesired event (accident) and proceeds to break down the events continues until the base events (accident causes) are identified. And ETA is an analysis technique for identifying and evaluating the sequence of events in a potential scenario following the occurrence of a given initiating event (accident). ETA utilizes a visual logic tree structure known as an event tree. It determines whether the initiating event will develop into a serious mishap or if the event is sufficiently controlled by the safety systems.

Briefly show the Federal Rai Administration ion's (FRA) in the U.S, whose top priority is safety, and develop a strategy to eliminate risk on the railroad in the United States. The strategies are

1. continuing a rigorous regulatory and inspection program based on the strategic use of data;

2. Advancing proactive approaches for early identification and reduction of risk; and

3. Capital investments, and robust research and development.

It improves safety, by developing rules based on facts, incident and accident causation analysis, comparison of alternative mitigation measures, and cost-beneficial solutions. This shows a guideline document to develop advanced safety that considers human factors safety,

grade crossing safety, and trespassing prevention to reduce risk. In addition, many countries developed a guideline for safety, such as (Setola, 2020)**,** and (Bulakh, 2007) by considering infrastructure design and standards to keep the railway safe.

Since railway transportation service is interrupted due to various reasons, identification of the problem that affects the safety of a train help to develop suitable countermeasures. From the study (Bäckman, 2002) some of the reasons are

2.1. Climate change/ natural disaster on railways

Whether natural disaster problems affect the rail transportation system by increasing the delivery delay, affecting transportation safety, reliability, and efficiency. So studies (Mcguirk *et al.*, 2009) assess the impacts of weather conditions on a railway to improve railway infrastructure ability, sustainability, and long-life performance ability of the rail.

Extreme weather events such as temperature, humidity, winds, rainfall, sea level, landslide, and storm rise have an impact on transportation infrastructure and other connected infrastructures. The intensity and frequency of extreme weather conditions caused by climate change hurt rail service performance and also increase total ownership costs (Thaduri, Garmabaki, and Kumar, 2021). The impacts on rail transportation are increased traffic disruption due to floods, heavy snow, rains, drainage overflow, increased precipitation because of flooded bridges, accumulation of water on the coastal roads due to adjacent sea level rise, blockage of roads due to landslides, create travel accident, affect the train travel frequency, and higher maintenance costs during the operation and maintenance (O&M) phase. Likewise (Jing, 2017) describes the geology, topography, weather, elevations, rainfall, distance from the river, and other natural conditions such as landslide problems that affect railway line safety. This paper provides fitting degrees as a countermeasure for the landslide on the railway line studied in Guizhou province, china. (Wang, Li and Han, 2020) indicate geological hazard assessment on railway needs to consider natural environmental factors and also construction factors. Because the construction of railway lines affects the geological nature of the land by affecting its stable form. Such as the greater the engineering slope gradient is, the greater the probability of the landslide. Here to obtain a map of geological hazard areas GIS is used.

On the other side (Zulpikar and Yasuo, 2014) explored the problem of driving in the area of a desert environment. High temperatures or very hot weather cause buckled railroad tracks, highways, and bridges. According to (Mcguirk *et al.*, 2009) if the weather is heated up beyond the design criteria, thermal misalignments or track buckles may result and derailments are possible. In other papers, track-alignment problems were a significant cause of accidents from weather-related factors (Rosset, 2002). Studies also examine the effects of weather conditions during travel behavior in Singapore which has a hot and humid climate. As stated by this study higher temperature (>30.9°C), humidity (>55.8%), and rainfall (>0.28mm in the past 60 minutes) tended to elevate the level of traffic accident risk, also snow, heavy rain, and fog greatly elevate the traffic accidents. And longer periods of heat waves can disrupt railway operations. Rails, components in switches, and overhead lines can expand in heat and can cause traffic disruptions and damage to the track. If this heat exceeds the design limits, then there will be an increase in the probability of the occurrence of rail defects. On the other side, warmer winter decreases the amount of snow this climate change crates slippery railway conditions, rail buckling, and frost bursts. Which causes serious problems such as train derailments and damage to human life. This researcher is better than the others by describing the effects of weather or climate conditions briefly on the railways by identifying their factors, impact, and consequences on the railway and by showing the consequences to rail operations, developing a guideline to address the challenges that arise due to extreme weather condition.

According to (Thaduri, Garmabaki, and Kumar, 2021) studies, sea-level rise can also have a compounding effect on bridges and drainage systems surrounding railway infrastructure, increase in flooding risk from rivers and sea-level lead to inadequate drainage conditions that could lead to an increase in the deterioration of railway infrastructure. Flooding damages or softens rail bed support structures, and causes overflow onto tracks and mudslides that damage rail structures. Because of rising sea levels, low-lying rails and bridges can be flooded and become unusable for shorter or longer periods. This increases the infrastructure replacements and renewals cost but this is comparatively less as compared to the accident that occurred due to this condition.

Other studies (Spike, 2022) briefly show that blizzards and freezing are the most important weather disasters that can have a crucial and serious impact on the track. It stated that heavy snow has no impact on the railways due to the heavy self-weight of the train. But the accumulated snow and ice on the track make the turnout structure not move to the right place. This leads the train not to turn in the right direction, leading to high accidents. The maintenance and repair of railway turnouts account for 70% of the total maintenance, to remove this barrier three methods are developed by this researcher. Which are manual snow and ice removal, manual ice removal with burner, and is equipped with an electric heating turnout. This kind of problem is easily solved if the railway line is an electrified type of line. Operational measures to adapt to weather-related temperature extremes include

- lower speeds
- shorter trains to shorten braking distances and
- Lighter loads to reduce track stress.

Based on (Mcguirk *et al.*, 2009) these adaptations affect the efficiency of railway operations, increasing the per-unit cost of transport. To improve the level of safety researchers suggest real-time and predicted weather information is necessary, especially in wet weather conditions.

2.2. Infrastructure design on the railway line

The appropriate design for the layout of inland terminals for containers with dangerous goods involved in the rail system will increase the safety and operability of rail transport by avoiding accidents. Similarly, poor Infrastructure design and lack of uniformity across the platform as corresponding to the train length have an impact on the safety of the railways during train travel. Poor Infrastructure design is like fences, sloping platform edges, improper location of signals, lighting problems that are too intense or lighting that is too dim (Jones and Jain, 2006), and the interface between train and platform. The gap between the train and the platform is a major impediment to safety discussed by (Moug and Coxon, 2013). This study shows that a yellow line on a platform acts as a warning line for passengers not to cross this distance mark until the dwell time identifies. On the other side (Barnett, 2022) overview safety of fences, defines safe from unsafe regions and safeguards

against falls into such regions. The critical geometry, strength, and stiffness of this structure are briefly described to protect the passengers and also the train travel safety.

According to (Read *et al.*, 2021) Collisions between trains and road vehicles at rail level crossings occurred due to installed road markings, power active warning devices the design problem of separation between the user's infrastructure. This study shows that the functional purpose of road marking, signals or posts, and reflector devices (large mirrors to indicate and guess the relative distance of the approaching train) is to protect road users and protect rail users. Its effectiveness would be measured through the safety-related measures of 'minimize collisions', 'minimize trauma/injuries/fatalities', and 'minimize risk'. This type of collision remains an intractable transport safety issue. All the infrastructure of railways like sleepers, fasteners, rail, platforms, and others need inspection work taken day and night (Wang , 2020).

2.3. Geometric Design

Assessments of the structural part of the geometric layout in a railway take appropriate remedial measures before the disturbing phenomenon occurs and becomes dangerous for human life and traffic safety risk rail. Jerzy Kisilowskin and Rafał Kowalik (Turnout and Diagnostics, 2021) to ensure the security and smoothness of the train track, it is necessary to reasonably select the basic plane alignment (tangent line, circular curve, and transition curve) of the line.

(Chen, 2021) Parameters that determine or affect the geometry of a track are

1. Gradients in the track, including grade compensation, rising gradient, and falling gradient

2. Curvature of the track, including horizontal and vertical curves, transition curves, sharpness of the curve in terms of the radius or degree of the curve, cant or super elevation on curves, etc.

3. Alignment of the track, including tangent as well as curved alignment.

Most train derailment from a civil engineering perspective is due to track defects. As a railway track designed to sustain the load and speed of the train to meet safety and economic requirements. Unless on a straight track, the train may derail due to defective cross levels,

defective alignment, defective gauge, and low joints, and on a curved track, the train may derail due to improper super-elevation, improper radius curve, and improper speed.

2.4. Vandalisms and robbery on a railway

Vandalism on a railway is illegal and dangerous that can cause a delay on the train by damaging and stooling railway material equipment. Similarly, robberies like cable theft, signaling cables, power lines, damaging signs, and demolishing fences also risk safety and cause disruptions and delays of a train. Researchers (Bernasco, Ruiter, and Block, 2017) state robbers must attack at the right time at the right place. The author collects different data in different locations and states robberies take place at night rather than in day time. Before allowing trains pass to through those areas maintenance takes place because safety is a priority in the railway.

2.5. Trespassing Act

"Trespass is both a civil and criminal wrong because it can cause injury, violation of legal rights as well as damage to one's person and property substantially if a physical attack takes place". To solve the dispute that comes with trespassing the courts evaluate the following factors:

(1) The nature and character of the trespass;

(2) The nature of the protected property;

(3) The amount and substantiality of the trespass; and

(4) The impact of the trespass on the owner's property interest by (Shubham Khunteta', 2016), besides (Savage, 2007) almost 90% of trespasser fatalities occur when the trespasser is struck by a train, while almost 40% of non-fatal injuries occur in circumstances that do not involve being struck by a train. Those trespassers stuck by a train sustain fatal injuries. This researcher classifies trespassing into categories

- people who are loitering near the tracks
- suicides
- those looking for transportation and

- Everyone else like (mixed a bag of thieves, vandals, thrill seekers, and those taking a shortcut or along the tracks.)

Many researchers consider trespassing as a problem because it leads to train-pedestrian collisions and important delays in addition to the distraction of fences to take a short path. This paper develops a measure for trespassing and vandalism act and considers the trespasser act a problem that does not seem to be going away from all the paper as revised but according to this paper, the most promising safety and security measures are education, enforcement and engineering measures like the design of stations, platforms, carriage, public walkways and improving terrain nearby the railway.

Sila and Luoma (Silla and Luoma, 2011) state that railway infrastructure bisects or divided communities for this results in the activity of people for shop, school, and residential areas initiate trespassers by using a shortcut and avoiding the grade crossing path. Safety at level crossings is one of the most critical issues to be addressed on railways. (Silla , 2021) conclude that there is not a single country in the world that is so rich that can remove all level crossings accidents at the intersections of railways and road traffic. These studies use statistically recorded accidents, to enable the determination of safety levels for each level crossing individually. Probabilistic parameters at road level crossing, average sensory and motor abilities of drivers, driving culture and habits, reliability of signaling and safety devices, road quality at level crossings, visibility (meteorological), time of day, air temperature, and humidity, devices acoustic audibility, the severity of accidents (number of injured or killed), etc.

For the safety of trespassers, the united states FRA (Federal Railroad Administration) states the following points

- Trains do not follow a set schedule, so they can come at any time of day from either direction.
- A train traveling at 55 MPH can take more than a mile to stop.
- Trains overhang railroad tracks by three feet or more on either side. Even when you are not standing directly on the tracks, you risk being hit by a train by being on railroad property.

- Despite their size, trains are relatively quiet and do not always sound warning horns when approaching a crossing.
- Never attempt to walk under, around, or between train cars, even when a train is at a complete stop.

This not helping only the trespassers but also prevents the railway line exposing to accidents. Studies show that fencing the entire rail corridor is not easy as a rail runs thousands of kilometers (Wang *et al.*, 2021).

2.6. Passenger activity

(Matsika *et al.*, 2012) have proposed passengers' concentrated activity at boarding on the platform area hurts the efficiency of the rail network and the reputation of rail travel as a whole. For this matter, there is a mark on the platform to avoid congestion in one area rather than passengers moving in less crowded cargo. (Zhang, Liu, and Holt, 2019) Researchers of track collisions, while (Ahmed, 2016) stud on safety at the platform, high fatality, and injury on the platform during boarding or alighting trains or at the platform edge not during boarding or alighting. Those are passengers fall from the platform and struck by a train cause a delay on the train and the unexpected compensation cost for the railway industry. This resulted in property damage and casualties.

2.7. Livestock or animal-train collision

The safety issues on the railway line are starting with keeping the train from a collision. This mainly occurred due to when train collisions with animals. Railway stations are not considered merely nodes where people change from one vehicle to another, but also places where spatial concentrations of high-value activity are recognized as having a positive impact on cities (Bruinsma, Pels and Rietveld, 2008).

Researchers show that planned railway constructions, allow the movements of animals under the construction of underpasses, overpasses, and fences. It is necessary to provide accurate and systematically collected data on the location of animal-vehicle collisions and determine the possible routes that the animals use mostly to construct this infrastructure. (Lala *et al.*, 2022) examine the influence of standard gauge railways in the African savannah ecosystem. As this paper shows, wildlife crossings were classified into three sections this is

bridges, culverts, and embankments. From this study wildlife that crosses the embankment is stopped by the electric fence this shows that the electric fence along the embankment also can protect the wildlife-train collision. Also For underpass construction, the height, and width of animals are very important. Finally, this paper provides a fence, which has a funneling effect that directs larger animals toward culverts, especially for huge animals or livestock this is a major solution in this paper.

2.8. Terrorism and war

Public transport is an activity facing various problems from which terrorism is a dangerous criminal activity. (Francesco, 2009). This study differs terrorism from vandalism by stating vandalism is violence or property distraction but based on the research terrorism wants to get international attention and cause a huge human and property loss that can happen at any time and anywhere. As a countermeasure, this study takes the design of a station that can be visible from all directions and free from dark areas.

Terrorist attack affects the inter-operation of transportation infrastructures including airports and rail stations, and the regional economy, and imposes additional costs of security or any countermeasures (Kaewunruen, 2018) successful attack is based on the terrorist's ability to defeat the security system. This study shows railway station terrorist attacks could cause a serious loss of lives and deterioration of the economy and the infrastructure as a whole. And as a countermeasure developing security frameworks and decision-makers in maintaining more security.

2.9. Safety Audit procedures

Van de Kerckhove, Johan font (Kerckhove and Dekker, 2022) define, Safety audits are a form of risk analysis and evaluation. In which a systematic investigation is carried out to determine the extent to which the conditions are present that provide for the development and implementation of an effective and efficient safety policy. According to the University of Southern California (USC). "Regular workplace inspections or audits represent a systematic and effective mechanism for identifying workplace hazards and assessing risks and thereafter implementing control measures to eliminate or minimize these risks."(Resource, 2022)

This guideline's purpose is to ensure that USC provides and maintains healthy and safe work through the identification of workplace hazards, assessment of the risk, implementation of control measures, and monitoring of these control measures to ensure effectiveness. Here to undertake the audit the first step is to identify tangible hazards through a checklist by inspection and observation. Then reviewing records by assessing previous audits, observing work practice, randomly selecting a cross-section of the workplace, and briefly interviewing them is used to support the hazard checklist.

In many studies' the first step of a safety audit is to collect data through the safety audit checklist. The data collection phase through the checklist includes a review of the questionnaires, minimizing waste of time in the data collection process and use of resources preparing material needed for data collection, identifying the key informant to be interviewed then data entry through the prepared form and summary all the data is needed. Such as analyze and take a proper action plan the summarized data need to be very clear. Similarly in the Workplace Health and Safety Management System (WHMS) guideline (UOW 2016), the auditor involves interviews, documentation review, or physical inspection of areas as determined from the scope of the audit.

So based on the researchers, the primary products of an audit are qualitative, rather than quantitative (e.g. numerical). These include lists of identified issues, assessments of relative risk, and suggested corrective measures (FHWA, 2006). Qualitative risk assessment can be fulfilled by various techniques such as interviews, checklists, and brainstorming techniques (Thompson and Perry eds., 1992)

According to (Guidelines *et al.*, 2008) guideline, assessments provide evidence that safety requirements are met based on and structured as a series of safety audits and safety assessments. This guideline shows, that audits provide evidence that the planned safety management approach has been followed and is effective. Auditable records are maintained to provide evidence that the planned safety activities have been carried out. The records shall be valid, complete, unambiguous, consistent, auditable, and comprehensive. And the record may include (but is not limited to):

- The results of the design activity,

- Safety analyses,
- Test procedures and test reports,
- Review records,
- Records of near misses, incidents, and accidents about the specific project,
- Maintenance and renewal records,
- Records of decisions that affect safety.

As seen by the researchers the steps of a safety audit are similar but (Resources, 2022) briefly described the steps

1. Hazard Checklist – identify the hazards and prepare a checklist

2. Undertaking the audit----should systematically inspect the work area and record their findings directly onto the checklist and also review records, including; induction and training records, documented risk assessments, and previous audits.

3. Audit findings-here analysis and action plan formulated, by using risk assessment guidelines.

4. Developing an action plan--an action plan must be formulated to ensure that appropriate controls are implemented within an acceptable time frame.

2.10. Changing Qualitative safety assessment into Quantitative safety assessment

Accident analysis and prevention (Bridgelall and Tolliver, 2021) safety culture is studied in both qualitative and quantitative ways. Based on (Antonsen, 2009) the qualitative definition of safety culture is that it represents shared frames of reference that guide individuals' interpretations of actions, hazards, and identities. Which motivated and legitimizes behaviors that have an impact on safety. The quantitative definition of safety culture defines it as a safety climate, which can be conceived of as «snapshots», or manifestations of safety culture, measured by using quantitative surveys (Flin et al., 2000).

Benoit Heynderickx (Heynderickx, 2022) states that qualitative analysis is used to obtain general information on the level of risk. Developing qualitative-based risk assessment into quantitative can give real tangible indicators to decision-makers the author compares the outcome of the qualitative and quantitative methods, the quantitative method involved a larger effort to gather the input data such as incidents and reliable sources of information. Meanwhile, the richness of information given in the quantitative method gave more informed and meaningful information by giving a realistic range interval for the decision makers as opposed to the qualitative information.

To link qualitative and quantitative risk or safety issues assessment Rossi, Paolo (Rossi, P. 2007) study the risk category undertaken after risk is identified for better identification of the common source of risk. Those are two different techniques used to evaluate risk or issues that can be a problem for a project.

- **Qualitative risk analysis** requires the probability and consequence of the risk in terms of very high, high, moderate, low, and very low.

- **Quantitative risk analysis** is used when enough data is available and its main advantage is to determine the probability of achieving a specific project objective, quantify the risk exposure for the project, and identify risks that require most the attention by quantifying their relative contribution to project risk. This process is numerically analyzed the identified risk and used to model the safety risks. FTA and ETA are currently used methods in railway safety risk analysis.

The Federal Transit Administration (FTA, 2019) guidelines to provide a structure for safety risk assessment. Which are a foundation for the safety risk assessment

- Hazard Identification

  A single hazard may have multiple potential consequences so need to assess the likelihood and severity range for a single hazard. These potential consequences could be environmental, equipment damage, and so on.

- Assessing safety risk

  Once identifies potential consequences related to a hazard, it can assess these potential consequences for likelihood and severity.

- Severity category and criteria

Identifies several potential criteria for consequence categories, including death, injury, damage to the environment, and damage to facilities, equipment, rolling stock, or infrastructure.

This guideline (FTA, 2019) shows a different table matrix for the analysis of severity and likelihood for a single hazard, as table 1 shows

Table 1: Sample Safety Risk Assessment Matrix

SAFETY RISK ASSESSMENT MATRIX				
Severity / Likelihood	(1) Catastrophic	(2) Critical	(3) Marginal	(4) Negligible
(A) Frequent	High	High	High	Medium
(B) Probable	High	High	Medium	Medium
(C) Occasional	High	Medium	Medium	Low
(D) Remote	Medium	Medium	Low	Low
(E) Improbable	Medium	Low	Low	Low

The matrix format combines severity and likelihood assessments to establish the overall risk rating of a potential consequence of a hazard. Based on this guideline, a risk assessment matrix typically assigns a number to the potential severity and a letter to the potential likelihood. This means the severity ranks from (1) Catastrophic up to (4) Negligible, and likelihood ranks from (A) Frequent up to (E) improbable.

According to (Delivery, 2017) the risk color in the Risk Matrix represents the following risk levels:

Green……Low Risk

Yellow…….. Medium Risk

Red ……..High Risk

The higher the risk score, the higher the risk level associated with the risk that is being analyzed. The color of the risk (red, yellow, green) is used to bring attention to high-impact risks and provide a comparison to other project risks.

To do this category a standard frequency of occurrence for each problem or safety issue be measured in calendar days, weeks, months, years, or decades. Similarly from Guidelines for integrated risk assessment and management in large industrial areas (WHO, 1998) the frequency of the various accidents used for quantification for Fault tree analysis and Event tree analysis.

Quantitative risk analysis is used to estimate the total risk level numerically by calculating the severity, frequency, and detection of the problem, especially in models that are used to level the safety risk such as FTA, ETA, and FMEA.

But in FMEA the steps for the quantitative approach are used to calculate the RPN value to change the qualitative assessment into a quantitative safety assessment (Macura, 2022)

1. Determining the types of the potential failures
2. Determining the effects of the potential failures
3. Determining the cause of the potential failure
4. Determining the detection methods of the potential failure
5. Determining the RPN (risk priority number)

RPN = S × O × D, which consists of Severity, Occurrence, and Detection

According to, Military standard MIL-STD-1629A (Helicopters, 1990) different tables are provided for the classification of severity, Occurrence, and Detection.

– Severity value S, is described as the effect of any failure on the operation of the system. According to the MIL-STD629A, Severity is a numerical measure in the range of (0; 4)

– Occurrence O is a value that determines the probability of the appearance of any type of failure. It is concerned with the failure rate.

– Detection D is the probability that the potential failure will be detected before it occurs.

The risk severity level is estimated based on the injury level or the harmful impact on people. Here the role of the severity component is more important than the others. This is because the risk of low severity may rank low in the priority order even if it occurs very frequently (even if it has a high probability). Similarly, in the exact opposite condition, even if the probability is low, a risk with a high severity needs to be placed higher in the priority order, and more resources are needed to eliminate such risks.

Finally, by using quantitative risk assessment, the potential causes, and consequences of a hazardous event and the characteristics of a system can be identified, assessed, and understood. Identifying risks from possible failures is vital to maintaining the safety of railways. Mature tools, such as fault tree analysis and event tree analysis, are applied to investigate possible risks to railway safety. In this research paper, the risk level (RL) is assessed in terms of failure frequency (FF) and consequence severity (CS). And these studies show that qualitative risk assessment may be used where the numerical data or resources are inadequate for quantitative analysis. Failure modes and effects analysis (FMEA) (SEMATECH, 1992) is a typical semi-quantitative risk assessment technique. The objective is to produce a more expanded ranking scale than is usually achieved in qualitative assessment (to identify the hazardous conditions, along with their possible causes and their consequences that affect the safe operation), not to suggest realistic values for risk such as is attempted in quantitative assessment (AS/NZS, 1999).

2.11. Impact of Accident

STELIOS C. Zyglidopoulos study the Impact of Accident severity and based on this study severity refers to the extent of the “damage” caused by a particular accident. According to this study at least two kinds of damage can be identified with any accident: damage to human life and environmental damage.

Damage to human life refers to people who were injured or killed because of a particular accident, whereas environmental damage refers to the harm done to various aspects of the environment, such as wildlife, natural resources, and human and animal ecosystems (Zyglidopoulos, 2001). Similarly Ranasinghe (W.A.Asanka1 and M. Ranasinghe, 2015)

studied accident impact, as described accident happened unintentionally and unexpectedly and mainly from the construction industry higher fatality rate were reported and it create construction delay.

Since railway safety is very important, it concerns human lives (Chen, 2013). In addition to that accident have impacts on the transportation, economy, and road vehicle delay due to traffic volume change and also land use impact arise due to grade separation (Rail Safety & Standards Board, 2007; Zhou, 2015). It also have a noise impact on the surrounding area for this (Taggart et al, 1987) studied noise level under different condition. According to the power of accident, (Bridget M. Hutter And Sally Lloyd-Bostock, 1990) the impact of accident varies with the seriousness of the injuries and damage caused by the accident. Major disasters can affect policy changes and even need government actions.

2.12. Summary and Gaps in the Literature Review

Railroad infrastructure is a complex system of dependencies, in which the weakest element decides the safety level of the whole system. As seen minimum safety issues bring a huge loss and damage to railway transportation.

Literature also shows railway transportation covers an extensive range of disciplines, and many researchers consider one safety problem on the railways such as (Matsika *et al.*, 2012) only on passenger activity on safety issues, (Ahmed, 2016) only on infrastructure platform, and also (Mcguirk *et al.*, 2009) for weather or climate effect on railway studied but to assess safety issues, identifying the risks and assessing different case help .

Accidents on the railway can happen due to many reasons like natural hazards, vandalism, terrorist attack, weather condition, geometrical arrangement, collisions, etc. From the studies, the key problem of safety issues is identified suitable measures can be taken based on the type of problem. Those accidents not only affect the train delay time it also affects the train passing across the network, the coming and going train. The delay will affect the passing network line between two trains at the junction.

By most researchers, safety assurance of geometric design should be considered as early as possible in the design process but during the operation of the train, the geometry has face defects due to the train load capacity and the train speed. Similarly, if fencing is not

provided (Wang *et al.*, 2021), the railway industry continue to injure people, and animals and increase trespassers' activity that exposed the railway company to spending much more costs on compensation and maintenance for the entire life of the train.

As a countermeasure for the railway safety that arises due to the above case, the staff of the railway company take the major responsibility by observing signals and equipment are functioning properly, maintenance and repair are taken on time, making sure the railway line is free from the stacked object and make sure to creating awareness between all the users, while others avoid fencing since railway cover thousands of path, and concluding railway accident is not avoidable, after locating the main accident area others (Thaduri, Garmabaki, and Kumar, 2021) recommend to replace the location of the railway line in a different area this brings a huge loss on both the economy and developments of the rail industry. All the accidents have an impact on the delay of the train and barriers for train speed to function on its capacity side by side create a huge loss on the industry.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Research Area

The Ethio- Djibouti railway line is 759 km in length. Which connects two different countries Ethiopia and Djibouti. This electrified standard meter gauge railway line in East Africa transports both passengers and cargo. Which has 21 stations and different infrastructures like 61 bridges, 37 frame bridges, and 453 culverts along the route (Taju, 2020). This research was conducted in the area of this railway line by using video documents, and on-site observation of some areas of the railway to assess the major safety issues and provide a proper countermeasure. The figure below shows the layout of the railway line.

Figure 2: Ethio- Djibouti railway line layout

The importance of railway safety is one of the major country concerns, as the construction of the railway is very costly. Maintaining railway safety help to identify the problem to take

proper action before a huge loss occurs. So identifying the number of passengers are significant for a better risk assessment in railway mode of transportation for better safety assessment through risk identification. From the data obtained from the head office of Ethio-Djibouti Railway Company in Addis Ababa, the passenger statistics are described below.

Table 2: 2018-2021 Traffic statistics of passenger flow

Year	**Number of Passengers per year**
2018	128,982
2019	93,589
2020	21,357
2021	139,100

source (EDR passenger flow report, 2021)

3.2. Research Approach

This research followed a qualitative and quantitative approach based on the data obtained from primary and secondary sources. Safety issue assessment studies use a different approach, from them the better way of methodology for road safety audit or railway safety audit is better to combine both. Because during safety assessment using only the qualitative method can lead to ambiguous information. To make research more reliable and useful the quantitative method helps to analyze the obtained data and provide clear information. So the methodology of safety assessment on the Ethio- Djibouti railway uses both methods. Here the approach fulfills the literature review gaps and uses proper countermeasures to avoid the barriers caused by the safety problem on the railway line.

3.3. Sources of data

3.3.1. Qualitative safety assessment methodology

3.3.1.1. Primary data

The primary data was obtained from the video camera installed on the train of the Ethio-Djibouti railway line. This help to observe and evaluate the railway safety along its way, which needs road or rail safety audit procedure in addition to on-site observation.

Road safety audits are versatile because they can be used to evaluate existing roadways and also roadways in the planning and construction processes it's a proactive way for transportation agencies to diagnose safety deficiencies before crashes and injuries occur (Jones and Jones, 2013). And it's both effective and cost benefits as a proactive safety improvement tool. Even though this safety review is used after the construction process is done, maintaining safety is unstoppable activity to function the railway line without any barriers. This study shows that the purpose of a road safety audit on an existing road is

- To evaluate all roadway and roadside features, design elements, and local conditions that increase the severity of the crash.
- Review the intersection of various design elements and the surrounding networks.
- Observe how railway users are interacting with the railway facility.
- Explore emerging operational trends or safety issues at that location.

Similarly, it can be useful for railway safety assessment due to the nature of the railways. It can be affected by Railside features, design elements like signals, missing or demolishing various railway materials, and trespassing acts due to the railway line passing by different cities and sub-city by bisecting one area, so this and other different safety issues arise that need to explore to develop a countermeasure.

Here the recorded site videos are used to look at physical evidence like to see damage to the railway's infrastructure, Railside barriers due to natural conditions or passenger activity, and also the interaction with the surrounding. For this matter checklist was prepared and recorded common safety hazards from the video along the railway line to identify problems and improve safety.

1, Questionnaires

To gather additional information it's also important to have the owner's experience on safety issues. This can be done by distributing online questionnaires to the employees who work at the company. This questionnaire is formulated to collect additional data that challenge the safety of the railway line from the train operators, maintenance workers, and the engineer's perspective of the staff to identify more safety issues that were not observed at the time of

the video. The questionnaires contain a total of 24 questions used to mitigate the most accidental area to assess the safety problem together with the site observation for reliable information. As this questionnaire is filled online it can address at least each station safety employee along the railway line. And the result was analyzed through SPSS software.

The questionnaires include the following information

- General information on Age, Gender, occupation
- Likert scale questioners on each safety problem

Sampling Method

Questionnaires survey are based on Taro Yamane method survey sampling size and population formula

$n = \frac{N}{(1+Ne^2)}$ with N being the size of the total number of cases, n is the sample size and α an expected error.

To determine department staff from the population of 40 engineers and other related staff

$n = 40/ (1+40*0.05^2)$

$= \mathbf{36.66}$ approximately 37 population from the staff

A sample is a selection of respondents which can represent the total respondent as well as possible.

The two measures that affect the accurateness of the data to consider during sample size selection are

1, Margin of error (confidence interval); - it is the positive and negative devotion you allow to your survey results for the sample. It's 5%, 1%, or others as chosen.

2, Confidence level; -used to express the uncertainty in a quantity being estimated. The standard confidence level for quantitative research is 95%.

Response rate is the ratio of respondents that fill in the questionnaires they received as compared to the total number of surveys that were sent. For an online survey respondent rate of 20% is considered a good response rate.

So that from 38/50 *100 = 76%

As the sample size increases the margin of error decrease. As the variability in the population increase the margin of error increase and as the level of confidence increase the margin of error increase.

2, Interview Question

Passenger interview questions and people who live beside the railway line.

3.3.1.2. Secondary data

In addition to primary data, secondary data are used which include

* Previously recorded safety issues document
* Previously recorded accident document
* Accident location
* As built drawing of the railway project
* Research journal and safety documents of EDR.

From this, historically recorded accident and incident data were caused by the safety problem in the Ethio-Djibouti railway. The obtained historical and current data are used to generate a safety prediction model by using the checklist accident data. Here for the safety issues assessment, the Weibull Distribution Model is used for accident analysis and QGIS software for land use analysis to identify the major safety problem area based on the number of accidents.

3.4. Research analysis

3.4.1 Quantitative safety assessment methodology

From different studies, the road or railway safety audit process is qualitative so there have been limited quantitative studies of the benefits gained through road safety audits to avoid these gaps and to make the assessment clear, one of the quantitative analysis methods for the safety assessment of this research is used, which is Fault Tree Analysis. Which is used to analyze the safety issues obtained from different sources and find out the root cause. So it's helpful to change the qualitative method into quantitative analysis because Weibull Distribution and FTA use to describe by using a numerical value. In addition to that for the questionnaire Statistical Package for Social Science (SPSS) software is used. The questionnaire response can make a team response as it includes all types of departments,

with the ability of the knowledge, information, and experience of the respondent on the Ethio- Djibouti railway line.

1. Weibull Distribution Method For future prediction analysis

Weibull distribution applies to lifetime research and reliability theory (Using the Weibull Distribution, 2012). This model describes one of the discrete random variables, which is a variable that numerical value defines over a discrete sample space (Rahman, 2012). Here the daily number of accidents on the railway line is counted over each month, so using the Curve fit Expert developed a Weibull distribution equation by fitting the data into the software.

Curve Expert Professional is a cross-platform solution for curve fitting and data analysis. For this thesis, the data are obtained by counting the number of accidents that happened on the Ethio - Djibouti railway line and developing a model by using a toolbox of nonlinear regression models in Curve Expert Professional.

2. QGIS

When Safety risk is at a high-level accidents happen so to take special measures identification of the place of the accident is necessary based on their location (based on the mileage of the accident) the X Y coordinate is extracted and the major place of the accident is analyzed.

3. Fault Tree Analysis (FTA)

FTA is a top-down graphical approach, which displays the interrelationship between events and their causes with logical gates. As it is one of the classical methods for identifying risks, in a deductive way the level of risk is determined by calculating the probability of a failure occurring. To analyze the root cause of failure of safety issues observed during the data collection in the Ethio- Djibouti railway line, FTA is used quantitatively, FTA is used to describe the top event and connected by OR or AND logic gate to connect with its causes. As the research place is a complex project probability of each event occurring, and the dependency of each different event. (‘FTA_TreeGates_Template’, 2019)

Logic gate OR; - the presence of one positive input will produce an output.

AND; - both inputs need to be positive and present to produce an output.

Basic FTA structure

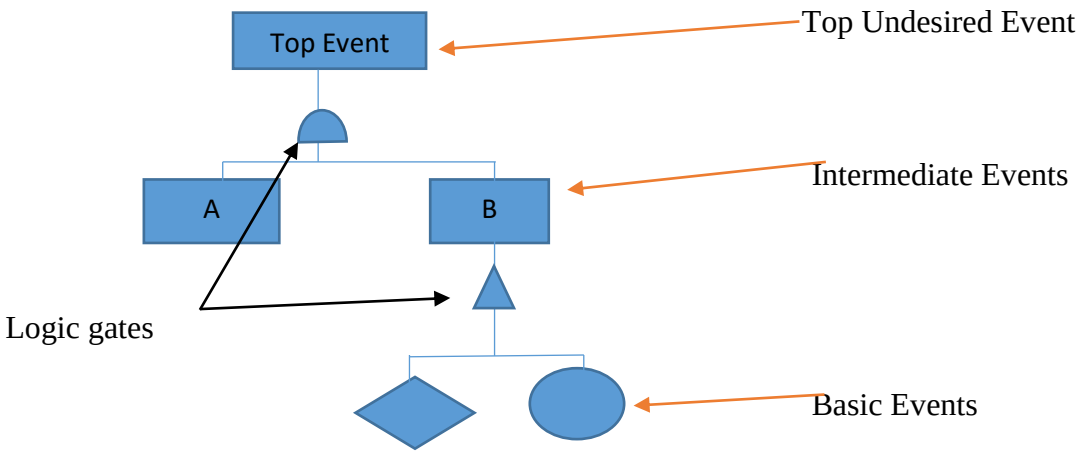


Figure 3: Basic FTA structure

Probability of Top Event calculation

Based on the type of gates the probability of occurrence of a top event by a bottom-up approach can be calculated

AND; - $P_{AND} = P_A \times P_B \times \ldots\ldots \times P_N$

The Probability of output at this type of gate is calculated by using this equation

$P(G) = \prod_{i=1}^{n} P(Ai)$

OR; - $P_{OR} = 1 - ((1 - P_A) \times (1 - P_B) \times \ldots \times (1 - P_M))$,

The Probability of output at this type of gate is calculated by using this equation

$P(G) = 1 - \prod_{i=1}^{n} (1 - P(Ai))$

Where (A_i) is an event at the input and

P (G) event at the output

In FTA identification of a minimal cut set is one of the most important qualitative analyses, it can't be reduced without losing its status as a cut set. The top event occurs if one or more

of the minimal cut sets occur. So the minimal cut sets have the most influence on the top events.

4. Safety prediction model

There are 3 different predictive analytics models used in safety, these are

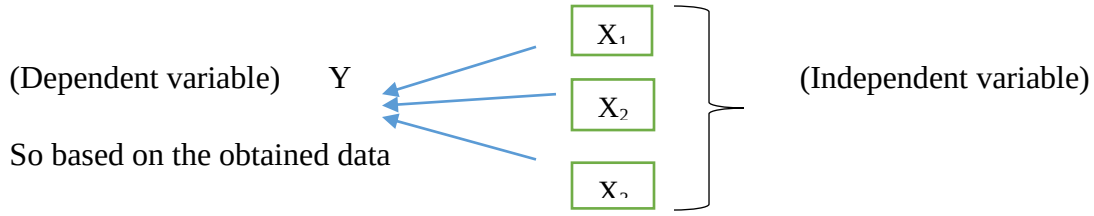
1. The forecast model
2. The classification model and
3. The outliers model

For this research, the **Forecast Predictive Analysis Model** is used to predict the safety of future outcomes. As forecasting is based on historical data, here historically recorded accident or incident data in the Ethio-Djibouti railway line are identified and assessed to generate a safety prediction model including the drawing document.

A quantitative forecasting method uses a regression model to forecast and predict. So for this assessment the regression analysis done by SPSS to develop the safety prediction model, two separate variables are needed this is dependent and independent variables are taken to create a formula.

Dependent variable; - whose values depend on the independent variable and are drawn on the Y axis on a graph.

Independent variable; - which is an explanatory variable or sometimes called causes and drawn on the X axis on a graph. These independent variables are vandalism, trespass, weather condition, natural disasters, vehicle collision, animal-train collision, and robbery, which affect the safety of the Ethio-Djibouti Railway line by increasing delay time and also leading to train travel cancellation.



Delay = f (safety initiatives)

(Variable X) Safety initiative ⟶ Regression Model ⟶ Y Predict (accident or incident rate)

3.5. Methodology

The flow chart below shows the research methodology steps designed for this thesis. Here different methods of analysis are used to identify the major safety problem by co-relating the results. Their co-relation is based on what are the problems, the major problem, how it occurred, where it occurred, how it affect, and what solution proposed to set the future occurrence of safety issues.

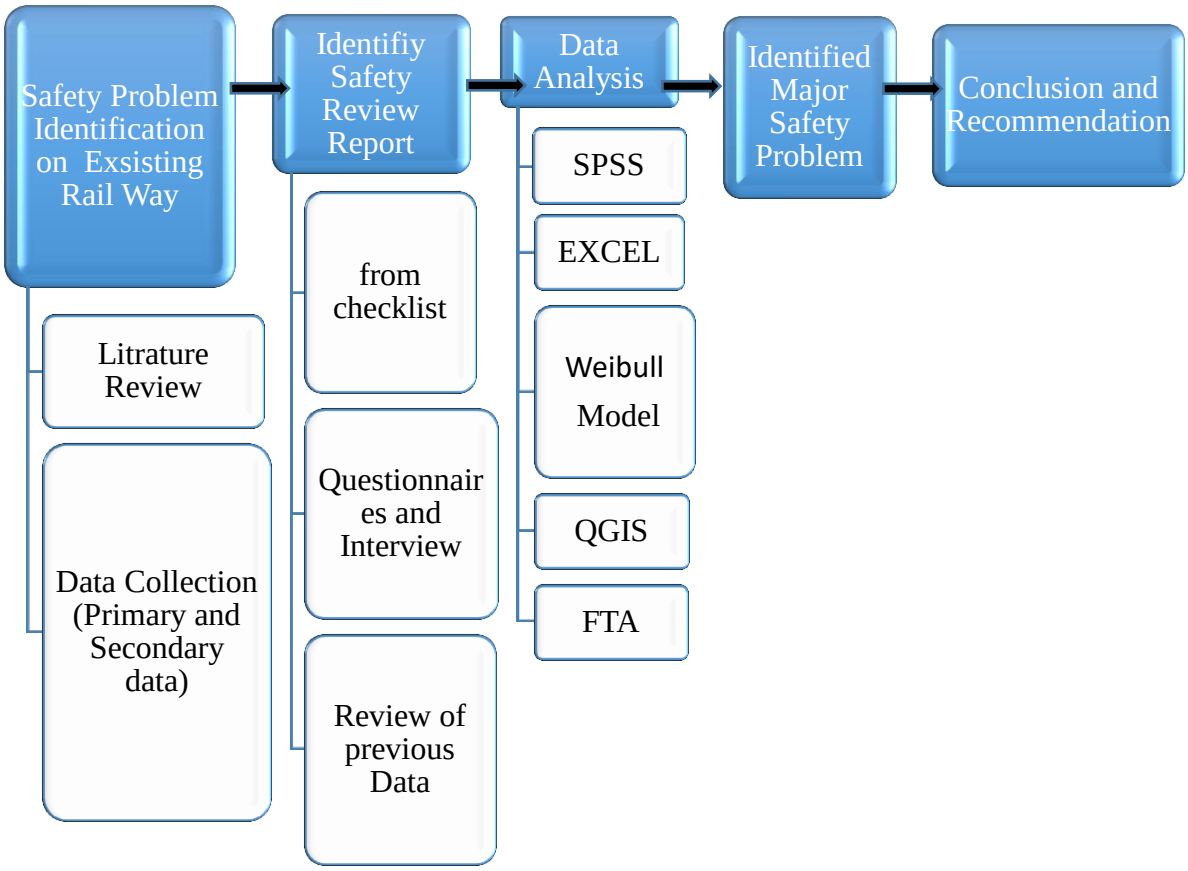


Figure 4: The methodology flow chart

CHAPTER FOUR

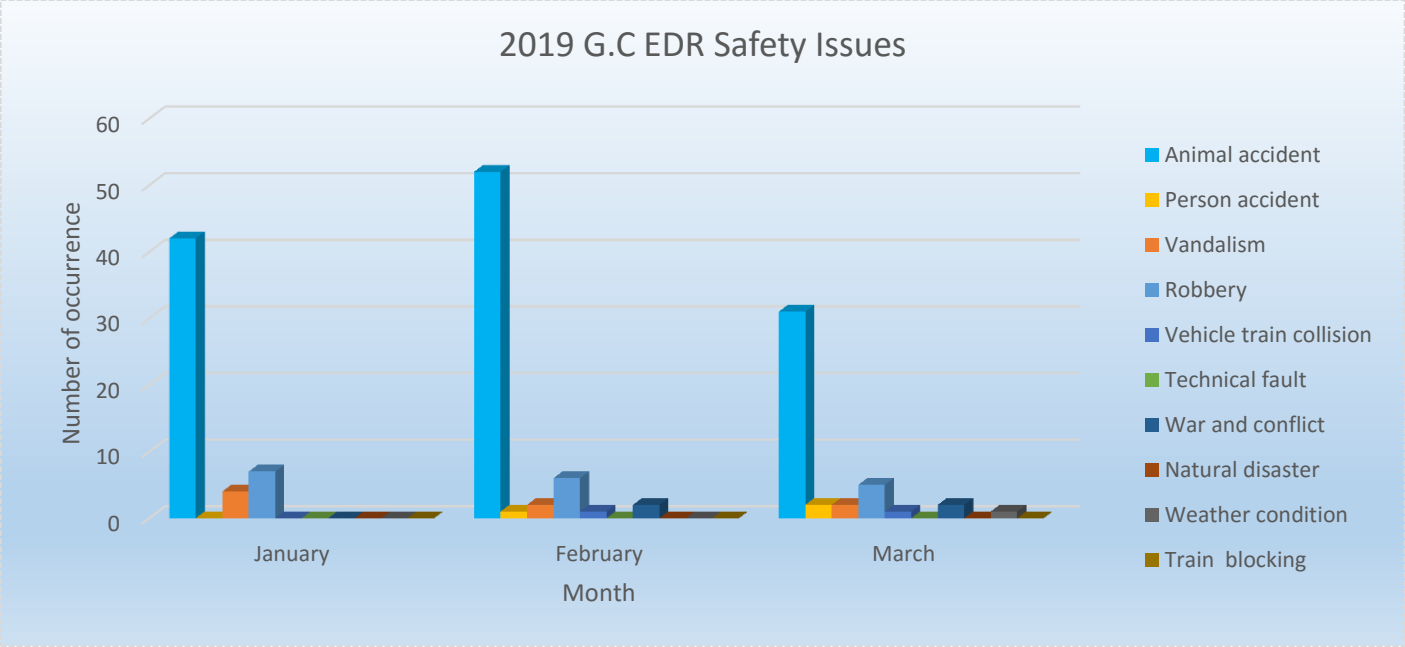
4. RESULT AND DISCUSSION

4.1. Data collection and Analysis Results

4.1.1. Ethio- Djibouty Railway Safety Inspection Results from 2019 G.C up to 2022 G.C

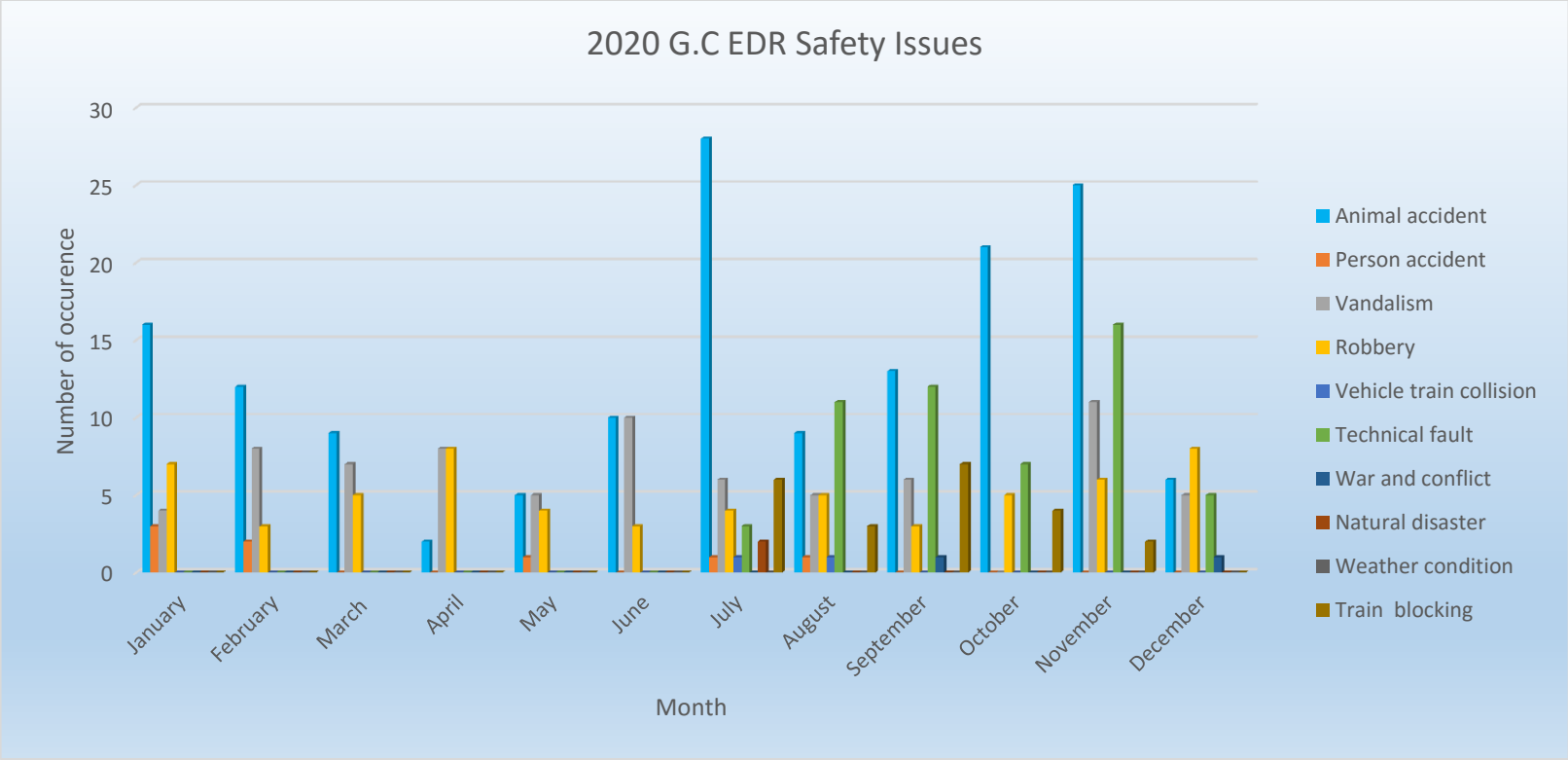
Safety audits are a form of risk analysis and evaluation in which a systematic investigation is carried out in order to determine the extent to which the conditions are present that provide for the development and implementation of an effective and efficient safety policy (Van de Kerckhove, Johan, 2011). Similarly according to FHWA Road Safety Audits Guideline 2006, a road safety audit is a formal safety performance examination of an existing or future road or intersection by an independent audit team. The team considers the safety of all road users, qualitatively estimate and report on road safety issues and opportunities for safety improvement.

Based on the safety inspection checklist table 21 on the Annex's A, the different type of safety challenge the railway face from 2019 G.C up to 2022 G.C are described below .



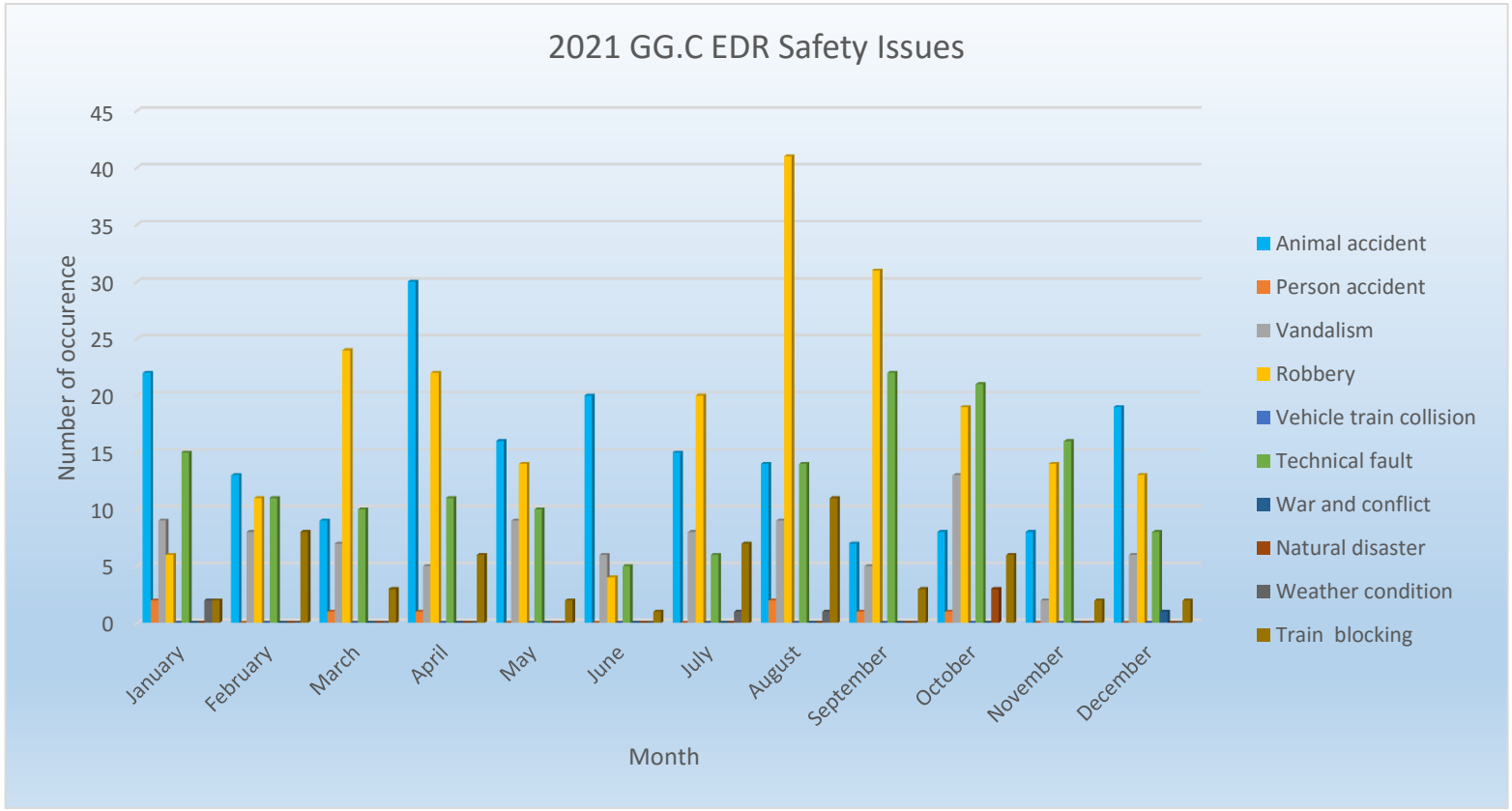
A,

The safety audit result shows that eight type of safety issues are facing by the company and assessed from 2019 up to 2022 G.C and fig A, shows that in 2019 G.C animal accident was the highest frequency that happened more than 50, in number of occurrence per month. It cause major safety problem that danger the life of animal and the compensation cost for the company increase, delay and traffic flow of the train flow challenged due to this.



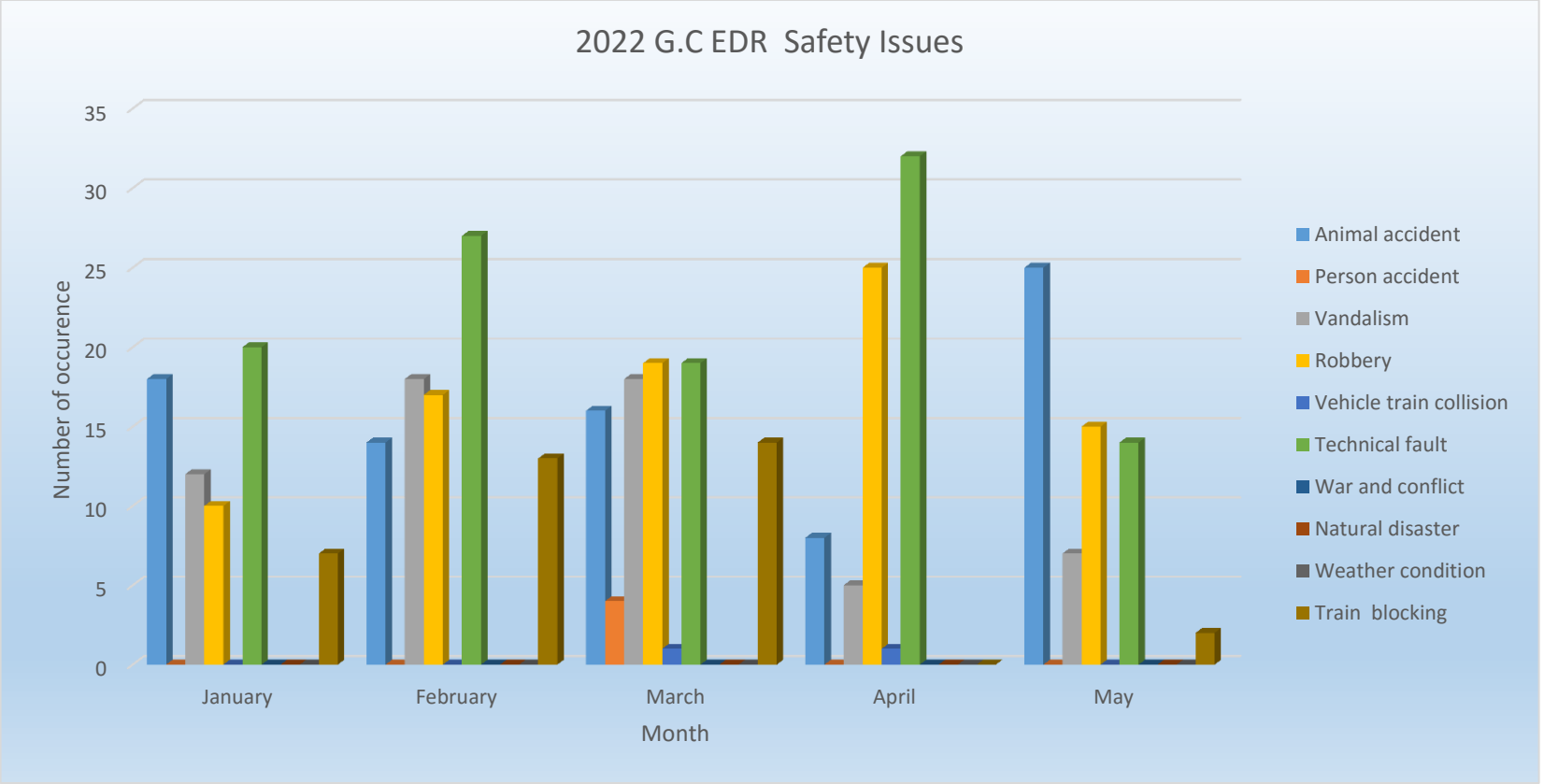
B,

From fig. B, it's shown that in 2020 G.C animal accident was the highest frequency that happened more than 25, in number of occurrence per month. In addition to that person accident, vandalism, robbery, technical faults, natural disaster and war and conflict are the other type of safety problem in Ethio-Djibouti railway.



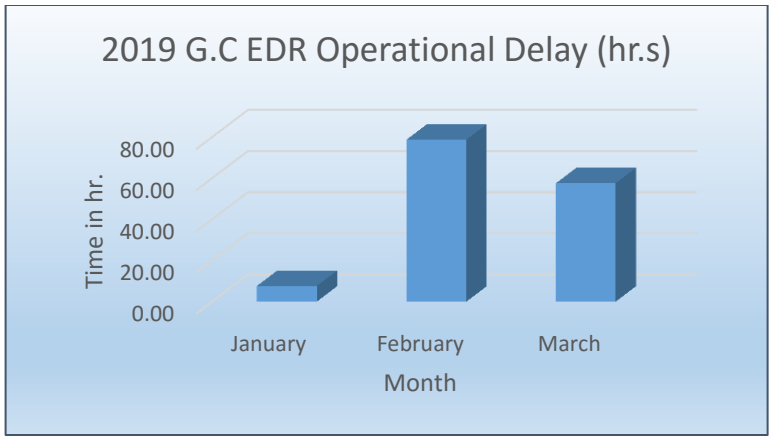
C,

From fig. C, it's shown that in 2021 G.C Robbery activity was the highest frequency that happened more than 40, in number of occurrence per month. In addition to that in this year vehicle train collision, person accident, weather condition and train blocking activity are safety issues in addition to the safety issues that mentioned in fig A and B.

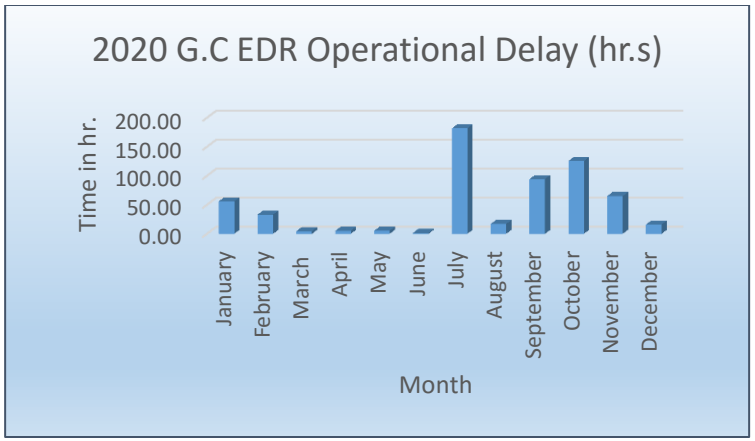


D,

From fig. D, it's shown that in 2022 G.C Technical faults are the highest frequency that happened more than 30 times in number of occurrence per month. In addition to that three accidents are occurred more than 20, in number of accident per month occur. In this year some safety issues are going high and some have a change in the occurrence but to identify the major problem other method have to be used.



E,



F,

G,

H,

Figure 5: Bar chart A-H shows safety issue occurred in EDR between 2019 up to 2022

From the chart of fig. E-H one of the main safety issues Delay is described and from 2019-2022 G.C its increasing more than 100 hour per month but in 2022 its major record was 100 hour delay per year. From the checklist, some of the detailed safety issues are observed from the recorded video and onsite observation.

4.1.2. Employee response to questionnaires

As the questionnaire is Five Point Likert scale interpret the result by assigning the choice by number and from the sample size 37, all 40 people are responding and some are missing, the employee did not respond correctly.

Table 3:Questionnaire Result SPSS output and their frequency rank

Statement			**Respondent frequency**
	Demographic question		
1.	Gender	Male	28
		Female	10
		Missing data	2
2.	Age	<30	13
		31-40	25
		Missing data	2
3.	Education status	Diploma	3
		Degree	14
		Masters	21
		Missing data	2
4.	Department	Electrical	10
		Rolling stock	2
		Civil	11
		Safety	3
		Driver	12
		Missing data	2

	Safety issues problem on Ethio- Djibouty Railway	Agree	Disagree	Strongly agree	Strongly disagree	Neither agree nor disagree	Missing data
1.	I think passenger behavior of crowding around the door of the train has a safety problem.	26	4	6	1	1	2
2.	Removing or demolishing train equipment of Passenger activity inside the train has a safety problem.	24	1	11	2	0	1
3.	The use of previous routes by the local people is the main reason for the trespassing act.	22	5	8	1	2	2
4.	The level crossing is far from each other and a reason for the trespassing and collision accidents.	23	1	9	1	4	2
5.	Deliberately distracting (vandalism act) company property is the primary safety problem on the railroad.	13	2	22	0	1	2
6.	The company is losing an irreplaceable amount of material due to vandalism and robbery act.	12	0	24	0	2	2
7.	High rainfall and flooding cause erosion and surface sliding on the railway substructure.	23	3	8	0	4	2
8.	Earthquakes are one of the natural disasters that challenge the site.	13	12	3	4	5	3
9.	I think some geometric such as alignment, curve, slope, and elevation problems are seen along the way.	25	8	2	1	2	2
10.	The safety of the railway is profoundly influenced by train-animal collisions.	13	2	21	1	1	2
11.	Compensation expense is the company's primary payment for accidents and injuries losses.	24	3	8	0	3	2
12.	I think to increase safety fencing structures have to install around the railroads.	21	6	11	0	0	2
13.	Some drainage infrastructures have a problem of clogging and alluvial due to their small size.	26	1	5	2	4	2
14.	I think major technical faults are seen in the mechanical	12	16	2	1	6	3

	part.						
15.	I think major technical faults are seen in the electrical part.	18	10	5	0	4	3
16.	I think major technical faults are seen in the civil part.	20	7	5	0	6	2
17.	Sometimes war and terrorism acts are seen on the railway line.	19	7	6	3	3	2
18.	Mainly safety issues occur by freight trains rather than passenger trains.	15	11	7	0	5	2
19.	The safety problems along the route influence the speed of the train.	14	2	19	3	0	2
20.	In general, the Ethio-Djibouti railway has excellent safety.	9	17	2	10	0	2
	Total						

Concerning to the above Table 3, most of the respondent have a master's degree on their education level beside as a railway is working by different department in combination the majority of the respondent department was from civil staff. As seen safety issues identified from the safety audit result are clearly notice by the questionnaire respondent because most of the causes for safety problem are agreed by the respondent with different frequency such as passenger behavior and activity there congestion on train doors during exit and entry as well as demolishing the train equipment activity agreed by 26 respondent. Correspondingly illegally passing the property of the railway line to take the shorter path along the bisected route and also avoiding the underpass constriction for the movement of animal increasing trespassing act and 22 respondent agreed. Weather condition such as flooding & natural disaster like earthquake responded as agree by 23 and 13 respectively. In addition to that 25 respondent agreed on the safety of the railway line affected by geometric alignment similarly as this railway was a cross border railway line the fencing structure is available only on the nearby station and highly populated area because of the long distance but 21 respondent agreed that if fencing structure is placed along the whole line the safety can increase. One of the main infrastructures in the railway is a drainage system but 26 respondent agree that the improper size and construction of the drainage system is affecting the line safety. Personal activity such as, war and conflict also a safety issues along the line was occurred and affect the safety of the company agreed by 19 respondent. The other type of safety issues are the technical faults, it happened and affecting the safety condition along the Ethio-Djibouti railway mainly railway have three stream technical work Electrical, Mechanical and civil but according to the respondent 20 agree technical faults are occurred from the civil work side. In addition this railway line serve for both passenger and freight train, 15 respondent agree most of the safety issues are caused by the freight train rather than passenger train.

The other rank which is strongly agreed by the respondent are vandalism, robbery, animal accident and speed of the train are affecting the safety of the railway with 22, 24, 21 and 19 respondent rank respectively. From this 24 are coming from robbery act so overall from the questionnaire result robbery is the major safety issue problem for the company and with the same rate the compensation cost was affecting the stability of the company economy. In general EDR have a safety problem based on the respondent frequency .

4.1.3. Weibull Distribution Accident Analysis Model

4.1.3.1. Model safety prediction Results

Weibull Distributions Model used for future prediction as described in page 28. In this thesis the cumulative distribution function is used to develop the Weibull equation, from the total accident data so unlike the normal distribution, the Weibull CDF is expressed in closed form. As (McCool, 2021) state that there are two forms of Weibull distribution distinguished by the presence of either two or three parameters. The CDF of the three parameter version of the Weibull distribution is given by

$$F(x) = 1 - \exp\left(-\left((x - \gamma) / \eta\right)^{\beta}\right);\ x > \gamma$$

Where Υ, is the location or threshold parameter

η, scale parameter and

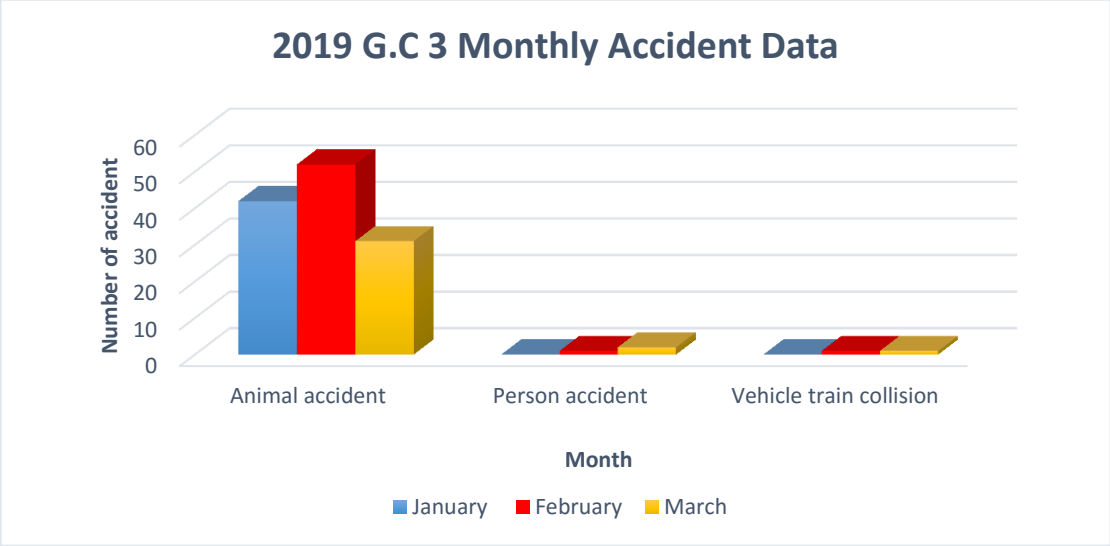
β, is called the shape parameter and the parameter η and β are positive.

When Υ is zero the three-parameter Weibull distribution specializes to the much more widely employed two-parameter version. And for $\beta=1$ two parameter Weibull distribution specializes to the exponential distribution. Here the Weibull model was calculated by using curve Expert Professional to fit the curve and obtain the equation.

For this thesis, the accident data is measured as a discrete variable. Which used Discrete Weibull Distribution, the cumulative distribution function with total number of accident done by Excel. And the Weibull distribution equation is developed by the Curve Expert Professional. (McCool, 2012)

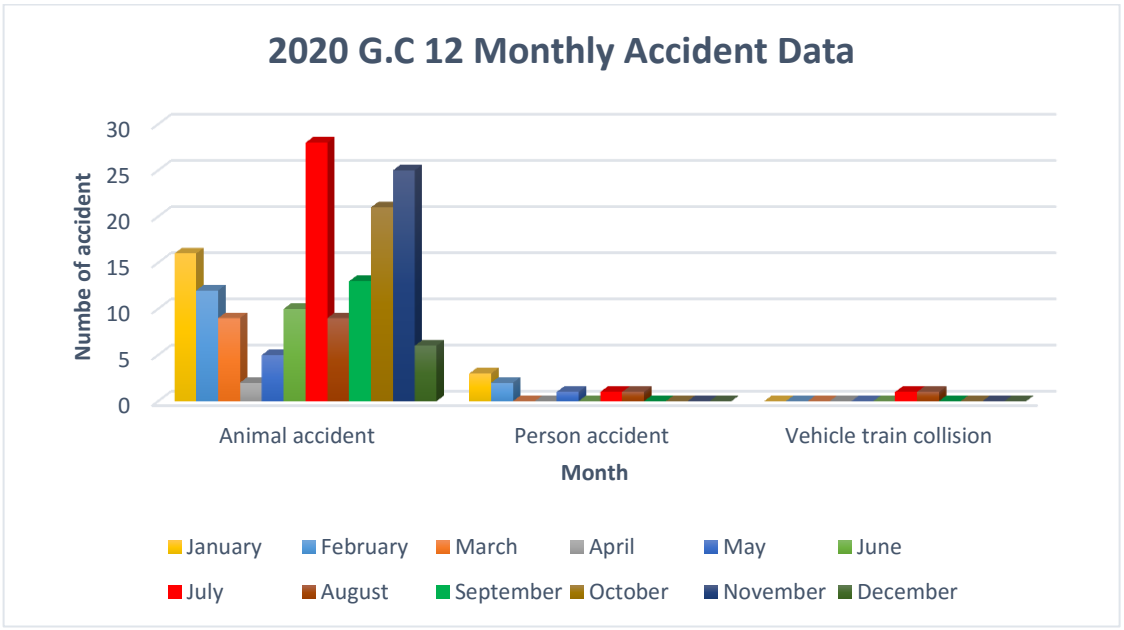
The nonlinear regression of one of the sigmoidal family Weibull Equation for total accidents per month needs an initial guess to yield the result as it a discrete data. So that the cumulative distribution data is used to fit the model in Curve expert Professional. Below the accident data and the cumulative distribution calculation described.

Accident Data in EDR from 2019-2022 G.C



A,

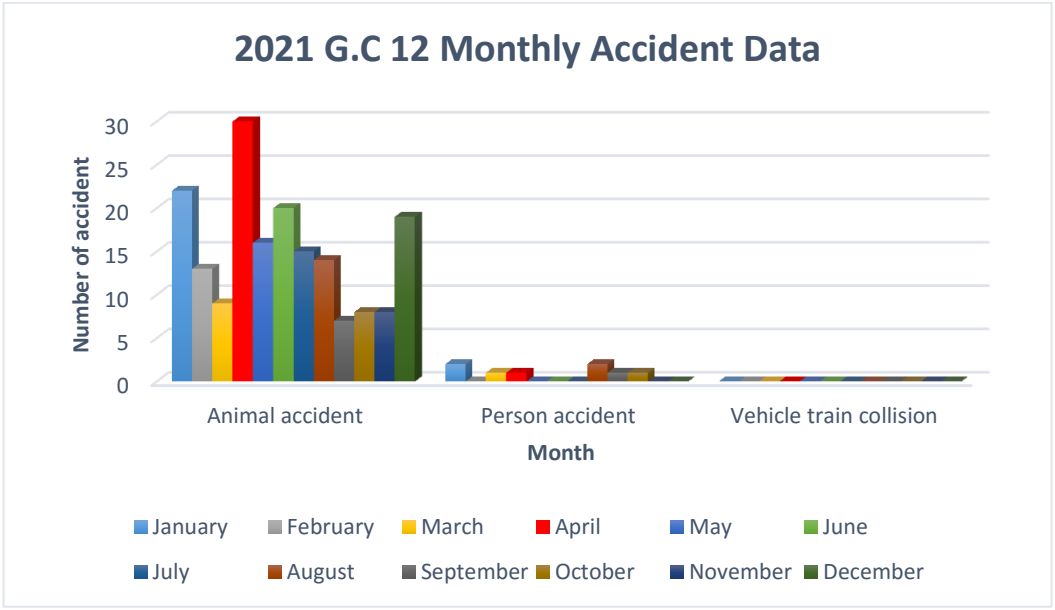
Fig A, shows 2019 G.C accident data collected as first year but due to the COVID 19, problem the company didn't work after April so the data is only for three month. Even if its three month the three type of accident registered which is animal, person and vehicle train accident and the animal accident take highest number 50 as compared to the other accident.



B,

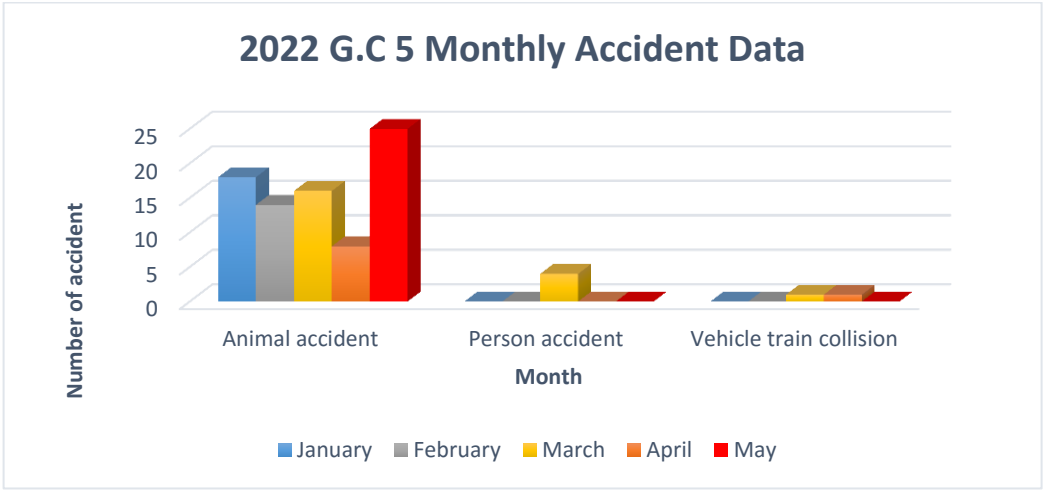
Fig B, shows 2020 G.C accident data collected for twelve month. Here the three type of accident registered which is animal, person and vehicle train accident and the animal

accident take highest number as compared to the other accident in each month and the highest was more than 25 in number.



C,

Fig C, shows 2021 G.C accident data collected for twelve month. Here two type of accident seen which is animal and person accident. The animal accident take highest number as compared to the other accident in each month and the highest number was more than 28 in number.



D,

Figure 6: Bar chart A up to D, shows accident data in EDR from 2019 G.C-2022 G.C

The accident data shows three type of different accident with different frequency happened on the railway line. According to 2022 G.C data fig 6. D, shows that five month accident

data and all the three types of accident occurred here also the animal accident take the highest number of occurrence within the month.

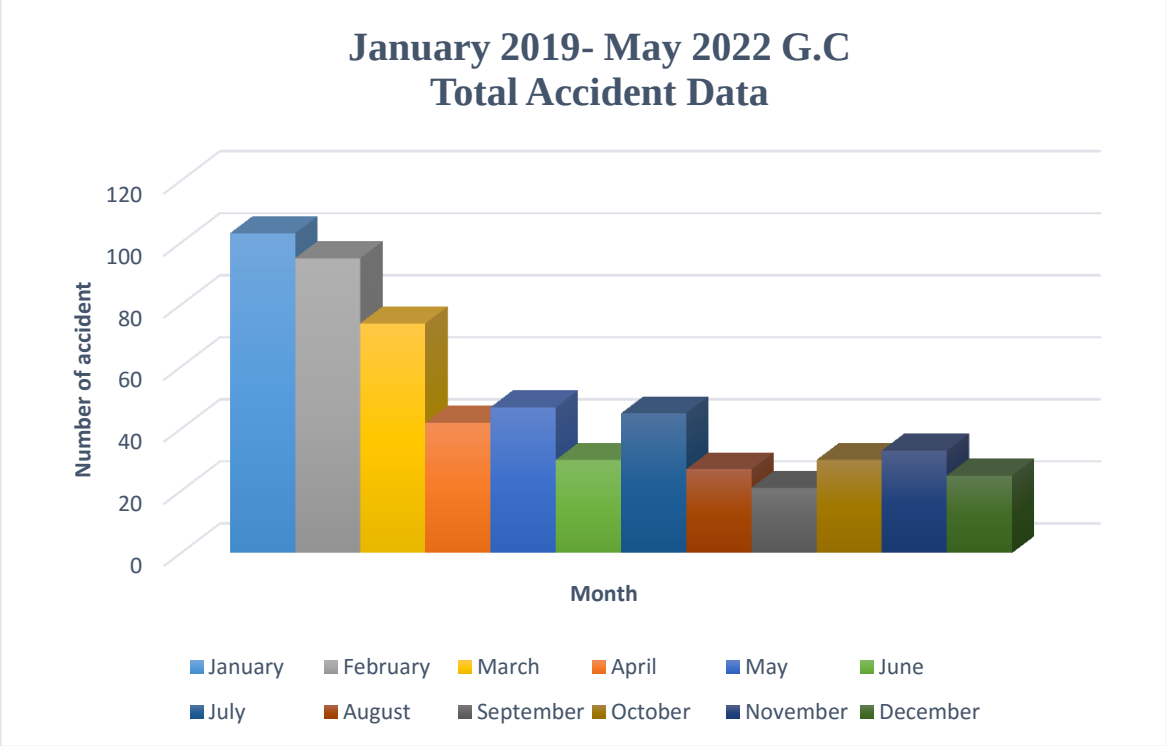


Figure 7: Total Accident Data in EDR

From the fig 7, total accident data as shown from the chart is decreasing from more than 99 up to 20 number of accident within a month but the accident is continuous and fluctuate starting from the month of May up to December. To find out the main accident status the cumulative distribution of the graph is plotted below.

Total accident data with the cumulative distribution function

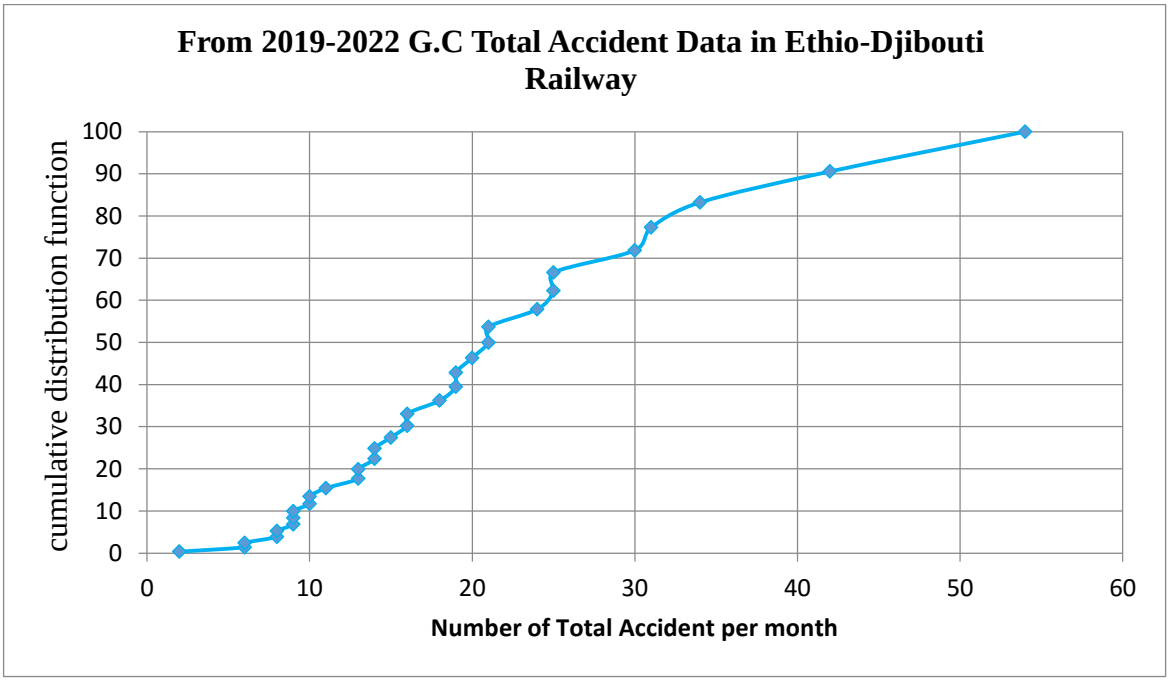


Figure 8: Total accident versus cumulative distribution

The total accident data was the total number of accident for animal, person and vehicle train accident. Due to the small sample size data the individual accident is not enough to give satisfactory result so that the total accident data is used to predict the safety issues based on their cumulative distribution result. It's used to describe the probability distribution of random variable. It can be used to describe the probability for a discrete variable. For the discrete random variable X, the cumulative distribution function describe the probability that x be less than or equal to a given value.

So Figure 8, CDF plot shows the empirical cumulative distribution function of the data. Its not easy to predict the future probability because as seen from the graph it have vertical and also horizontal jump and it didn't have a uniform function so to set the prediction on the right suggestion the following model was developed.

Curve Expert Professional Results and Description

Table 4: Model Description

Overview

Name	Weibull Model
Kind	Regression
Family	Sigmoidal Models
Equation	y = a - b*exp(-c*x^d)
# of Indep. Vars	1
Weighting	Default
Standard Error	2.15307329656
Correlation Coeff. (r)	0.997448
Coeff. of Determination (r^2)	0.994902832585
DOF	28
AICC	51.665499

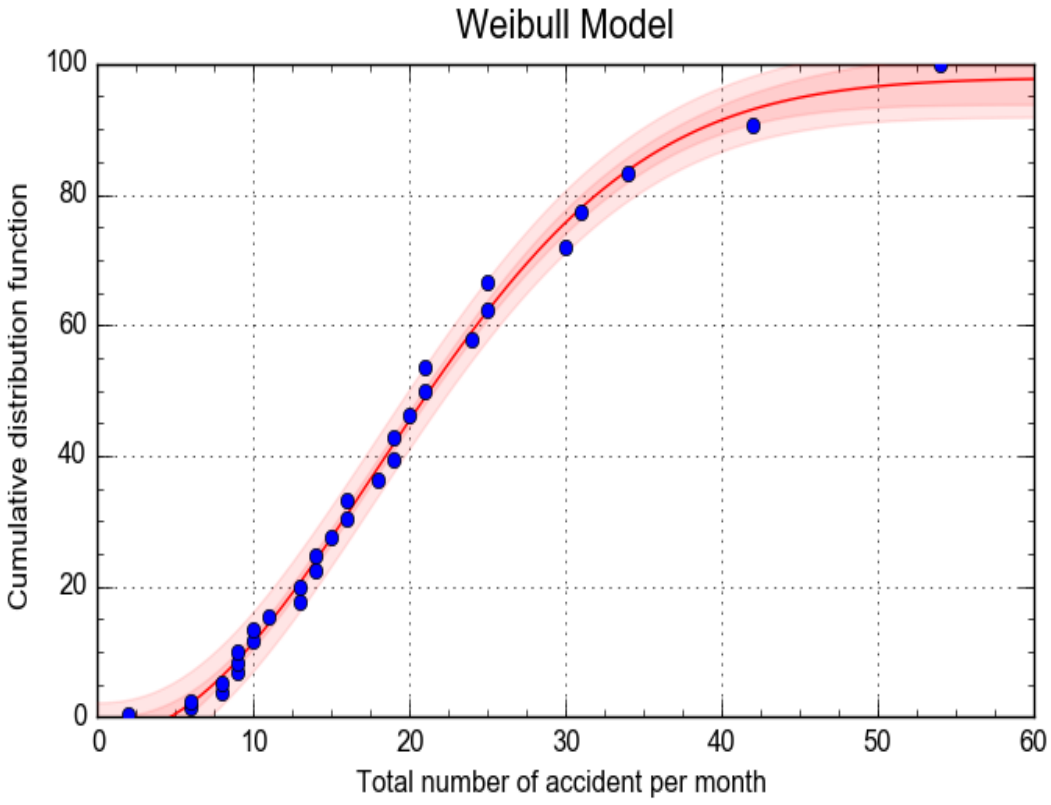


Figure 9: Weibull plots of CDF and total accident

The model Weibull describe the data more reliable than the other type of curve fit model because correlation coefficient and coefficient of determination are 0.99 and 0.99 respectively which shows that the model is best fit for the analysis. Here the discrete total number of accident data are different from the CDF because of the number sum in the CDF the data become continuous and easily predictable. Even though based on the fig 9, the accident location are scattered and not touch by the line smoothly. So once the equation is developed and its convenient model by using EXCEL uniform graph developed and its suitable for the future prediction see fig 13 on page 50.

Table 5: Weibull Model Equation Coefficients and Detail description

Parameters

	Value	Std Err	Range (95% confidence)
a	97.841114	2.053703	93.634294 to 102.047934
b	101.071341	2.898209	95.134629 to 107.008054
c	0.001344	0.000416	0.000493 to 0.002195
d	2.066748	0.101085	1.859684 to 2.273812

Some sample analysis graphs for prediction purposes

1, when X=28

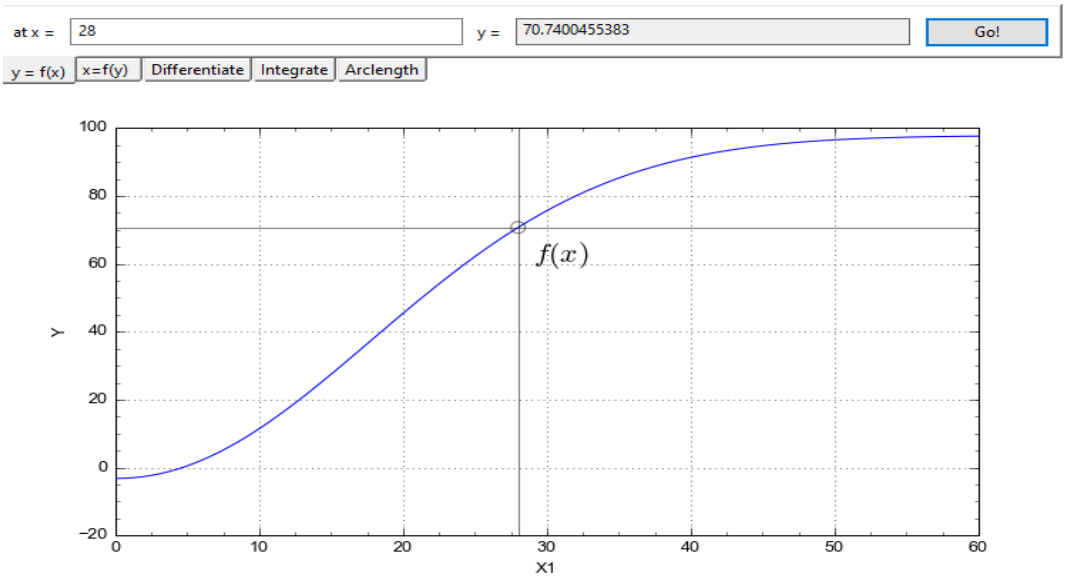


Figure 10: Total number of accident versus CDF at x=28

2, when X=35

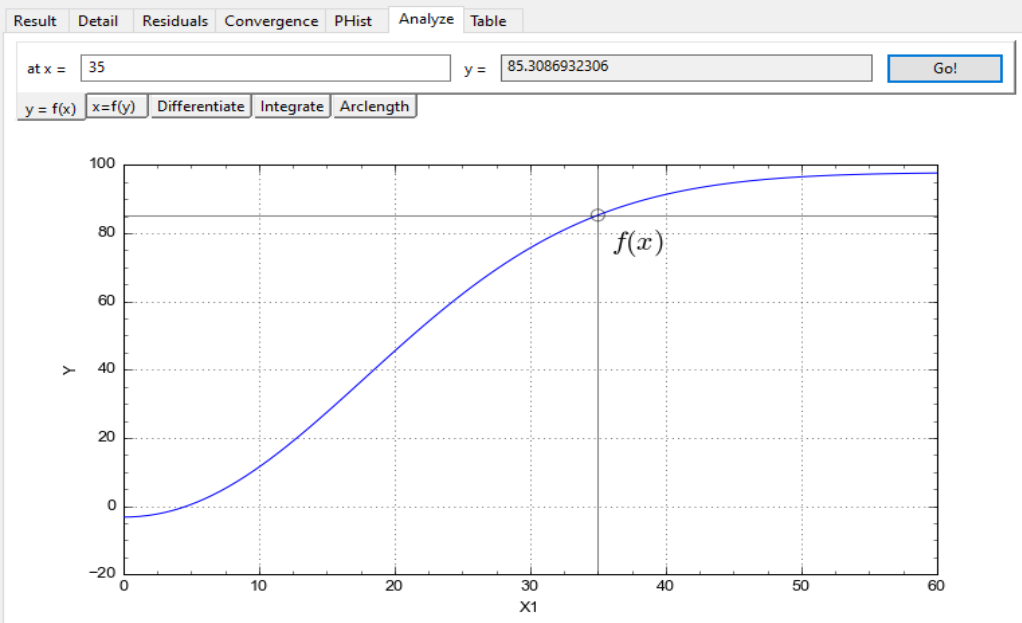


Figure 11: Total number of accident versus CDF when x=35

3, When X=45

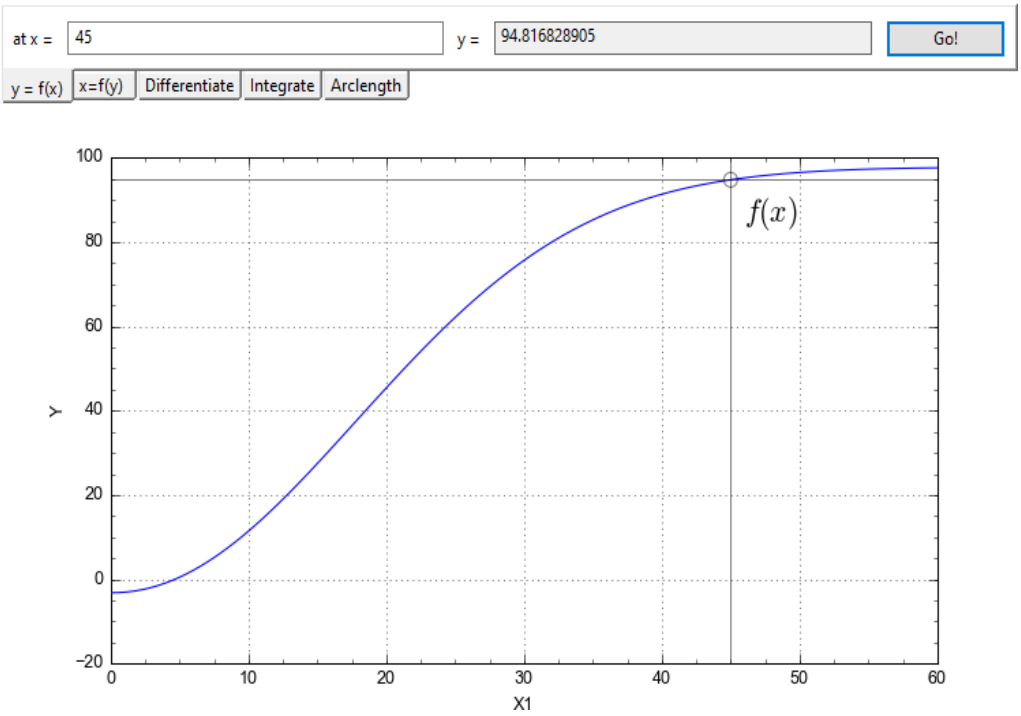


Figure 12: Total number of accident versus CDF when x=45

Future Prediction

Weibull analysis helps to look into the future and determine the probability of an accident or failure in the future based on previous performance. Here are the 3 samples of Weibull analysis results shown in the fig 10 up to fig 12.

1, Number of total accident per month ----------28

Probability of the accident ----------70.85

2, Number of total accident per month ----------35

Probability of the accident ----------85.30

3, Number of total accident per month ----------45

Probability of the accident ----------94.816

4.1.4. EXCEL Result for the Weibull equation

Weibull equation and coefficients from the developed nonlinear sigmoidal family Weibull equation and coefficients

Table 6: Weibull equation and coefficients

Weibull Model equation		
y = a - b*exp (-c*x^d)	Coefficients	(-c)
a	9.78E+01	
b	1.01E+02	
c	1.34E-03	-0.001344092
d	2.07E+00	

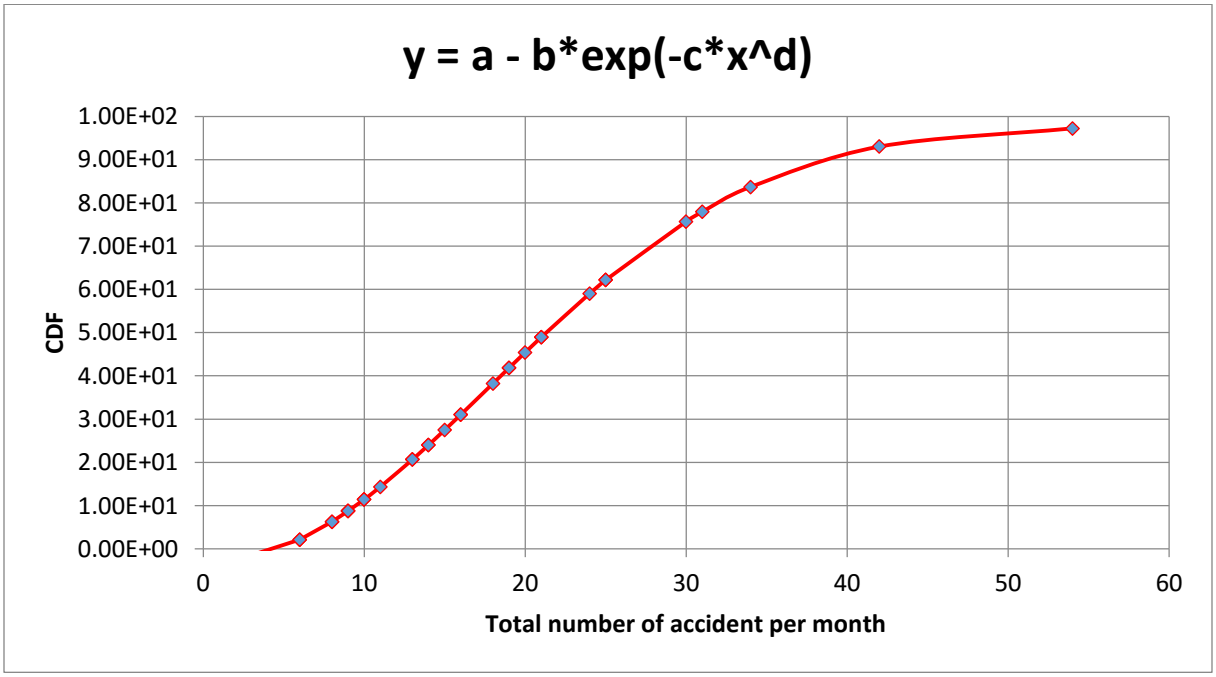


Figure 13: Weibull Distribution Model

Figure 13, shows clear prediction on the accident safety of the railway and this graph touch all the points as its developed through the Weibull equation. So it's best as compared to fig 9 a graph developed by the Weibull model.

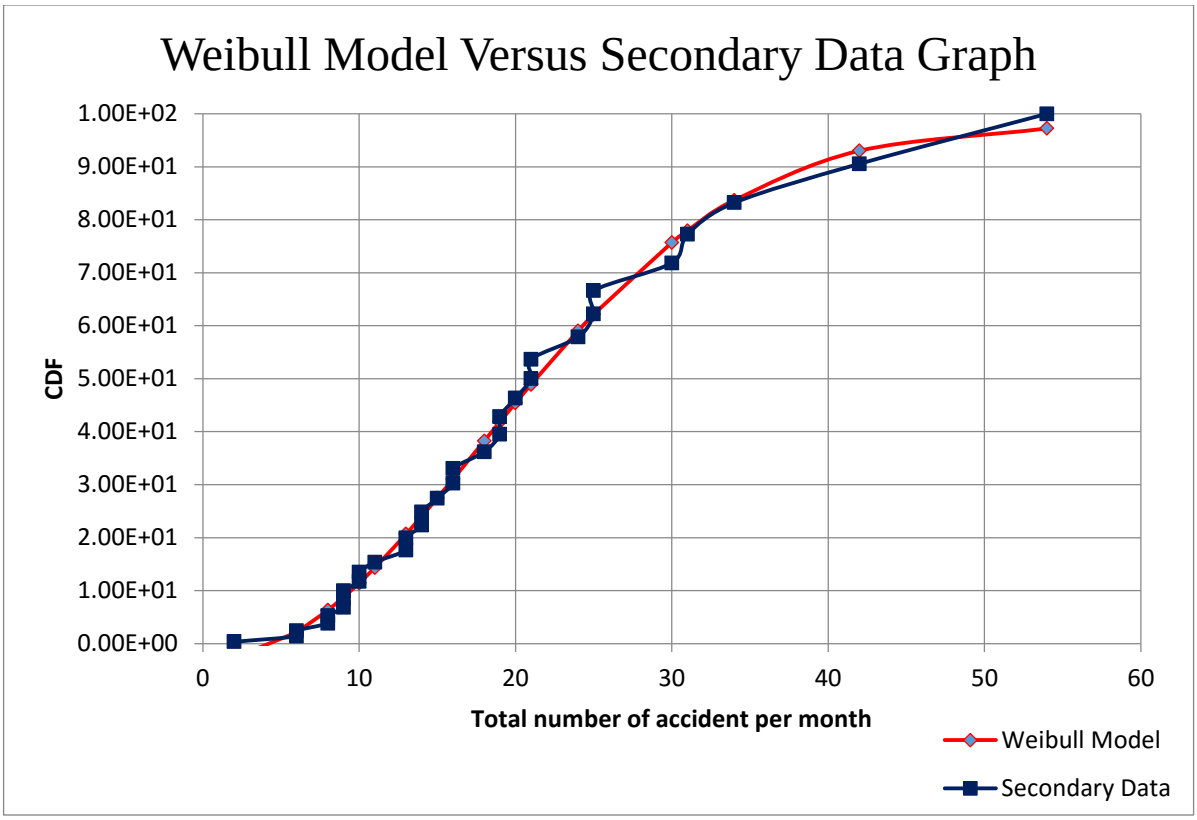


Figure 14: Comparison graph

From the comparison graph of Figure 14, the graph of the secondary data shows the number of accident are increasing and at some point it's constant and later its increasing constantly and not easy to develop equation and set interpretation but the Weibull Model graph shaped like an ogive cumulative distribution probability graph. It shows the cumulative frequency or probability on the vertical axis is increasing with the number of accident in the horizontal axis. This means the number of accident will increase unless the reason for the accident, that affect the safety of the railway is find out. So that the next model shows frequent location for accident and the reason will be research.

4.1.5. Geometric Alignment and Geometrical design Analysis Result

4.1.5.1. Geometric Alignment and Accident location

From one of the secondary data of the railway drawing, geometric alignment of the accident place is extracted based on the mileage in each year and then compiled to monthly accident data by giving number assignation for the geometric alignment condition in the place of accident and present calculation where done by EXCEL. Number nominations are 1 and 0 for the accident refer annex's (Table 22).

If the accident occurs at the type of the geometric location number 1 assigned and accident does not occur at the geometric location 0 assigned, based on this the sum of the total accident at the location type is listed below.

Table 7: Accident Summary in Geometric Alignment

Type of Accident	Total number of accident on Vertical Alignment		Total number of accident on Horizontal Alignment		Total accident
	sag	crest	Curve	tangent	
Animal Accident	257	271	310	268	543
Person Accident	11	11	10	12	23
Vehicle Accident	3	3	3	3	6
	556		606		572

Concerning to the above Table 7, out of the total number of 543 animal death 257 occur at sag, 271 at crest, 310 occur at curve and 268 animal death at tangent line of the geometric alignment. Similarly from a total of 23 person death 11 occur at sag, 11 occur at crest, 10 occur at curve and 12 occurred at tangent line. For vehicle-train accident also 3 collision accident occurred at sag, crest, curve and tangent line of the geometric alignment. From this more accident occur on the railway curve and tangent line of the horizontal alignment than the vertical alignment. If single occurrence of accident count at the geometric alignment

position the horizontal alignment undertake 376 which is from (172+204) accident occur than the vertical alignment 364 which is from (179+185) refer Table 22.

Table 8: Accident Percentage Description

Type of Accident	Percentage of total number of accident on Vertical Alignment		Percentage of total number of accident on Horizontal Alignment		Total accident
	sag	crest	Curve	tangent	
Animal Accident	47.3%	49.9%	57.1%	49.4%	543
Person Accident	47.8%	47.8%	43.5%	52.2%	23
Vehicle Accident	50.0%	50.0%	50.0%	50.0%	6
		97.2027972		105.9440559	572

Concerning to the above Table 8, Percentage of total number of animal accident on crest is 49.9% and 47.3% accident occur at sag of Vertical Alignment but in case of the Horizontal alignment 57.1% animal accident occur at curve and 49.4% occur at tangent line. For person accident 47.8% occur for both type of vertical alignment and 43.5% at curve and 52.2% at the tangent line of the horizontal alignment but for the case of vehicle train accident 50.0% occur for both vertical and horizontal alignment. At all the total number of accident on Horizontal Alignment is greater than the accident that occurred in Vertical alignment.

4.1.5.2. Geometric Design and Accident location Analysis Result

Most of the geometric design horizontal and vertical measurements are taken from the secondary drawing data but the vertical drawing do not have much more information so using the horizontal geometric design data find out which has more impact with relation to the accident safety issues.

Table 9: Accident data at curve

Total Accident	At curve (Radius)
91	800
1	1000
71	1200
39	1600
9	2000
1	2200
1	2500
4	2800
13	3000
4	3300
17	3500
6	4000
4	4500
16	5000

1, Result for accident and curve geometric design relationship

Table 10: Correlation between accident and curve

Correlations			
		Total Accident	At curve (Radius)
Total Accident	Pearson Correlation	1	-.528*
	Sig. (2-tailed)		.052
	N	14	14
At curve (Radius)	Pearson Correlation	-.528	1
	Sig. (2-tailed)	.052	
	N	14	14

As indicated from Table 1010, there is no correlation between accident and curve of the railway line, because p=0.052 which is more than 0.05.

Table 11: Model description

Model Name		MOD_4
Dependent Variable	1	Total Accident
Equation	1	Quadratic
Independent Variable		At curve (Radius)
Constant		Included
Variable Whose Values Label Observations in Plots		Unspecified
Tolerance for Entering Terms in Equations		.0001

From Table 11, the model description table shows that number of total accident is the dependent variable and curve of the radius is the independent variable with the quadratic equation.

Table 12: Model summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.709	.502	.412	21.527

The independent variable is at the curve (Radius).

As indicated in Table 12, the R-square value is 0.502 which shows that the independent variable caused 50.2% change in the number of accident in the dependent variable.

Table 13: ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	5146.732	2	2573.366	5.553	.022
Residual	5097.625	11	463.420		
Total	10244.357	13			

The independent variable is at the curve (Radius).

In Table 1313, the ANOVA result shows that the relationship between independent and dependent variables are significant because p=0.022 is less than 0.05, hence there is a significant relationship between accident and curve.

Table 14: Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
At curve (Radius)	-.057	.021	-2.652	-2.709	.020
At curve (Radius) ** 2	8.162E-6	.000	2.176	2.223	.048
(Constant)	101.414	26.722		3.795	.003

Table 1414, shows the coefficient results, as indicated the beta value have a negative and positive value, which means that the positive change in the independent variable by one unit can have a negative and positive value that will bring about the change in the dependent variable by -2.719 and 2.192 respectively.

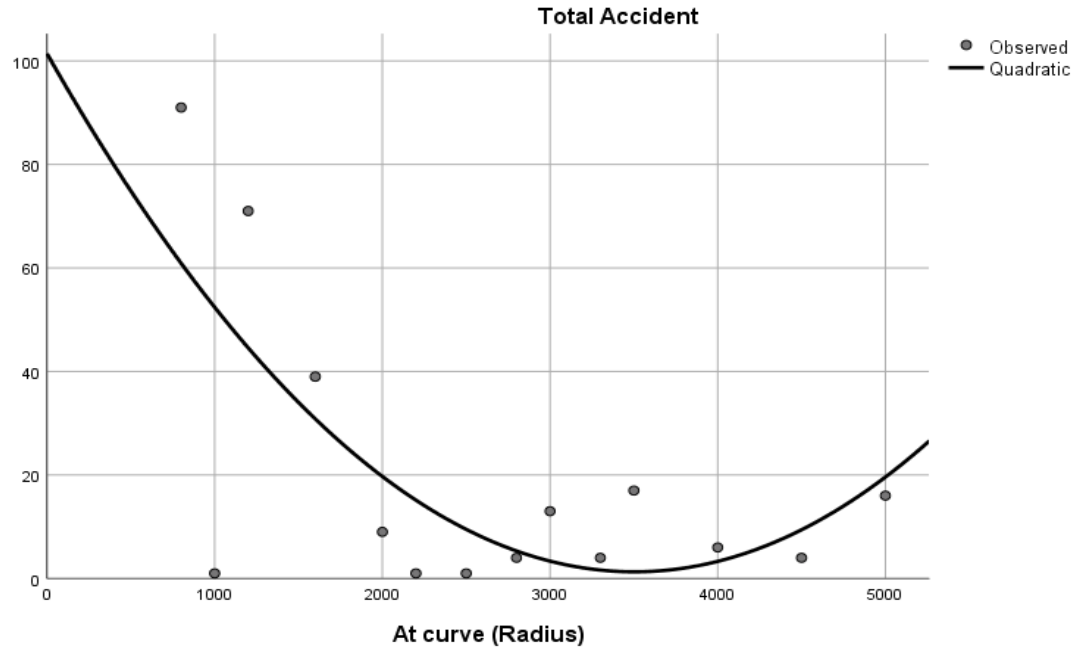


Figure 15: Quadratic graph for accident at a curve

Quadratic Regression

One of the horizontal geometrical designs of the curve was tested to find out the relationship with the accident number. There are three ways to check the analysis method one is the standard error, the scatter plot, and the R^2 value so based on this the Quadratic regression expressed better rather than the other types of nonlinear regression. From the coefficient table, the first row b1 is radius for the linear part and the second row b2 is for the quadratic effect in radius, both are significant.

Interpretation

Equation 1 Quadratic equation for the accident at a curve

$Y = b0 + b1x1 + b2x1^2$…… equation 1

Where b0 = intercept (the value of Y when x1 is 0)

b1 = regression coefficient for the linear effect of X on Y

b2 = regression coefficient for quadratic effect on Y

$$Y = \text{constant} + b1\ (\text{Radius}) + b2\ (\text{Radius})^2$$

$$Y\hat{} = 101.414 - 0.57\ X_1 + 8.162E\text{-}6\ X_1^2$$

The b1 is linear and b2 is quadratic, meaning curvilinear with one bend. The value of b1 represents the downward linear trend in the value of Y along the x-axis and the value of b2 represent the curvature in the data. The effect of radius and radius^2 are significant. The quadratic term (Radius^2) are positive implying that the total number of accident increase over the radius and about 50.2% of the variation in several accidents explained by the model. (See Table 12)

2, Results for accident and tangent-line geometric design relationship

Table 15: Correlation between accidents with tangent line

Correlations			
		Total Accident	At tangent (m)
Total Accident	Pearson Correlation	1	.539**
	Sig. (2-tailed)		.000
	N	100	100
At tangent (m)	Pearson Correlation	.539**	1
	Sig. (2-tailed)	.000	
	N	100	100
**. Correlation is significant at the 0.01 level (2-tailed).			

As indicated from Table 15, there is a positive significant correlation between accident and tangent of the railway line, where p=0.000 which is less than 0.01.

Table 16: Model description

Model Description		
Model Name		MOD_1
Dependent Variable	1	Total Accident
Equation	1	Exponential[a]
Independent Variable		At tangent (m)
Constant		Included
Variable Whose Values Label Observations in Plots		Unspecified
a. The model requires all non-missing values to be positive.		

From Table 16, the number of total accidents is the dependent variable and the tangent line of the railway is the independent variable with the Exponential equation.

Table 17: Model summery

R	R Square	Adjusted R Square	Std. Error of the Estimate
.294	.087	.077	.906

As indicated in Table 17, the R-square value is 0.087, which shows that the independent variable caused 8.7% change for the number of accidents in the dependent variable.

Table 18: ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	7.407	1	7.407	9.018	.003
Residual	78.023	95	.821		
Total	85.429	96			

In Table 18, the ANOVA result shows that the relationship between the independent and dependent variable is significant because p=0.003 is less than 0.05, hence there is a significant relationship between the accident and tangent line.

Table 19: Coefficient

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
At tangent (m)	7.793E-5	.000	.294	3.003	.003
(Constant)	1.718	.201		8.565	.000

The dependent variable is ln (Total Accident).

Table 19, shows the coefficient results, as indicated the beta value is positive which means that the positive change in the independent variable tangent line by one unit will bring about the change in the dependent variable accident by 0.294.

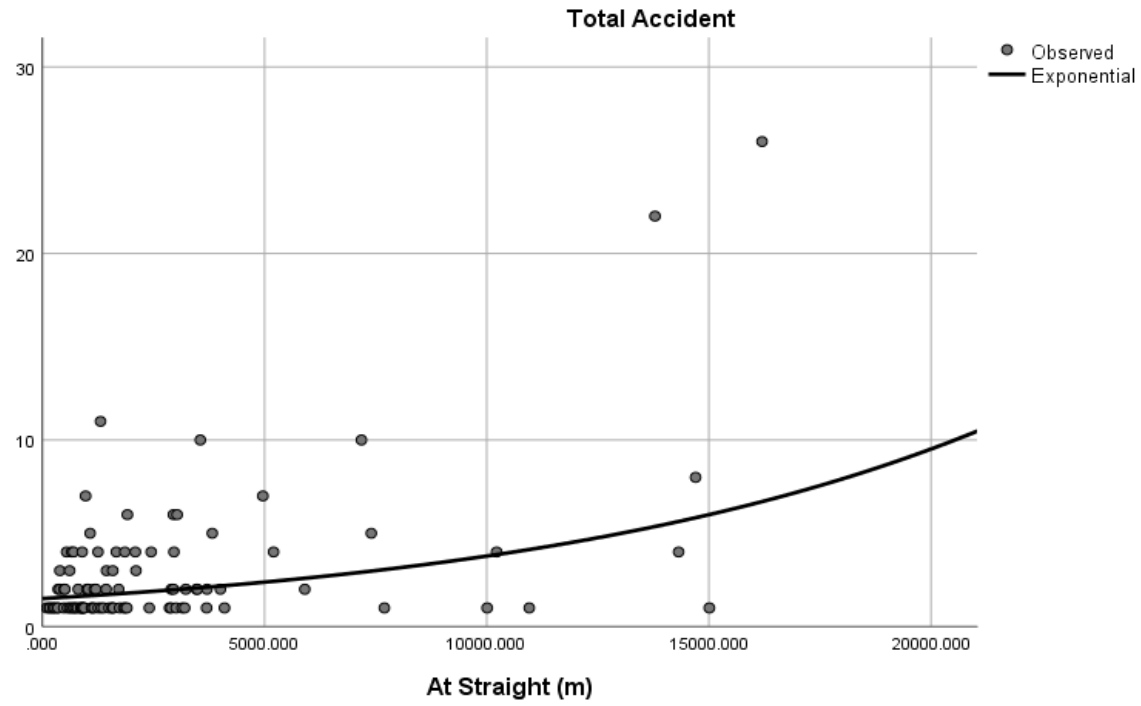


Figure 16: Total accident at a tangent line

Exponential Regression

Here three ways to check the analysis method are the standard error, the scatter plot, and the R^2 value so based on this the Exponential regression expressed better rather than the other types of nonlinear regression method. From the co-relation, there is a positive relationship between the accident and tangent line of the horizontal geometric design but R^2 value describe less percentage and on the regression, the constant and the exponent term both are significant where (P< 0.05, which is 0.003 and 0.000).

Equation 2: Exponential equation for accident at tangent

$Y= ab^x$ where a = the constant term 1.718

b = 7.793E-5

As it has a positive co-relation the number of accident increase when the long tangent line of the horizontal geometric design increase. About 8.7% of the variation in the total number of accidents is explained by the model this was due to the smallest sample size of the original data. But from the graph it's clearly seen that the scattered plot is not clearly covered by the Exponential equation graph.

$$\mathbf{Y = ab^{x} = 1.718(7.793E\text{-}5)^{x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots equation\ 2}$$

Overall the curve and tangent line of the railway section with the total number of accident data in the location do not have a relationship and they are not describing the relationship between accident and the geometrical alignment of curve and tangent line of the railway line. Similarly as seen from the graph the number of accident are scattered and didn't touch the line and they didn't have a uniform relationship with the section even if both are significant.

4.1.6. Land use Analysis Result from QGIS Based on the Accident location

The major safety problem causes hazard on life of animals or persons. The Ethio- Djibouti railway had a total of 572 accident for the past three ad half years. This accidents are take place in different location so that based on the accident type and mileage the X-Y coordinate of the place was extracted from google earth to assess the location and to relate with their corresponding land use type. Based on that, the following fig show which area was experiences major accidents due to safety problem issues are analyzed through QGIS version 3.26 Heat map.

The type of accidents are animal death, persons death and vehicle-train collision.

- ✓ Due to the Livestock-Train Collision a total of 543 animals lost
- ✓ Due to the Trespassing act of a person 23 people's life lost and
- ✓ Due to Vehicle collisions 3 times the train collided with a vehicle and 3 times the property of the railway was damaged by a vehicle intruding into the railway property.

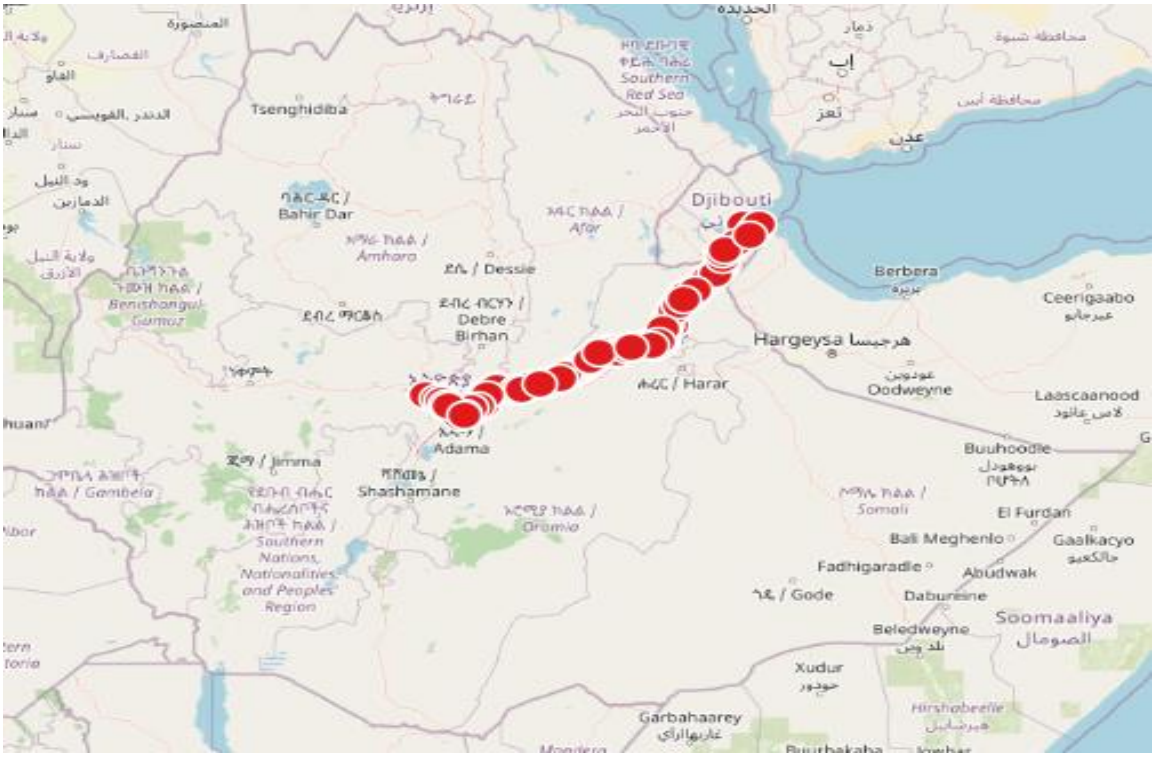


Figure 17: Total Accident area of Ethio-Djibouti railway

As indicated from the fig 17, shows the total accident along the route of the Ethio-Djibouti railway line starting from the start up to the end. Which indicate that accident can occur at any place along the route. To identify which accident occur the most in a particular area, below the individual accident with their corresponding location is shown.

Major Accident Area for Animal Train Collision

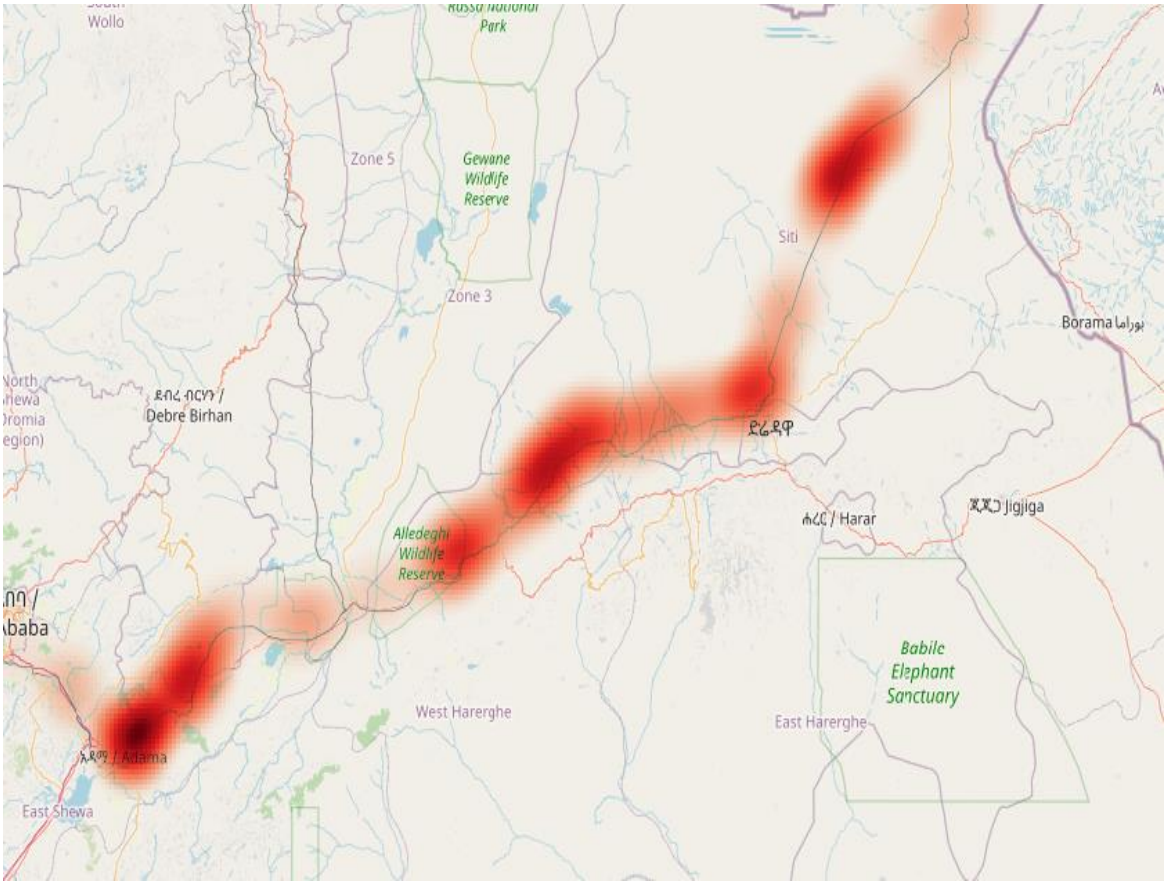


Figure 18: Adama is the major animal accident location

From the map render color (see Figure 18) 3 place are detected but the location of the major animal accident location is Adama rather than the other Afdem and Shinele area but all three areas have similar horizontal geometrical designs because the accident occurs on the curve sections.

Major Accident Area for Trespassing (Personal Accident)

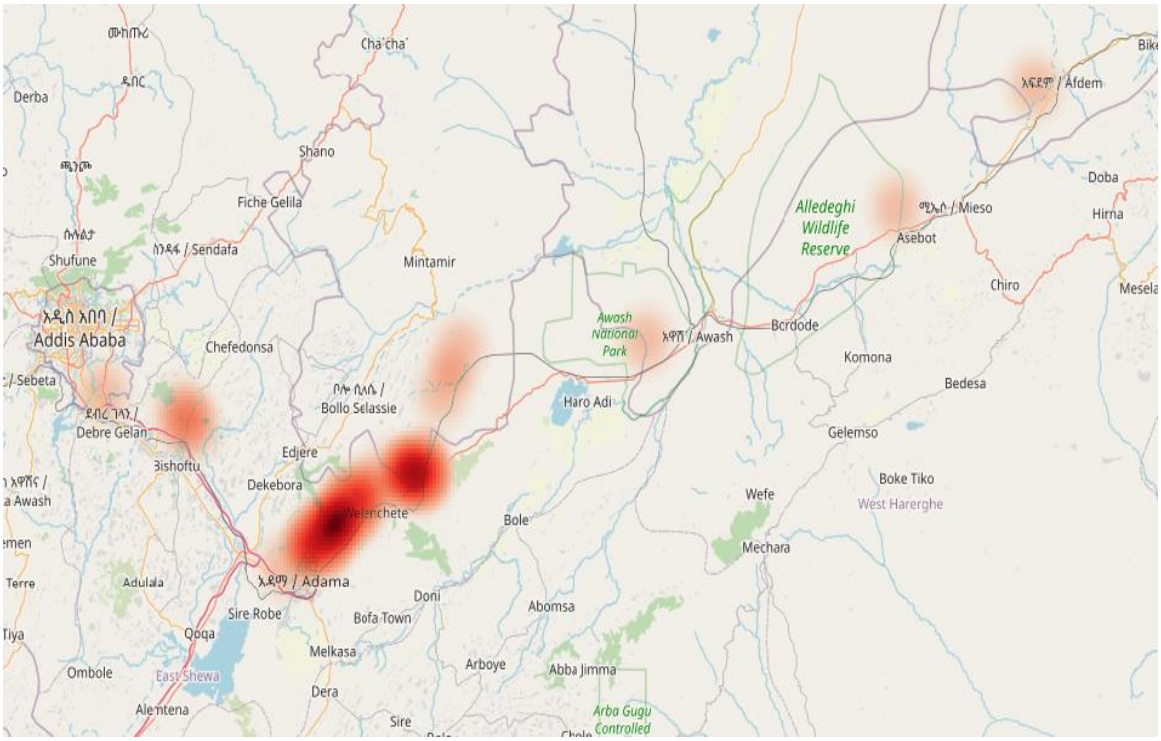


Figure 19: Adama frequent location for person accident

Land use condition at Adama area

From the company document the Ethio- Djibouti railway 113.7 km length of the track is a double track from Sebeta to Adama and the rest 638 km are single track. So the land use situation of Adama area have a double track rail line so the traffic flow of the train increase in both direction. In addition to that this location is the place where the train leave the city and entering in to farm land bisected by the railway line. This condition characterize the location to have congestion living area. The surrounding living area of school, hospital, social institution and other necessary location also bisected by the railway line. This initiate the people to travel from one section to the other and this trespassing activity increase person death in the location. For this reason many of the fencing structure are demolished by people to use shorter path. In addition to that there is a high movement of animals also take place to use their bisected farm land from one side to the other and they use shorter direction to pass the railway property illegally. Due to this reason major animal and person accident are occurred in the Adama region. (See fig 18 & 19)

Major Accident Area for Vehicle Train collision

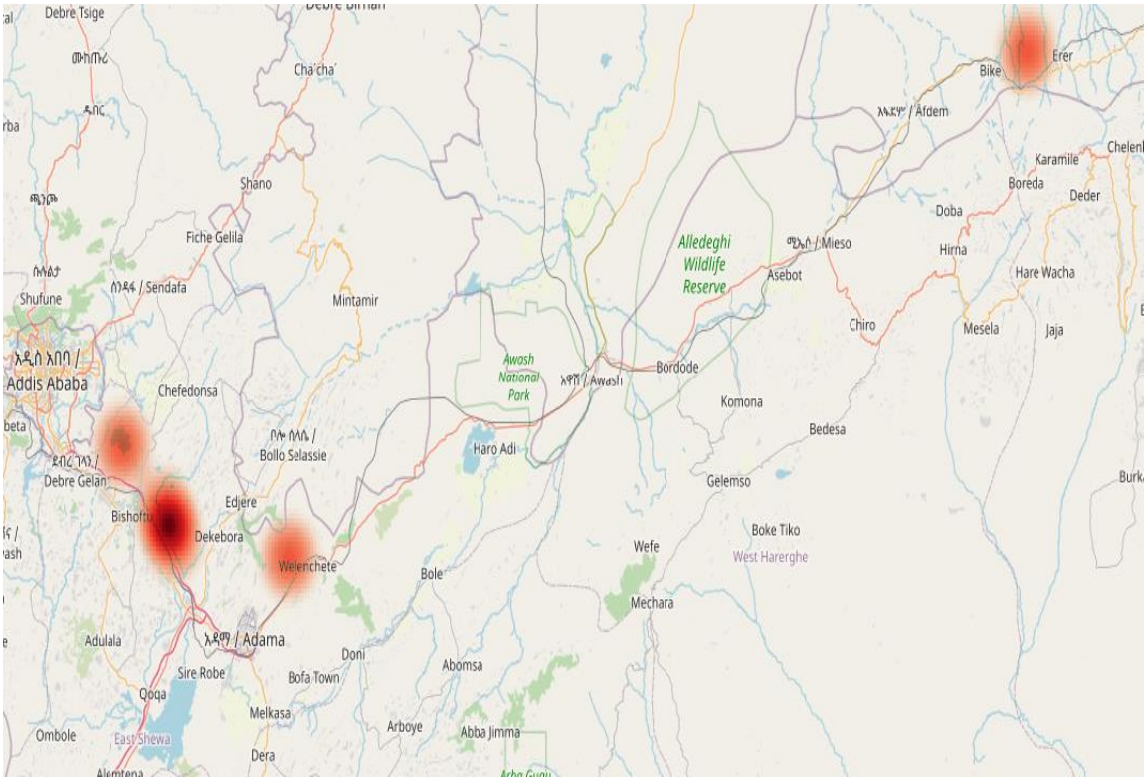


Figure 20: Bishoftu major location for vehicle train accident

Land use condition at Bishoftu area

As indicated in Figure 1720, major vehicle train collision accident occur at Bishoftu area. As seen from the company document Bishoftu area also have a double track railway line because this location is between Sebeta and Adama region. This condition exposed the area to have high traffic flow of train in both direction. In addition to that the level crossing are located between two large sub cities of Bishoftu so there is high flow of vehicle pass through the level crossing and this level crossing do not have any railway barrier or alarm system to notice the driver to stope on their section before entering in to the railway property. Similarly vehicle driver are ignoring the coming train sound and try to pass the crossing even if they are aware of there was an upcoming train on the line. This behavior of drivers also increase the vehicle train collision on the area.

4.1.7. FTA Result for Operation Failure

The Other type of safety issue is delay (see Figure 5, E up to H) and cause operation failure due to reasons listed below (see Table 20) as obtained from the secondary data. Those safety issues are listed in the table and the frequency of the delay in hours per year collected from the secondary data and its listed in the table.

Table 20: Reasons for Operation failure

Failure types	Frequency in (hr./year)
Trespassing	
Animal accident	66.99
Person accident	23.53
Manmade stop to avoid animal accidents	70.36
Vandalism	48.87
Robbery	8.40
Vehicle collision	31.87
Technical fault	
Electrical fault	193.10
Mechanical fault	52.92
Civil fault	3.23
War and conflict	6.57
Natural disaster	7.00
Weather condition	1.28
Train blocking	113.91
Total Delay	628.03

4.1.6.1. FTA Figure Description

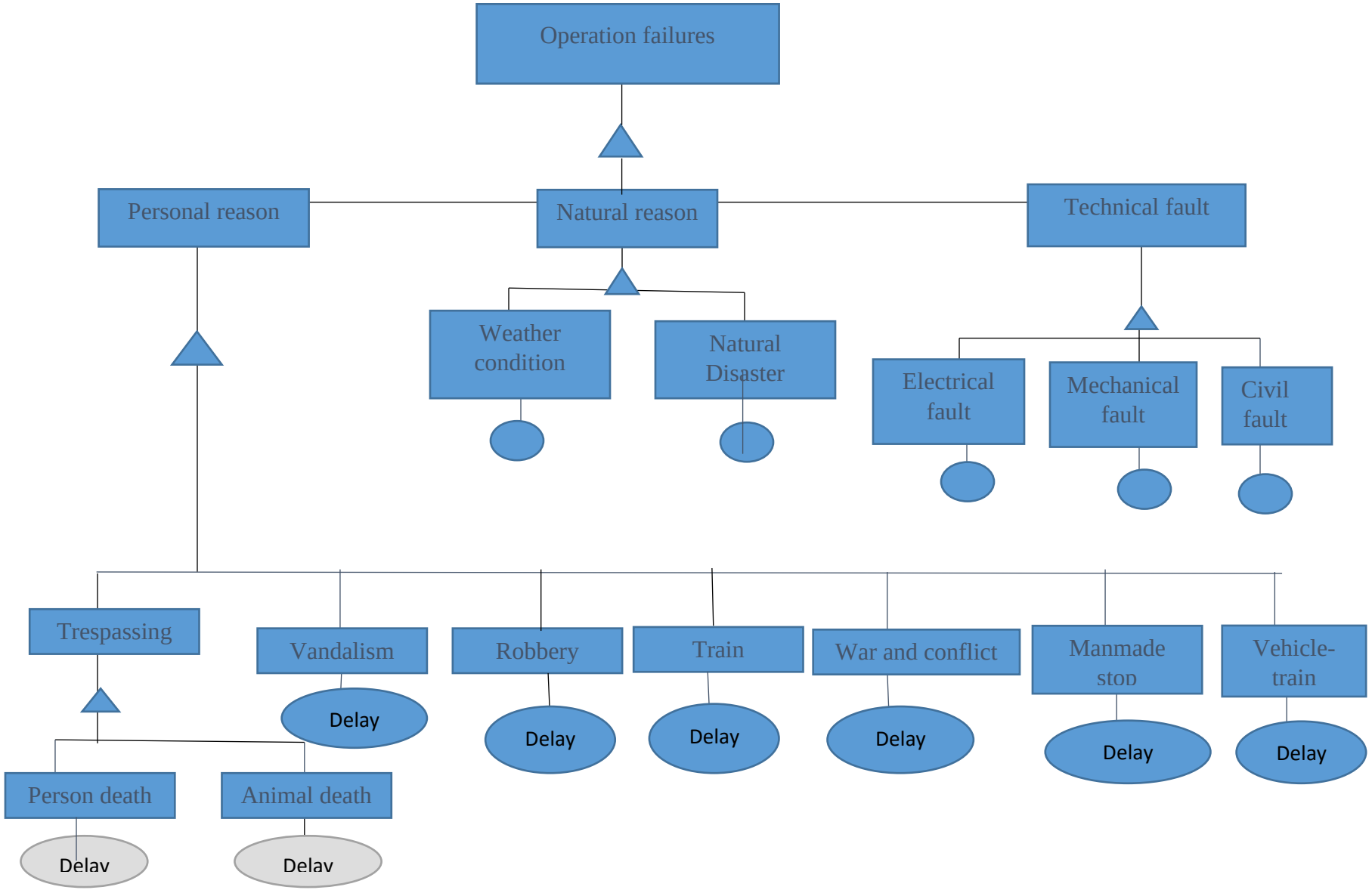


Figure 21: FTA flow

Based on the FTA diagram the logic gate connection was done by the OR gate  which uses summation.

Total Operation Failure Frequency Evaluation

1, Frequency of trespassing act = F person death + F animal death

= (23.53+66.99) hr. /year = 90.52 hr. /year

2, Frequency of Personal issues = F trespassing + F vandalism + F robbery + F train blocking + F war and conflict + F vehicle-train collision + F man-made stop

= (90.52 + 48.87 +8.40 + 113.91 + 6.57 + 31.87 +70.36) hr. /year= 370.5 hr. /year

3, Frequency of Natural reason = F weather condition + F natural disaster

= (7.0+ 1.28) hr. /year= 8.28 hr. /year

4, Frequency of Technical issues = F electrical fault + F mechanical fault + F civil fault

= (193.10 + 52.92 + 3.23) hr. /year = 249.25 hr. /year

5, Frequency of Operation failure = $F_{\text{personal reason}} + F_{\text{natural reason}} + F_{\text{technical reason}}$

= (370.5 + 8.28 + 249.25) hr. /year = 628.03 hr. /year

From the frequency evaluation, more of the operation failure was coming from personal reasons or faults of safety problem, which are 370.5 hr. /year. Correspondingly, the main contribution for the highest value of person issues of safety problem was coming from train blocking. Which is the activity of the local people trying to block the passing train.

4.2.Discussion

This thesis study demonstrates that various types of safety issues (like vandalism, robbery, trespassing, geometric designs, infrastructures, war, natural disasters, weather conditions, and technical or operational faults) can be a reason for accidents. Major safety issues that lead to animal accidents, personal accidents, and vehicle accidents are identified with their location along the Ethio-Djibouti railway.

Based on the questionnaire respondent most of the safety issues problems are available and respondents agree. Those problems are passengers' activity, trespassing act, weather conditions, natural disasters, geometric alignment, infrastructures problem, war and conflict, and technical faults but from the result, the major problems are vandalism and robbery because 24 respondents are strongly agree as compared to the others safety issues that caused by personal reasons, in addition (Table 21: 2019-2021 Checklist Safety problems in the Ethio - Djibouti Railway) from the annex's , vandalism and robbery together recorded 614 times for 32 months between in the year of 2019 and 2022 G.C. Similarly from the total trespassing accident and vehicle-train collision accident 572 accidents are recorded and as it was analyzed by Weibull model the probability of the accident for future prediction also increases continuously. From the Weibull model total number of accident increase with the cumulative distribution and accident can happen at any place as seen from the QGIS heat map total accident coordinate location (see Figure 17, 18 and 19) and both animal and person major accident occurs at the curve section in Adama also Table 138, shows accidents at curve section have a significant effect. The other safety problem as describe by the FTA (Figure 21), which is a deductive reasoning, and 628.03 hr. /year delay occur and cause operation failure due to personal reasons, which is 370.5 hr. /year delay. From this 370.5 hr. /year, train blocking activity take 113.91 hr. /year delay (see Table 20). Which is the major illegal activity in the railway industry.

This thesis study provides new insight into the relationship between safety issues and accidents. It shows assessing safety issues are necessary to find out and identify the major problem that leads to accidents. While previous research has focused on a single issue (Wang, Li, and Han, 2020) only on the natural environment, (Jones and Jain, 2006) only on the infrastructures and also those discussed in the literature review but this studies

demonstrate all safety issues to find out the major problem on the railway line. This help to give priority to major safety problems to set countermeasure instantly. However based on the findings of similar studies, a more possible explanation is given by the Weibull model, FTA, and Heat map analysis used to find out major geological accident areas like (Rahman, 2012), (Debbech, Bon, and Collart-dutilleul, 2019) and (Bäckman, 2002), and (Wang, Li and Han, 2020) respectively.

In general, the small sample size of accident data and lack of description on the vertical Geometric design drawings res are failed to give a significant impact on safety problems. During the gathering of primary data type interview questions the passengers respond more on the Electrical, Mechanical, Information system, and Customer service of the safety problem that they face rather than the scope of the title, so it influences the analysis result of safety issues to raise and compile with their perspective.

The finest result from this thesis was the assumption and the news that the speed of the Ethio- Djibouti train is working below the design speed because of the animal accident is changed. This is due to animal accident being one of the safety problem but not the major safety problem that the company face because this case study identified that the major safety problems are raised due to personal activity like robbery, vandalism, and train blocking activities for personal reasons. Also as seen from the Weibull model safety issues increased as a reason for the CDF of total accidents not only by animal accidents because during analysis individual accidents fail to give significant effect. However, the total accident originated due to trespassing of animal accident, trespassing of personal accident, and vehicle-train collision accident. In general, this case study is better for further understanding safety problems in the railway industry. Even if known safety issues are available rather than pointing out one issue and state, assessing and developing a model for the different type of safety problem help to find out the major one. So as discussed above and see the different safety issues the Ethio-Djibouti railway is highly affected by personal faults.

CHAPTER FIFE

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As seen from the analysis results and discussion part most of the safety problems are occurred due to personal reasons. Person activity like trespassing, vandalism, robbery, train blocking, and collision-accident is the main reason for the safety problem of the Ethio-Djibouti railway line.

Different method were used to analyze the different types of safety problem to find out the major one. Multivariate regression was considered for the geometrical problem, even though the result didn't have any relation between the curve and tangent line of the line. The geometric alignment didn't show any effect on the safety issues. On the other hand the accident analysis prediction shows that the occurrence of accident increasing and affecting the safety issues (fig 14).

From the site observation the fencing infrastructure is built around the highly populated area and near the stations and as this railway covers 751.0 km the construction of the fencing structure is meaningless even if the questionnaire respondents 21 agree (see Table 3). This is because some of the constructed fencing structure is demolished to make a short pathway. This fencing structure has two types one built by steel and the other one built by concrete. The concrete fencing is precast and fixed on site so it's easily demolished and most of them are already stolen specially in Adama area because more of the fencing structure was constructed and high population people located on this area. As indicated from the land use analysis this region was the major place for animal and person death. This area is also a place where the railway line leaves the city and entering to farming land, so the railway infrastructure bisects communities social interaction area, farm land, school, hospital, shopping, and residential areas and other activity that initiate trespassing accidents and the need of people to take previous routes and initiate the people to demolish the fencing structure to take shortest path.

As seen from the background of the company this railway was constructed and is still run by the Chinese company, the local peoples consider the railway belongs to the Chinese people

and they also develop a habit of asking for compensation payment randomly and suddenly by blocking the railway line. Train blocking was the main reason for the operation failure or delay in the EDR. Sometimes they also put dead livestock animals to get compensation payment.

In general the key findings of this thesis result shows that the vandalism and robbery are the major safety issues which get strongly agreed by the questionnaire respondent and the major accident location, Adama for animal and person and Bishoftu for vehicle-train collision accident due to trespassing activity. Overall 17 people respond disagree for the general safety condition of the company, So to solve this some measure have to be taken by the company.

Overall the smallest and simplest faults in the railway can be a deathtrap for the life of a person and reason to damage railway property so this thesis combines and relate different analysis method which can be useful for any research to develop a solution by relating results and finding out the main problem. In addition, the society people who live beside the railway line safety increased, and accidents will be decreased

5.2. **Recommendation**

As this thesis is conducted on the operated railway company, the major findings ae helpful to set a possible measure before it leads to accident or major disasters safety problem on the railways. So the main countermeasures to be taken care of by the company EDR is creating awareness for all the surrounding area especially for the territory bisected by the train. The awareness help to notice the property is their own country infrastructure and used for city rail transportation from one station to another. Once people have awareness of all the robbery, vandalism, train blocking, and also trespassing activity that cause the major accident habits can be controlled because most of them are occurred due to personal bad behaviors.

Correspondingly a guideline based on law is needed to be followed by the company. This eliminate random crossing of the railway property line by person and animal. From the secondary source data, there is no fixed guideline for the measures to be applied to persons, who illegally act and make unallowable activity on the railway property. A person can be

responsible by the government if strict law of punishment is declared. For instance, train blocking is an internationally unallowable illegal act but as seen from table 20, 111 times train blocking was done over the past three and half year data result and cause a 113.91 hr. /year delay. So guidelines have to be set and implement accordingly. War and conflict between regions and asking for compensation payment for the dead animal was the reason for the train blocking. From both, the major reason was blocking the train way for compensation payment. This is due to no declared scale payment or payment guideline to follow by the company during accident time. See table 3, so the compensation payment is based on discussion and the people can block the train way at any time if they think the payment is small. These increases the delay hour of the operation time (see Figure 5, E up to H). In a general setting, a strict law guideline is one of a countermeasure used to increase safety by decreasing the cause of delay hour of a train in random places.

From the land use accident analysis, vehicle-train collision accidents occur at Bishoftu. As this place was spotted as the main accident location between the train and the vehicle. In this place the railway has a double track, so accidents can happen much more rather than the single track. In addition to that from onsite observation, this level crossing has some railway signs without having level crossing barriers, light and also alarm system. So as a countermeasure building level crossing barriers, which operated by railway staff. The railway staff has to be informed from the nearby station before the train arrives at the level crossing. This is because there is no displaying, noticing, or alarming system that shows or informs the location of the upcoming train at this location. So introducing some alarm systems avoid accidents by notice the car drivers before the train arrives.

In general, to enhance safety in the EDR, the three types of recommendation are suggested by this case study. Those are giving awareness, setting strict guidelines or law and building railway infrastructure level crossing barriers. In addition to that Ethio- Djibouti railway can apply the recommendation as a solution to limit the safety challenges and accident problems for developing safe conditions.

Other recommendation for further study which is not covered by this thesis such as

- Due to the small sample size of accident data some results of the geometric design fail to give satisfactory results so at least 5 years of accident data have to be taken for further studies.
- Some information data on the vertical geometric drawing are unavailable so this is the limitation of this thesis so future research has to look into it.
- The AC system- as Ethio- Djibouti railway is one of the electrified railway systems once the power is broken or some failure happens the AC system of the train switched off and as a low without the station, the train doors are not allowed to open because of that reason there is the high temperature inside the train especially in desert areas and face really hot climate condition inside and outside of the train for that matter children and elderly people are hard to breathe while traveling from Addis to Djibouti. So that as the railway is a combination of three mainstream that need side-by-side work the traction stream has to investigate it. (Source: interview questions).
- Customer services- Implementation of rules and regulations by the company because once they already have tickets and seat numbers the crowd and fight of the passengers at the door of the train injured children and elder people. (Source: interview questions).
- Information and technology- from the interviewer the train cancellation and delay of the train on the way challenge the safety of the passengers. As it's the first electrified railway in East Africa developing the information system has to be on some Platform to meet customer satisfaction.
- Alarm system- this has to be seen by the traction stream group to place on the track system before the level crossing in Bishoftu. To prevent vehicle-train collision accidents by giving sound systems for car drivers by noticing there is an upcoming train.

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ANNEX'S A

Table 21: 2019-2021 Checklist Safety problems in the Ethio - Djibouti Railway

Months	Animal accident	Personal accident	Vandalism	Robbery	Vehicle train collision	Technical fault	War and conflict	Natural disaster	Weather condition	Train blocking	Delay (hr)
January	98	5	29	30	0	35	0	0	2	9	191.77
February	91	3	36	37	1	38	2	0	0	21	267.63
March	65	7	34	53	2	29	2	0	1	17	178.53
April	40	1	18	55	1	43	0	0	0	6	45.92
May	46	1	21	33	0	24	0	0	0	4	111.18
June	30	0	16	7	0	5	0	0	0	1	37.23
July	43	1	14	24	1	9	0	2	1	13	197
August	23	3	14	46	1	25	0	0	1	14	85.43
September	20	1	11	34	0	34	1	0	0	10	140.02
October	29	1	13	24	0	28	0	3	0	10	268.78
November	33	0	13	20	0	32	0	0	0	4	134.55
December	25	0	11	21	0	13	2	0	0	2	18.78
Total	543	23	230	384	6	315	7	5	5	111	1676.82

Table 22: Geometric alignment type for accidents

					Vertical Alignments		Horizontal Alignments	
	Mileage	Animal death	Person death	Vehicle collision	Sag	Crest	Curve	Tangent
1	410km+000m	1			0	1	0	1
2	130km+200m	1			0	0	1	0
3	448km+300m	1			0	1	1	0
4	411km+939m	1			1	0	1	0
5	277km+078m	1			0	1	1	0
6	203km+048m	1			1	0	1	0
7	245km+929m	1			1	0	1	0
8	203km+113m	1			1	0	1	0
9	144km+795m	1			0	1	1	0
10	639km+574m	1			1	0	1	0
11	103km+880m	2			0	1	1	0
12	403km+100m	1			0	1	0	1
13	530km+338m	1			0	1	0	1
14	346km+651m	6			1	0	1	0
15	411km+515m	1			0	1	0	1
16	353km+954m	2			0	1	1	0
17	39km+954m			1	0	1	0	1
18	326km+311m	2			0	1	0	1
19	464km+700m	1			1	0	1	0
20	308km+097m	1			0	1	0	1
21	403km+036m	1			0	1	0	1
22	393km+300m	1			0	0	1	0
23	215km+536m	1			0	1	0	1
24	409km+606m	2			0	1	0	1
25	744km+793m			1	1	0	0	1
26	59km+850m	2			1	0	0	1
27	504km+080m	1			1	0	0	1
28	204km+669m	1			1	0	0	1
29	471km+433m	1			1	0	1	0
30	345km+000m	1			0	1	1	0
31	119km+600m	2			1	0	1	0
32	339km+550m	5			0	0	1	0
33	280km+900m	1			1	0	1	0
34	302km+633m	1			1	0	0	1
35	462km+576m	1			0	1	1	0
36	296km+200m	1			1	0	0	1

37	306km+926m	3			1	0	1	0
38	538km+880m	2			1	0	0	1
39	353km+113m	3			0	1	0	1
40	247km+000m	1			0	1	0	1
41	639km+586m	1			1	0	1	0
42	457km+608m	1			0	0	0	1
43	335km+500m	1			0	1	0	1
44	60km+100m	1			1	0	0	1
45	182km+607m	1			1	0	1	0
46	448km+116m	2			0	1	0	1
47	282km+000m	1			1	0	1	0
48	222km+600m	1			1	0	1	0
49	658km+442m	1			1	0	1	0
50	504km+385m	1			1	0	0	1
51	334km+900m	2			0	1	1	0
52	526km+981m	2			1	0	0	1
53	94km+050m	0	1		1	0	1	0
54	60km+650m	1			1	0	0	1
55	281km+300m	2			1	0	1	0
56	334km+900m	1			0	1	0	1
57	61km+100m	1			1	0	0	1
58	455km+862m	1			0	1	1	0
59	54km+222m	1			1	0	0	1
60	358km+317m	1			1	0	1	0
61	282km+044m	1			1	0	1	0
62	254km+038m	1			1	0	0	1
63	459km+600m	1			0	1	0	1
64	315km+907m	3			0	1	1	0
65	247km+000m	1			0	1	0	1
66	314km+100m	1			0	1	0	1
67	292km+549m	1			1	0	1	0
68	139km+907m	2			0	1	1	0
69	364km+752m	1			1	0	1	0
70	532km+755m	1			1	0	0	1
71	475km+210m	1			1	0	0	1
72	279km+305m	1			0	1	0	1
73	406km+413m	1			0	1	1	0
74	448km+825m	1			1	0	1	0
75	483km+837m	1			1	0	0	1
76	455km+941m	0	1		0	1	1	0
77	304km+998m	1			1	0	1	0

78	483km+387m	1			1	0	0	1
79	448km+273m	1			0	1	1	0
80	375km+551m	1			0	1	1	0
81	532km+400m	3			1	0	0	1
82	120km+438m	0	1		1	0	0	1
83	403km+100m	1			0	1	0	1
84	308km+461m	1			0	1	0	1
85	131km+020m	1			1	0	1	0
86	151km+800m	7			1	0	0	1
87	401km+806m	2			0	1	1	0
88	370km+741m	1			1	0	1	0
89	104km+150m	1			0	1	1	0
90	289km+200m	1			1	0	1	0
91	215km+536m	1			0	1	0	1
92	365km+623m	1			0	1	1	0
93	420km+800m	1			0	1	0	1
94	529km+846m	1			1	0	0	1
95	107km+300m		1		1	0	1	0
96	154km+500m	2			1	0	0	1
97	629km+345m	3			1	0	0	1
98	116km+458m	1			0	1	0	1
99	228km+048m		1		1	0	0	1
100	29km+478m	1			1	0	1	0
101	252km+902m	6			1	0	1	0
102	356km+405m	10			0	1	1	0
103	616km+152m	3			0	1	0	1
104	102km+0658m	3			1	0	0	1
105	228km+048m	4			1	0	0	1
106	98km+527m	4	3		1	0	1	0
107	103km+495m	1	1		0	1	1	0
108	717km+214m	1			1	0	0	1
109	97km+798m	1			1	0	1	0
110	653km+837m	2			0	1	1	0
111	710km+345m	1			1	0	0	1
112	101km+425m	1			1	0	1	0
113	384km+296m	4			1	0	1	0
114	81km+932m	1			0	1	0	1
115	574km+342m	3			0	1	0	1
116	542km+552m	18			0	1	1	0
117	289km+700m	1			1	0	0	1
118	277km+751m	1			0	1	1	0

119	635km+381m	1			0	1	1	0
120	112km+630m	0		1	0	1	1	0
121	366km+576m	1			0	1	1	0
122	344km+452m	1			0	1	1	0
123	395km+940m	1			1	0	1	0
124	648km+729	1			1	0	0	1
125	130km+550m		1		0	1	1	0
126	62km+500m	1			1	0	0	1
127	374km+750m	1			1	0	1	0
128	112km+630m	1			0	1	0	1
129	180km+616m	1			0	1	1	0
130	328km+800m	1			1	0	0	1
131	309km+330m	1			0	1	1	0
132	328km+996m	1			1	0	0	1
133	115km+700m		1		0	1	0	1
134	397km+290m			1	1	0	1	0
135	103km+851m	1			0	1	1	0
136	484km+998m	1			1	0	0	1
137	404km+670m	1			1	0	1	0
138	174km+735m	1			0	1	1	0
139	410km+772m	1			1	0	0	1
140	30km+563m	1			0	0	1	0
141	560km+550m	3			0	1	0	1
142	352km+940m	1			0	1	1	0
143	383km+980m	1			1	0	1	0
144	23km+812m	1			1	0	0	1
145	65km+100m	2			1	0	1	0
146	157km+600m	2			1	0	1	0
147	348km+98m	1			1	0	0	1
148	315km+750m	1			0	1	1	0
149	225km+715m	1			1	0	0	1
150	157km+407m	1			0	1	1	0
151	645km+722m	1			0	1	0	1
152	159km+911m	1			1	0	1	0
153	451km+590m	1			0	1	0	1
154	431km+120m	1			1	0	0	1
155	382km+965m	1			1	0	1	0
156	203km+508m	3			1	0	0	1
157	361km+500m	2			1	0	0	1
158	284km+300m	1			0	1	0	1
159	426km+500m	1			1	0	0	1

160	294km+455m	2			1	0	1	0
161	204km+018m	1			1	0	0	1
162	381km+912m	1			1	0	0	1
163	334km+800m	1			0	1	0	1
164	361km+500m	2			0	1	0	1
165	284km+300m	1			0	1	0	1
166	426km+500m	1			1	0	0	1
167	294km+455m	2			1	0	0	1
168	204km+018m	1			1	0	0	1
169	381km+912m	1			1	0	1	0
170	334km+800m	1			0	1	0	1
171	558km+503m	1			0	1	0	1
172	61km+193m	1			0	0	0	1
173	402km+916m	1			0	1	0	1
174	532km+939m	1			0	1	0	1
175	223km+988m	1			0	0	0	1
176	418km+748m	1			0	1	0	1
177	526km+538m	1			1	0	0	1
178	447km+143m	1			0	1	0	1
179	349km+300m	1			1	0	1	0
180	256km+727m	1			0	1	0	1
181	190km+537m	1			0	1	1	0
182	489km+907m	1			1	0	1	0
183	569km+802m	1			0	1	0	1
184	533km+153m	1			1	0	0	1
185	108km+749m	1			1	0	0	1
186	448km+000m	1			0	1	0	1
187	302km+519m	1			0	1	1	0
188	538km+937m	2			1	0	0	1
189	385km+471m	3			1	0	1	0
190	345km+663m	1			0	1	0	1
191	140km+129m	1			0	1	1	0
192	210km+724m	1			0	0	0	1
193	378km+076m	1			0	1	1	0
194	365km+960m	1			0	1	0	1
195	572km+525m	1			0	1	0	1
196	524km+300 m	1			0	1	0	1
197	326km+035m	1			0	1	0	1
198	46km+700m		1		0	1	1	0
199	126km+817m	1			1	0	0	1
200	357km+762m	1			0	1	1	0

201	445km+250m	1			1	0	0	1
202	116km+811m	2			0	1	0	1
203	163km+632m	1			1	0	0	1
204	366km+065m	2			0	1	0	1
205	439km+500m	2			1	0	1	0
206	184km+882m	1			1	0	1	0
207	390km+360m	1			0	1	0	1
208	657km+199m	1			0	1	1	0
209	116km+756m		1		0	1	0	1
210	368km+674m	3			1	0	1	0
211	242km+460m	1			1	0	0	1
212	144km+721m	1			0	1	0	1
213	315km+800m	1			0	1	1	0
214	329km+804m	2			0	1	0	1
215	158km+040m	1			1	0	1	0
216	448km+157m	1			0	0	0	1
217	530km+191m	1			1	0	0	1
218	130km+978m	2			0	1	1	0
219	153km+682m	1			1	0	0	1
220	267km+565m	1			0	1	1	0
221	369km+491m	1			0	0	1	0
222	107km+855m	1			1	0	1	0
223	291km+003m	1			1	0	1	0
224	361km+134m	1			0	1	0	1
225	25km+996m	1			1	0	1	0
226	425km+746m	1			0	1	0	1
227	425km+971m	2			1	0	0	1
228	458km+067m	1			0	1	0	1
229	206km+379m	1			0	1	0	1
230	24km+787 m		1		1	0	1	0
231	425km+971m	2			1	0	0	1
232	458km+067m	1			0	1	0	1
233	425km+746m	1			0	1	0	1
234	289km+067m	3			1	0	0	1
235	25km+162m	1			1	0	1	0
236	361km+134m	1			0	1	0	1
237	25km+996m	1			1	0	1	0
238	174km+700m	1			0	1	1	0
239	355km+946m	1			0	1	1	0
240	447km+636m	1			0	1	1	0
241	477km+746m	2			0	1	0	1

242	352km+719m	1			0	1	0	1
243	131km+043m	1			0	1	1	0
244	291km+569m	3			1	0	1	0
245	156km+967m		1		0	1	1	0
246	441km+900m	1			1	0	1	0
247	369km+100m	1			1	0	1	0
248	390km+600m	1			0	1	0	1
249	447km+300m	1			0	1	1	0
250	569km+591m	15			1	0	0	1
251	486km+719m	1			1	0	0	1
252	365km+150m	1			1	0	0	1
253	723km+749m	2			1	0	0	1
254	362km+054m	1			1	0	0	1
255	590km+600m	2			0	1	0	1
256	429km+688m	1			1	0	1	0
257	126km+509m	2			1	0	0	1
258	530km+997m	1			1	0	0	1
259	146km+733m	1			0	1	0	1
260	150km+454m	1			0	1	0	1
261	123km+827m	2			0	1	0	1
262	157km+600m	1			0	1	1	0
263	345km+600m	1			1	0	1	0
264	550km+325m	2			1	0	0	1
265	533km+382m	1			0	1	0	1
266	106km+825 m	13			0	1	1	0
267	438km+838m	2			0	1	0	1
268	375km+053m	2			1	0	1	0
269	448km+350m	1			0	1	1	0
270	279km+158m	2			0	1	0	1
271	182km+075m	1			0	1	0	1
272	479km+600m	2			1	0	0	1
273	533km+089m	1			1	0	0	1
274	554km+614m	2			1	0	0	1
275	227km+257m	1			0	1	1	0
276	70km+025m	1			0	1	1	0
277	375km+053m	2			1	0	1	0
278	448km+350m	1			0	1	1	0
279	409km+727m	1			0	1	0	1
280	490km+612m	2			1	0	1	0
281	307km+400m	1			0	1	0	1
282	597km+519m	2			0	1	0	1

283	129km+688m	1			0	1	1	0
284	681km+419m		1		0	1	0	1
285	604km+013m		1		1	0	0	1
286	562km+240m	4			0	1	0	1
287	105km+242m	1			0	1	1	0
288	437km+200m	1			1	0	1	0
289	148km+825m	1			0	1	1	0
290	330km+611 m	1			1	0	0	1
291	526km+950m	1			1	0	0	1
292	108km+100m		1		1	0	0	1
293	366km+571m	1			0	1	1	0
294	54km+719m	1			1	0	0	1
295	105km+059m	1			0	1	1	0
296	656km+697m	1			0	1	0	1
297	408km+439m	1			1	0	1	0
298	107km+820m		1		1	0	0	1
299	552km+493m	1			1	0	0	1
300	612km+546m	1			0	1	0	1
301	399km+289m	1			1	0	1	0
302	529km+424m	1			1	0	0	1
303	148km+550m	3			1	0	1	0
304	490km+250m	1			1	0	1	0
305	296km+493m	1			0	1	0	1
306	117km+299m	1			0	1	0	1
307	63km+462m	1			0	1	1	0
308	128km+539m	5			0	1	1	0
309	619km+415m	4			1	0	1	0
310	95km+751m	3			0	1	1	0
311	533km+200m	1			1	0	0	1
312	611km+850m	3			1	0	0	1
313	641km+173m	1			0	1	1	0
314	279km+745m	1			0	1	1	0
315	561km+400m	1			1	0	0	1
316	434km+267m	2			1	0	0	1
317	472km+401m	1			0	1	0	1
318	153km+644m	1			0	1	0	1
319	160km+959m	1			0	1	1	0
320	97km+382m	1			0	1	1	0
321	569km+149m	1			1	0	0	1
322	276km+600m	1			0	1	1	0
323	178km+134m	1			0	1	0	1

324	318km+285m	1			0	1	1	0
325	516km+700 m	1			1	0	0	1
326	325km+138m	1			0	1	0	1
327	345km+520m	1			1	0	0	1
328	25km+108m	1			1	0	1	0
329	387km+242m	1			1	0	1	0
330	441km+200m	1			0	1	1	0
331	254km+100m	1			0	1	0	1
332	300km+753 m	1			0	1	0	1
333	650km+886m	1			1	0	1	0
334	34km+229m	1			0	1	0	1
335	119km+492m	1			1	0	0	1
336	130km+228m	1			0	1	1	0
337	660km+770m	1			1	0	0	1
338	216km+327m	1			0	0	0	1
339	211km+305m	1			0	1	1	0
340	406km+471 m	1			1	0	1	0
341	330km+255m	1			0	1	0	1
342	276km+988m	1			0	1	1	0
343	215km+540m	3			0	1	0	1
344	43km+800m	2			0	1	1	0
345	339km+423m	1			1	0	1	0
346	247km+673m	1			0	1	0	1
347	479km+207m	1			0	1	0	1
348	216km+850m		1		0	1	0	1
349	387km+080m	1			1	0	1	0
350	334km+300m	3			0	1	1	0
351	148km+691m	1			1	0	1	0
352	528km+777m	1			1	0	0	1
353	480km+984m		1		0	1	0	1
354	52km+296m		1		0	1	0	1
355	404km+064m	1			1	0	0	1
356	541km+000m	3			0	1	0	1
357	455km+202m	1			1	0	0	1
358	139km+021m	1			0	1	0	1
359	294km+750m	1			0	1	0	1
360	323km+682m		1		0	0	0	1
361	105km+500m	1			0	1	1	0
362	158km+922m	1			1	0	1	0
363	730km+900 m	1			1	0	1	0
364	104km+242m	1			0	1	1	0

365	132km+435m	2			1	0	1	0
366	358km+384m	1			1	0	1	0
367	279km+150m	1			0	1	0	1
368	62km+500m	0		1	1	0	0	1
369	704km+116m	1			0	1	1	0
370	119km+704m	1			1	0	0	1
371	440km+332m	1			1	0	1	0
372	104km+767m	3			0	1	1	0
373	248km+992 m	2			0	1	0	1
374	66km+324m	0		1	0	1	1	0
375	410km+807m	1			1	0	0	1
376	103km+899m	13			0	1	1	0
Total		543	23	6	179	185	172	204

Addis Ababa University

Degree of Masters of Science in Railway Engineering (Civil Infrastructure) Program

Dear respondent,

Thank you for your cooperation to fill out this online questionnaire. This questionnaire is designed to collect information from the staff of the Ethio- Djibouti Railway Company and aim to analyze the major safety issues on the railway company. As you were working on the mentioned company your response is very useful to identify other safety issues in addition to other data. **Modeling the Safety Conditions of a Railway Line: The Case of Ethio-Djibouti Railway** is a research subject for the Partial Fulfillment of the Requirements for the Degree of Masters of Science in Railway Engineering Civil Infrastructure.

Your response would have been used only for academic purposes and kept confidential.

Thank you in advance for your co-operation

Kalkidan Teshome

E-mail: kalkidanteshome27@yahoo.com

Addis Ababa University

Addis Ababa Ethiopia

- **Note:**
  - ❖ No need of writing your name
  - ❖ Please put a tick (√) in the appropriate box

Thank you in advance for willingly filling out this questionnaire!!

No	**General Question**					
1.	Gender ☐ Female ☐ Male					
2.	Age ☐ <30 ☐ 31-40 ☐ 41-50 ☐ >50					
3.	Education status ☐ Diploma ☐ Degree ☐ Masters ☐ Ph.D. ☐ Other					
4.	Under which department is your work position? ☐ Electrical ☐ Rolling stock ☐ Civil ☐ Safety ☐ Drivers ☐ Others					
	Safety Problem on the Ethio-Djibouti railway Please tick (√) and rate the safety condition based on the following scale: 1) Agree 2) Disagree 3) Strongly Agree 4) Strongly Disagree 5) Neither Agree nor Disagree					
		1	2	3	4	5
5.	I think passenger behavior of crowding around the door of the train has a safety problem.					
6.	Removing or demolishing train equipment for Passenger activity inside the train has a safety problem.					
7.	The use of previous routes by the local people is the main reason for the trespassing act.					
8.	The level crossing is far from each other and is a reason for the trespassing and collision accidents.					
9.	Deliberately distracting (vandalism act) company property is the primary safety problem on the railroad.					
10	The Company is losing an irreplaceable amount of material due to vandalism and robbery act.					

11	High rainfall and flooding cause erosion and surface sliding on the railway substructure.					
12	Earthquakes are one of the natural disasters that challenge the site.					
13	I think some geometric such as alignment, curve, slope, and elevation problems are seen along the way.					
14	The safety of the railway is profoundly influenced by train-animal collisions.					
15	Compensation expense is the company's primary payment for accidents and injuries losses.					
16	I think to increase safety fencing structures have to install around the railroads.					
17	Some drainage infrastructures have a problem of clogging and alluvial due to their small size.					
18	I think major technical faults are seen in the mechanical part.					
19	I think major technical faults are seen in the electrical part.					
20	I think major technical faults are seen in the civil part.					
21	Sometimes war and terrorist acts are seen on the railway line.					
22	Mainly safety issues occur by freight trains rather than passenger trains.					
23	The safety problems along the route influence the speed of the train.					
24	In general, the Ethio-Djibouti railway has excellent safety.					

Interview question

1, what are the safety challenge that you face or observe on the Ethio-Djibouty railway?