Improving Safety of Rail Operation by Risk Management of Accidents at Level–Crossing: case study of AA-LRT

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This is to certify that the thesis prepared By Getaneh Amene, entitled: *improving safety of rail operation by risk management of accidents at level crossing* and submitted in partial fulfillment of the requirements for the degree of Master of Science (electrical and computer engineering) complies with the regulations of the university and meets accepted standards with respect to originality and quality.

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Abstract

Ethiopian Railway Corporation has constructed a light rail transit for Addis Ababa. The LRT Project in Addis Ababa, the capital city of Ethiopia, consists of the East-west Line and the South-north Line. Risk management involves assessing the risk sources and designing strategies and procedures to mitigate those risks to an acceptable level. This paper considers the assessment of engineering infrastructures, human factors and surrounding environment as the three main factors contributing or determining accident at railway level crossings (RLC). Accidents at railways level crossings clearly dominate the railway accident. An important first step towards eliminating the cause of these accidents is through understanding and assessing the risks associated with a given level crossing and acting on them. This paper introduces a risk management process which involves several activities, including, hazard identification, risk evaluation, risk assessment, risk treatment and control and illustrates how it can be systematically applied to mitigate risk to AA-LRT level crossing. Improving safety of rail operation by risk management of accidents at level–crossing is considered as significant as a guarantee of the safe, efficient operation of the whole railway and to better safety at level crossings and upgrades to improve level crossings safety performance. Railway level crossings, which are used by high number of vehicles and trains each and every day, can severly affect the efficiency and safety of road. Railway safety will be improved by organized risk management system for assessing level crossing safety and safety enhancement measures. Human factors and technical factors are the two major factors of accidents at AA-LRTS. Guard fence damaged and signal equipment damaged is considered as intolerable risk in AA-LRTS and none of the accidents recorded are broadly acceptable. Railway-controlled crossing has low cost, minimum delay and high safety and best for the future AA-LRTS. Generally; this thesis presents improvment in safety of rail operation of Ababa-Ababa LRT by risk management of accidents at level–crossing.

Key words: Railway Level crossings, Risk management, Risk Analysis, hazard, risk assessment, ALARP Principle, risk ranking matrix.

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Abbreviations

AA-LRTS	Addis Ababa Light Rail Transit System
ACD	Anti-collision device
ALARP	as Low as Reasonably Practicable
CREC	China Railway Engineering Corporation
ERA	European Railway Agency
ERC	Ethiopian Railway Corporation
E-W	East West
FRA	Federal Railroad Administration
HAZOP	Hazard and Operability Analysis
HSE	Health and safety executive
ILCAD	International Level crossing Awareness Day
N-S	North-South
PHA	Preliminary hazard analysis
QRA	Quantified Risk Analysis
RLC	Railway Level Crossing
RSSB	Rail safety and standards board
SMC	Safety Management Committee
SMS	Safety management system

Chapter One

Introduction

1.1. Background

The railway industry plays a vital role in many countries. The LRT Project in Addis Ababa, the capital city of Ethiopia, consists of the East-west Line and the South-north Line. Ethiopian railway corporation (ERC) is the only government corporation responsible for managing all the railway projects. According to ERC construction agreement, the major companies those under construct more than 60% of the systems are held by Chinese companies. Most of the equipment those need to operate, monitor and control the overall railway systems are manufactured and imported from different counties (especially: from china) [1]. The AA-LRT level crossing is constitutes the intersection of two mode of transportation, which differ in physical characteristics and operation way. This project is implemented in the scope of the Phase I Project of these two lines and the total length of line is approximately 31km. About 3km is the sharing section for both E-W route and S-N route, which has the greatest passenger current.
The east-west line phase 1 project starts from Ayat and ends at Torhailoch. The total length is 17.4km. There are 22 stations, among which five are elevated stations, 1 underground station and 16 ground stations. The depot locates at the west end of the project.

The south-north line phase 1 project starts from Menelik Square and ends at kaliti. The total length is 16.97km. There are 22 stations; among which 9 are elevated stations (5 common stations at the common line), 2 underground stations and 11 ground stations.

The signaling systems of railway level crossings of AA-LRT are not synchronized at stations; the railway gates are closed before the train approaches to level crossing, there is no warning signal and no road markings at the locations of stations that make the situation unsafe for pedestrians to pass and for train safety. The protection or control systems of level crossings of AA-LRT (especially around stations) are by humans waving red flags to clear the road-rail tracks or vehicles and pedestrians traffic for incoming train. Road users must follow road rules and signs and pay attention to the road environment when approaching of railway level crossings. LRT level crossings are the most prevalent in urban settings and it is imperative that these locations are clearly analyzed and designed such that these mode of transportation in synchronization with on-street automobile and pedestrian traffic [1]. Under all circumstances, the signaling system must be supported by advanced technology in such a way that risk will be minimized to the minimum level. Specially, RLC are identified that as a particular target point to road and railway infrastructure, seriously affecting the safety of train, vehicles and pedestrians. In road and railway infrastructure the level crossings systems requires a high level of safety. Nowadays, level crossings are protected by passively or active/automated systems. Based on protection systems results it is concluded that on average there is less driver obedience to passive crossings than active crossings. Due to that reasons, active system of protections supporting safe driving and information collection infrastructure for sensing level crossing conditions and supplying key information to the railway operator and train driver is mandatory to prevent an accident.

Railway safety is critical aspect of rail operation the world over. Level crossings are key interface between the railway and the road. Accidents at level crossings are the result of complex interactions between facors arise from design and operations of level crossings. Risk management involves assessing the risk sources and designing strategies and procedures to mitigate those risks to an acceptable level. Evaluating risk at level crossings to understand where to focus investment in risk mitigation is now common practice in many countries [2]. Clearly, while level crossings are significant risk area for the safe operation of the rail network RLC, which are used by high number of vehicles and trains each and every day, can severly affect the efficiency and safety of road and rail users and have major financial impacts on bussines and the state’s economy.

Railway level crossings representing a major risk to railway safety by exposing train drivers, pedestrains, motorists and cyclists to collissions that often result in series injures fatalites, as well as the financial cost of damage. Railway level crossing accidents is one of the major contributing factor of railway related fatality problems in many countries. RLC is considered as a unique intersection as systems are complex and dealing with at least two mode of transport [3]. Theirfore collissions between motor vehicles, pedestrains and trains is likely to happen at RLC and cause catasstropic consequences [4]. As in basic safety engineering studies; there are at least three basic contributing factors to accidents need to be considered. There are engineering infrastructure, surrounding enviroment and human factors [5].

Railroad trains have a much larger mass relative to their braking capability and, thus a far longer distance than road vehicles. In general trains do not stop at level crossings but rely on road vehicles and pedestrians to clrear the level crossing in advance. Level crossings consititue a significant safety concern internationally. On averege, each year 400 people are killed in the european union and over 300 in the united states in the level crossig accidents. Collisions can occur with vehicles as well as pedestrains, pesestrian collisions are more likely to result in a fatality. The most effective way to improve traffic safety at railroad level crossings is to put precautions at the level crossings [6]. Railway level crossings accidents are the shared responsibility of several transportation companys such as railways ,road and local authorities.

1.2. Statement of the Problem

RLC is more important area in railway transportation because it causes serious damage and cause more catastrophic accidents if a proper safety measure is not taken into consideration. AA-LRT is a new technology and a new design which started operation in Sep 2015, has no recorded data for risk analysis of accident. The signaling systems of railway level crossings of AA-LRT are not synchronized at locations of stations; the railway gates are closed before the train approaches to level crossing, there is no warning signal and no road markings at the locations of stations that make the situation unsafe for pedestrians to pass and for train safety. Railway level crossing (RLC) accidents are one of the major contributing factors of railway related fatality problems in many countries [7]. RLC constitute a significant safety concern internationally. Therefore, adequate perception of level crossing control devices and warning systems by level crossing users is critical to the overall safety of AA-LRT operation. Therefore, without doing safety risk management of accidents prior to implementation to study fault, their propagation and effects, the operation will exhibit the faults and may cause severe accidents. It is important to do a lot of investigation, management, assessment and analysis of all types of accidents like accident caused by human factors, driver of car, train driver, level crossing design, automated and manual gate control system, failure of warning signals, environmental and other factors and also the rate and frequency of accidents at level crossings must be assessed to improve safety of railway level crossings for AA-LRT. It is easier to visualize propagation of accidents from different factors or sources to the general output system that cause severe accidents to the train operation. In this research proposal improvement of safety of rail operation by risk management system is going to be assessed for the case of AA-LRT.

- There should be a signal which controls or works in coordinated way for road traffic and train, i.e. both the left and right side of road traffic light must show stop signal until the peoples leaves the station and the pedestrian passes the road at both sides of the track especially at locations of stations where traffic volume is very high, like as (torhailoch, saris, Ayat,…..etc.).
- The road traffic light for road vehicles will show green light after 45 sec delay of the peoples leaves the station and the pedestrian passes the road.

Figure 1: Torhailoch station of AA-LRT in the east-west line, March 14 2017.

Figure 2: Accident of collision of vehicle and train in AA-LRT.

Figure 3: the vehicle damages the train when the vehicles drivers try to beat the approaching train at RLC of E-W line.

So, to improve safety and the railway risk management system the following questions will be answered.

- Is the existing level crossing system of AA-LRT fail safe?
- Is there an organized or generic risk management system for AA-LRT?
- Are the current railways level crossings of AA-LRT are confortable for pedestrians to pass the level crossing?
- Are the railway gates of railways level crossings of AA-LRT are closed for long time before the train approaches to RLC?

1.3. Objective/Aim of the Study

1.3.1. General Objective

The main goal of this study is to reduce risk of rail operation by risk management of accidents at level crossings by assessing the current safety hazard and accident status of RLC system of N-S and E-W line of AA-LRT Transit.

1.3.2. Specific Objective

- To identify hazards of railway level crossing of AA-LRTS,
- To manage risk at railway level crossings,
- To develop continuing awareness, education and enforcement promotions to complement the improvements to infrastructure and traffic regulations,
- To identify and categorize accident factors at level crossings of AA-LRTS.
- To introduce an organized or generic risk management process system for AA-LRTS.

1.4 Methodology

- Reviewing the present status of AA-LRT level crossing accidents and suggest critical points which improve safety of AA-LRT.

- Present analysis on train, vehicle and pedestrian railway level crossing based on level crossing gates are left open for long time before train approaches, sight distance of railway level crossing is after the train approaches, automatic and manual gate control system for AA-LRT.
- Ranking consequences or severity of accident for AA-LRT by considering accident factors like engineering infrastructure, human errors, surrounding environment and other factors.
- Studying the quality of railway level crossing surface for AA-LRT, educating the level crossing users and make recommendations to build bridges (under pass or over pass) for AA-LRT,
- Analyze various alternative systems for RLC protection.
- Assessment of level crossing safety performance and safety measures in a selection of other countries like (Great Britain, United States of America and Japan) which are advanced in their railway development and can possibly provide possible "best practice" for AA-LRTS, and

1.5 Output of the Research

- Organized or generic risk management system will be introduced that reduce the frequency of accident and the consequences or severity of accident for AA-LRT in the future.
- Safety risks will be managed to level that are ALARP by using Qualitative approach which uses probability and consequence of accidents with risk ranking matrix.
- Generally; hazards factors, accident factors will be known for AA-LRTS.

1.6 Organization of the Thesis

This thesis is organized in six chapters. The first chapter includes introduction which provides clear information about the thesis work, statement of the problem, objective of the thesis, scope and methodology of the thesis. Based on the conclusions drawn from literature a review highlighting the need for an improved rail operation by risk management of accidents at level crossings is assessed using ALARP principle.

Chapter two is about theoretical background and literature review. This section provides clear understanding of various rail safety issues; problems and all micro-level factors that could contribute to rail accidents are discussed in this chapter. In addition, risk management system approaches ALARP, PHA, HAZOP and other approaches will be discussed. Besides to this, factors contributing to accidents at RLC, types of level crossing control system, description of components of railway level crossing system, and finally, other researchers work on the area of risk management of accidents and experiences of other countries on level crossing risk reduction mechanisms or safety risk management system at level crossing is presented.

Chapter three is about generic risk management process and railway safety management system (SMS). This section includes hazard identification, risk assessment or analysis and risk control procedures. In addition, it also includes railway level crossing safety management system, tools and techniques of risk analysis such as qualitative, semi-quantitative and quantitative risk analysis will be presented.

Chapter four is about methodology of the research which predicts accident level or severity of consequences and frequency of level crossing accidents. This section also includes an appropriate methodology for combining different key performance indicators (factors), with a view to assessing rail safety risk will be developed and presented, modeling proportion of hazard results by cause category of AA-LRT, accidents types and risk analysis of AA-LRTS, and finally risk control strategies of railway level crossing of AA-LRTS will be discussed and presented.

Chapter five is about findings, results and discussion of results. Then based on proportion of hazard result by cause category for AA-LRT accident rate is generated for different cause category and risk analysis of accidents of AA-LRTS of level crossing accidents also calculated.

Chapter six is the final chapter which is about conclusion and recommendations for improvements and future works. Here we conclude our work based on the result obtained and discussed in chapter five.

Chapter Two
Literature Review

2.1. Literature review

In this section, we try to provide an idea about the basics concepts of risk management of accidents at level crossings based on literature review. This includes generic definitions of risk, safety, risk assessment, accident factors, and risk ranking matrix, hazard and risk management systems.

Incident: is defined as an unintentional or undesirable event that may or may not result in an injury. An incident that results in an injury, fatality or property damage is defined as an accident. This definition clearly indicates that the occurrence of an incident or accident at railway level crossings is a random event caused by several factors.

Hazard: is a system state or set of conditions that, together with particular set of environmental conditions, that leads to accident.

Risk ranking matrix: is used to assess the probability and the severity or consequences of each hazard and to give it a risk ranking or rating.

Risk: is the probability that a safety hazard will result in an accident involving causalities (injury, fatality, property damage). Risk has been defined both qualitatively and quantitatively. Qualitative definition of risk is as a potential loss of life or injury resulting from exposure to hazards. This quantitative definition risk aims to estimate the degree or probability of loss related directly to the occurrence of hazards. Basically, risk is expected loss from a particular hazard and the chance that the safety hazard will result in an accident which cause causalities such as loss of life, injury and property damage. Statistically it is the probability of unwanted or event or unfavorable consequences of an event. Alikhani (2009, p.113) stated that an engineering definition of risk is generally given as [8]:

$$R = P_i * C_i$$

Where Pi probability of event

Ci consequences of event

Railway level crossing accidents is one of the major contributing factor of railway related fatality problems in many countries. RLC is considered as a unique intersection as systems are complex and dealing with at least two mode of transport [3]. Theirfore collissions between motor vehicles, pedestrains and trains is likely to happen at RLC and cause catasstropic consequences [4].

Risk management involves assessing the risk sources and designing strategies and procedures to mitigate those risks to an acceptable level. Evaluating risk at level crossings to understand where to focus investment in risk mitigation is now common practice in many countries [2]. Collisions can occur with vehicles as well as pedestrains, pesestrian collisions are more likely to result in a fatality. The most effective way to improve traffic safety at railroad level crossings is to put precautions at the level crossings [6].

LRT level crossings are the most prevalent in urban settings and it is imperative that these locations are clearly analyzed and designed such that these mode of transportation in synchronization with on-street automobile and pedestrian traffic [1]. Under all circumstances, the signaling system must be supported be advanced technology in ac such a way that risk will be minimized to the minimum level.

Many hazard identification techniques have been developed in various engineering disciplines [8]. A lot of researchers have been done in the area of risk management of accidents at level crossings. The Quantified risk analysis (QRA), (as low as reasonably practicable) ALARP Principle, hazard and operability (HAZOP) studies, preliminary hazard analysis (PHA), and probabilistic risk analysis (PRA) are the major applications or approaches (techniques) that have been implemented by many researchers in improving safety of rail operation by risk management at level crossings.

2.1.1. ALARP Principle

The ALARP (as low as is reasonably practicable) principle provides a means for assessing the tolerability of risk. In essence, it says if the cost of reducing the risk outweighs the benefit, then the risk may be considered tolerable. The ALARP Principle [9] in the railway risk management approach which is intended to ensure that the risk, or the probability, of railways accidents with serious consequences in terms of loss of life and injury, is kept to a level which is ALARP.

A risk is ALARP, if the cost of any reduction in that risk is greatly disproportionate to the benefit obtained from the reduction. The ALARP is relevant because of its widespread adoption in the UK as a means of assessing tolerability of risk, the ALARP principle is not protected in the UK law and it uses cost effective analysis methods.

ALARP Principle is applied as part of a risk management process or activities which are hazard identification, risk assessment and risk control. As the authority for maintaining safety, the rail sector needs to guarantee itself and the community (the public, passengers and the employees) that the safety risks are being managed to level that are ALARP.

ALARP defines three levels of risk:

- Intolerable risk, which cannot be justified or accepted except, in unexpected conditions;
- Tolerable risk, which can be accepted only if risk reduction is impossible or the cost of risk reduction is greatly exceeds the benefits gained; and
- Negligible risk is which broadly acceptable and does not require risk mitigation measures.

Table 1: hazards categorization based on ALARP principle/as risk ranking matrix [10]

Frequency/consequence	1 Very unlikely	2 remote	3 occasional	4 probable	5 Frequent
Catastrophic					
Critical		Acceptable (tolerable) risk		Intolerable (unacceptable) risk	
Major	Broadly acceptable risk				
Minor					
	Negligible risk		Tolerable risk		Intolerable risk

In the above table the risk is calculated as the product or a matrix between severity/consequences and probability of accidents. The implication of ALARP Principle is that is the risk is determined to be at the intolerable level (red condition); measures must be taken immediately to reduce it to tolerable level. Similarly, if risk is found to at tolerable level (yellow condition), risk mitigating measures should still be applied, provided that they are capable of practical application and the benefit to be gained exceeded the cost of their application and finally, if risk is found to at negligible or broadly acceptable level (green condition), no need of risk reduction method.

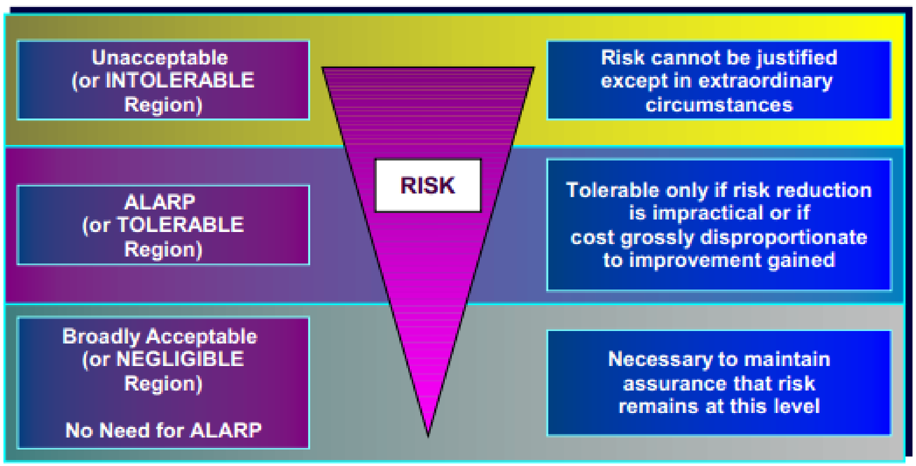


Figure 4: the ALARP principle [10]

The difficulties of applying the ALARP principle are that, firstly, to demonstrate that a risk is in ALARP, it is necessary to determine that all reliable risk reduction methods are impossible. To do this, it is clearly necessary to identify all reliable risk reduction methods. Hence, the identification of risk reduction methods is considered a group activity (analogous to HAZOPS). Secondly, it is expensive, because accurately determining the cost and benefits (CBA) of risk reduction can be difficult and time consuming.

2.1.2. Preliminary Hazard Analysis (PHA)

Preliminary hazard analysis (PHA) is defined as a semi quantitative analysis that is performed to identify all the potential hazards and accidental events that may lead to an accident then rank them according to their severity and thereafter identify required hazard control and follow up actions [11]. It is a simple; inductive method of analysis whose objective is to identify the hazards and hazardous situations and events and that can cause harm for a given activity, facility or systems. It also provides an initial overview of the hazards present in overall flow of the operations of any system. The Preliminary hazard analysis (PHA) provides a hazard assessment that is broad, usually not detailed. The PHA will often serve as the total hazard identification process when risk is low. In higher risk operations, it serves to focus and prioritize follow-on hazard analysis by displaying full range of risk issues. PHA is carried out in four main steps beginning with PHA prerequisites where the PHA team is established, the system to be analyzed, it components, boundaries and interactions are defined and described as well as the actors or materials that appear to be the most exposed to risk. Next, all hazards and possible accidental events must be identified. In third stage of PHA, the consequences or severity of hazards in terms of infrastructure damage, human injury or loss is evaluated and frequency of those identified hazards is also estimated. Severity and frequency classification may be used instead when historical data is not available to make accurate estimations. Finally, the different hazards are ranked in categories based on their severities and frequencies.

2.1.3. Hazard and Operability Analysis (HAZOP)

HAZOP is the Abbreviation for HAZARD and OPERABILITY study and it is a structured and systematic examination of planned or existing process in order to identify and evaluate problems that may represent risks to personnel or equipment, or that may prevent efficient operations [30]. HAZOP is a technique to identify risks to people, equipment, and environment and/or organizational objectives. It is difficult analysis method that uses a guide words to identify a potential deviations from design or operating intentions. The HAZOP technique was initially developed to analyze chemical process systems, but has later been extended to other types of systems and to complex operations and to software systems. This includes mechanical and electronic systems, procedures, and software systems. HAZOP is a qualitative technique which uses special adjectives (such as “more, “less, ‘no,’ etc.: being a unique feature) combined with process conditions (speed, pressure, flow etc.) to systematically evaluate deviations from normal conditions. The guide words are applied to some attribute or intention of the system, in order to consider how it might fail and what the consequences of that failure might be. HAZOP also ranks risk with their severity and likelihood and is best suited for the identification of safety hazards and operability problems of continuous process systems, specially fluid and thermal systems also to review procedures and sequential operations. A basic limitation of HAZOP and of the techniques that we introduced thus far is that they focus on one-event cause of deviations.

The benefits of HAZOP are it systematically identify hazards and thoroughly examines the potential consequences of deviations. Its limitations are the HAZOP is time consuming, system must be well defined and hazards may be missed due to focus on the equipment.

2.1.4. Experiences of other Countries on Railway Level Crossing

Accidents at RLC clearly dominate the railway accidents and not only are they dominant on their frequency, but they can be more severing in their consequences than other types of railway accidents.

There are approximately, 37,000 public, private and pedestrian highway railway crossings in Canada. According to transport safety board in between 2003 and 2012 there was 2165 crossing collisions in Canada resulted in 267 crossing fatalities. Six percent of the total collisions involved pedestrians, resulted in 59 percentage fatality [12].

2.1.4.1. Experience of United Kingdom in Safety Risk Management

In United Kingdom, administration of safety policy and standards in public domain is the responsibility of health and safety executive (HSE). However, until very recently, authority for railway safety management has been that of the infrastructure owner-initially British rail and laterally, rail track plc-with the HSE ensuring the safety guidelines policy and standards are observed.

There are three main types of level crossing protection types in Great Britain in recent years.

- Railway- Controlled Crossing

At these crossings, the opening and closings of the crossings to the railway or road is controlled by a number of railway staffs, a signaler or crossing-keeper. The operation of the crossing is almost interlocked with the railway signaling, so that it is not possible to clear the signals for train unless. Modern railway-controlled crossings have lifting full barriers either operated by a signaler at the site, or operated remotely and supervised by a closed circuit television.

- Automatic Crossings

These crossings are operated by the passage of trains without the intervention of railway staff. When a train approaching the crossing reaches a 'strike-in' point, it triggers the operational cycles: first there is a warning to road users; then the crossing is closed to road users; then the train passes; and finally, the crossing opens to the road again. The reason for having only half barriers is to provide an escape route for any vehicle or person already in the level crossing when the barriers fall.

- Passive Crossings: These crossings, including footpath crossings are called 'user-worked' crossings in Britain.

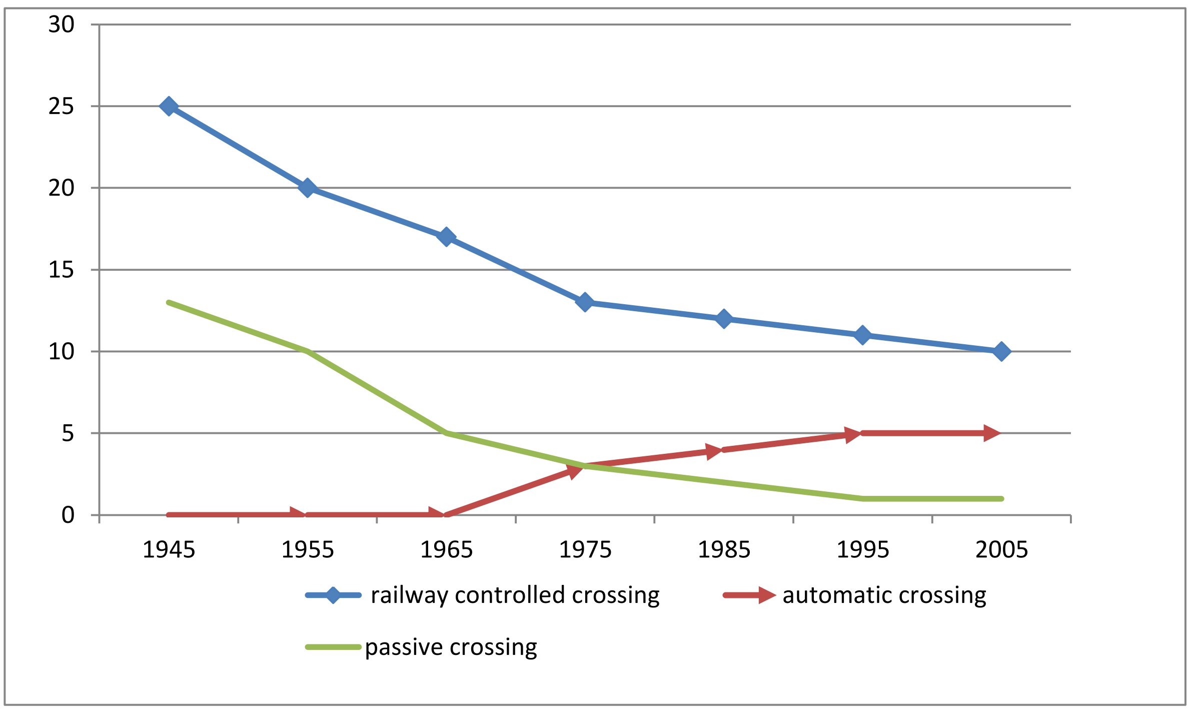


Figure 5: the overall numbers of accidents per a year [13]

Generally, the safety performance of the three types of level crossings has been very different. Railway-controlled crossings are the best performing crossing type with falling fatal accident rates. Automatic crossings have higher accident rates per crossings than railway- controlled or passive crossings, and accident rates have not been decreased. They have advantages on railway controlled crossings on public roads in not needing staff and imposing less delay on road users. Nevertheless, they are less safe, so a balance has to be struck between safety, cost and delay. Passive crossings are by far the most numerous, but many have low usage by road users.

2.1.4.2. Level Crossing Experiences of United States of America

In the United States the railway industry is dominated by large private companies. Regulation of the industry in all aspects of its operation, including safety, is the responsibility of the federal railroad administration (FRA).

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Level crossing accidents	6515	6525	5713	5386	4910	4892	4979	4633	4257	3856	3508
Level crossing fatalities	689	801	698	608	579	626	515	579	488	471	431
Level crossing injuries	2589	2868	2407	2094	1969	1837	1961	1894	1610	1540	1303

Table 2: trend in level crossing accidents and fatalities and injuries [14]

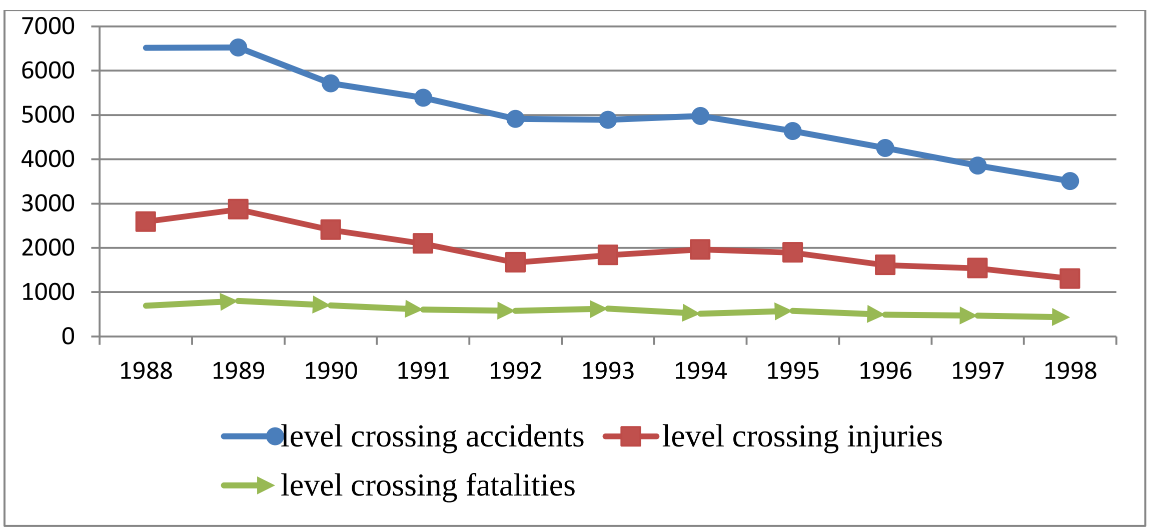


Figure 6: trend in level crossing accidents, fatalities and injuries, United States 1988-1998 [14]

2.1.4.3 Railway level crossing safety in India

The Indian railway network with a route length of 62,495 km has total of 40,445 level crossings or an average of one in every 1.5 kilometers. Of these total 16,132 level crossings are manned with some form of barrier protection facing road users, 20,528 are open crossings with fixed road warning signs, 948 are road crossings adjacent to canals without barrier protection, but road warning signs and 2,837 are simple open crossings with neither barrier protection and with no fixed road warning signs.

Indian railways have recently had a shift in their policy regarding level crossing to the effect that the decision has been taken to go for manning a large number of unmanned level crossings with a high level of usage by road and/or rail and not to construct any more crossings for unmanned operation. Subject to availability of funds, level crossings which have reached a traffic moment of 100,000 per day or more are being replaced by the construction of road over or under pass.

While the Indian railways have contributed to motor vehicle drivers and pedestrian education programme, it is clear that this had limited the impact, perhaps a reflection of a lack of safety awareness culture in India.

- Accidents

Level accidents comprise a small but a growing proportion of all railways accidents in India.

Table3: level crossings accidents in India, by type of crossing from 1988/89 to 1997/98 [15]

Unmanned crossings	36	29	21	39	44	58	54	53	45	49
Manned crossings	19	13	16	9	27	13	20	16	21	16
All crossings	55	42	37	45	71	71	74	69	66	65

Nearly two thirds of the total level crossings accidents occur at unmanned level crossings and this proportion been increasing over the past decade.

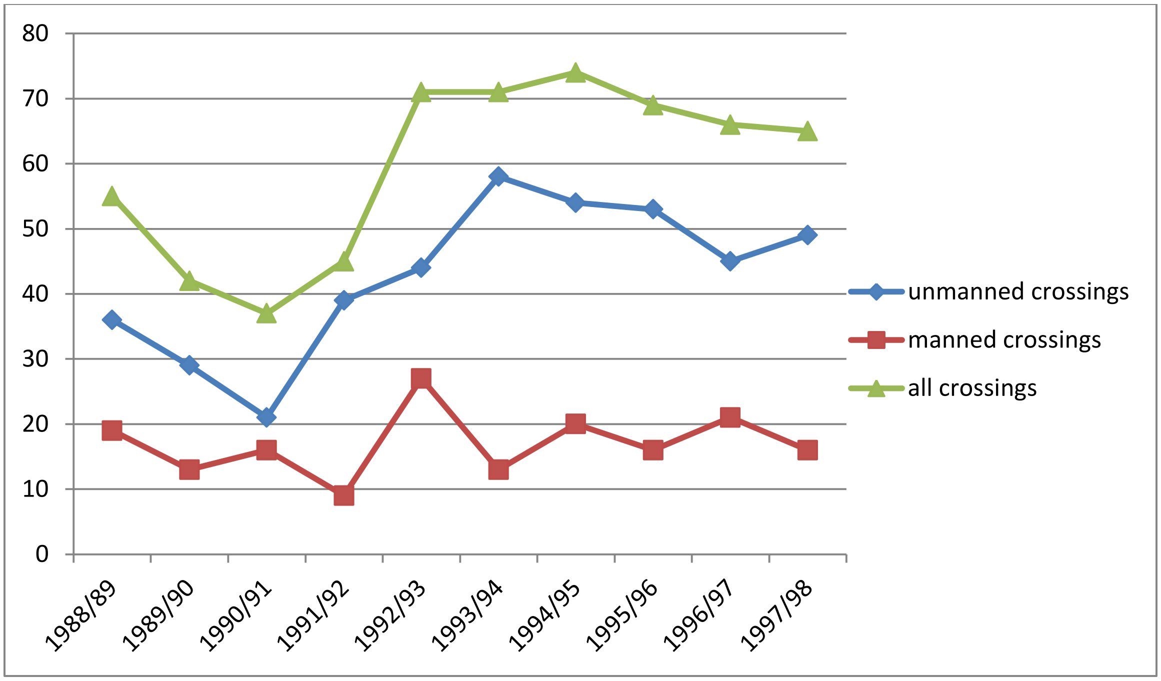


Figure 7: level crossing accidents in India, by type of crossing [15]

Level crossing safety initiatives in India includes:

- manning of unprotected crossings (progressive conversion of unmanned/unprotected crossings to manned/protected crossings)
- Other level crossing upgrading measures (road under pass or over pass) of level crossings with high traffic moment (volume).
- Road user education by use of mass media (TV and newspapers) to promote public awareness of the need for caution when using level crossings.

2.2. Factors Contributing to Accidents at RLC

Risk factors refer to crossing attributes that explain variation in risk including the expected number of collisions and their consequences. A risk factor can be a combination of number of independent variables which affect the prediction of accident risk.

Generally, there are three main factors contributing to accidents at level crossing in basic safety engineering studies,

- Human factor
- Engineering factor
- Environmental factor

2.2.1. Human Factor (Driver Behavior)

Human factors include familiarity with level crossings, misjudgment and distraction of rules and driver disregard to for the stop sign, vehicles zigzag movement, gate keeper and train driver errors and failure to look for a train. In a case study conducted by (Wigglesworth, 1978) [16] he found that the total of 85 fatal accidents occurred in victoria, Australia (1973 to 1977), 85 percent of accidents were due to road user familiarity of the level crossings near their locations especially if it was close to their residence or place of employment. The findings also shows 68 percent from 87 percent, due to the road user get through the RLC at least four times per week and another 19 percent used between 2 to 4 times per a week. Driver’s behavior such as slowing down vehicles in the approach of the level crossing remains as another contributing factors to accidents at RLC.

Caird (2002) cities the work of Lerner (1990) and NSTB (1998) in reviewing the driver behavior at passive level crossing [5] investigated that out of 60 accident cases, 49 cases were due to diver error. From 49 cases, 29 cases include driver disregard to for the stop sign and failure to look for a train. The remaining cases related to roadway and track conditions and affecting the ability to the driver to realize the passive crossing a head and the attendance of approaching train. Drives disobeying train-activated warning devices are among the many causes of accidents at active level crossings. Behavior such as driving around the lowered level crossing gate arm or ignoring the flashing lights are among the other deliberate decisions by drivers at active level crossing. In addition, unsafe actions (risk taking, not looking, distractions) and individual differences (age, gender) are human factors contributing to accidents at level crossing.

- Probable lack of awareness by road vehicle drivers of the road traffic rules as they relate to the level crossings;
- Driver interactions with different protection system (active and passive);

- Drivers unwilling to stop because they believe they have plenty of time to pass before the train arrives;
- Drivers are unable to stop because they are too close to the tracks at the onset of flashing lights,
- Those who are unaware of signals because they are careless or confused;
- Alcohol and drugs;
- Poor knowledge of road rules;
- Level crossings approaching behavior;

2.2.2. Engineering Factor

Engineering factors include highway and railway characteristics are contributing factors to accidents at railway level crossing and technical contributing factors related to configuration and design of RLC. Studied by the saccomanno (2003) showed that there is an ambiguous relationship between traffic volume on the road and the number of collisions at level crossing [16]. Engineering factors includes:

- Road design (the number of entry/exit points);
- Road traffic lights and the inter link with the level crossing warning system;
- The width of the crossing;
- Technical factors (rail equipment failure, signal and barriers and deficiency of vehicles

2.2.3. Environmental Factors

Environmental factors include visibility problems for drivers such as snow, heavy rain and sun reflections. Earlier studies conducted by Meeker (1989) reported that in US, over 57 accidents occurred at the RLC which activated by flashing lights, 56 cases involved visibility problems. It was due to the severe thunderstorm, snow, heavy rain and reflection of sun light at location during observation. Related work by Gau (2003) cities the work of Caird (2002) who reported that weather as another important factor of accidents occurred at passive level crossings [5]. Amongst the environmental factors affecting the visibility problems are snow, heavy rain, fog or blowing snow. The sun can also blind drivers due to sun reflections caused by sunrise and sunset when drivers try to check the approaching train at railway level crossings.

Environmental attributes includes weather (e.g. snow, rain, fog) plays an important role when assessing the risk at level crossing. Other factors such as view, visibility, adjacent land use and sun glare for train and vehicle drivers also significantly influence safety at level crossings.

2.3. Components of Level Crossing System

A road-rail level crossing can be viewed as simply as a special type of highway intersection or two mode intersection. As with a highway intersection, drivers must appropriately yield the right of way to the opposing traffic; unlike a highway- highway intersection, the opposing traffic the – train must only rarely yield the right of way to the highway vehicle.

2.3.1 Highway (Road) Components

- **Drivers:**

  The driver is responsible for obeying traffic control devices, traffic laws and rules of the road. Highway and railroad engineers who plan and design initial installations or latter improvements to traffic control systems at rail road level crossings should aware of several capabilities, requirements, needs and obligations of driver.

- **Vehicles:**

  The design and operation of the rail-road level crossing must take in to account the numbers and types of vehicles that can be expected to use it. The vehicles utilizing the highway-rail level crossing have widely different characteristics that will directly influence the design elements of level crossings.

2.3.2. Railroad Components

For the purpose of simplicity, the railroad components of highway-rail level crossing have been divided in to three categories: train, track and signaling.

- **Train:**

  Thus, design of traffic control systems at level crossing must allow for a wide variation in train length, train speed and train occurrence. Long trains, such as, unit trains, directly affect the operation highway traffic over crossings and indirectly affect safety as well.

Because of their lengths, unit trains will take longer to pass over a level crossing and in effect, close the crossing to highway traffic for a longer period of time. Because of the longer period of time during which the crossing is closed to high traffic, a vehicle drivers may take risks by passing over the crossing just a head of a train.

- Track:

Rail track is normally maintained by sophisticated, high production and mechanized equipment. Similar to highways rail-road track is classified in several categories depending on the utilization Interms of traffic flow. Main tracks are used for train movements between and through stations and terminals. Passing tracks are sometimes called sidings, are used for meeting and passing train.

- Signaling:

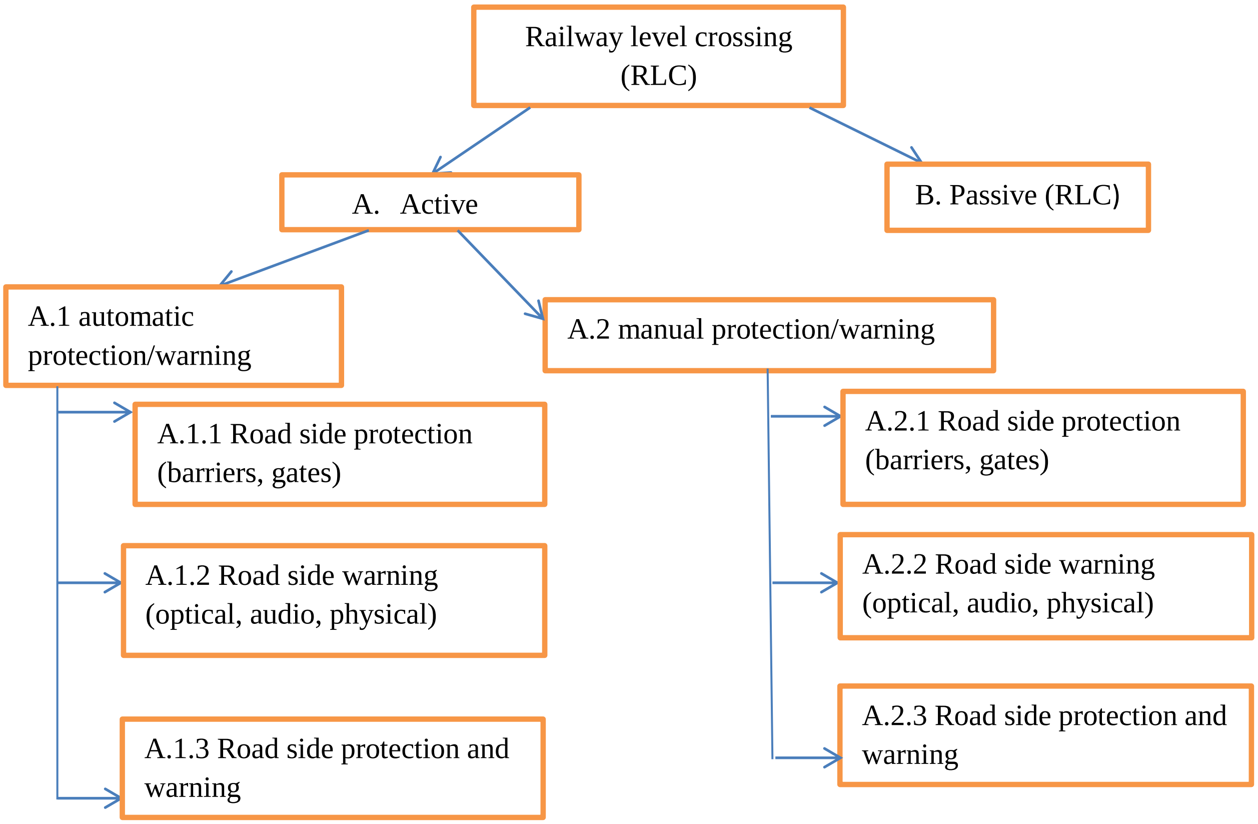
During the early railroading, methods had to be developed to ensure that two trains did not meet at the same time on the same section of track. This was initially accomplished the use of time tables and train orders. Block signal systems were developed, which indicated to the locomotive engineer whether or not a train was ahead in the next block of the track. These signals were set manually until the track circuit was developed, which sensed the presence of a train in block and set the signals automatically. The track circuit was designed to be fail-safe, so that if the battery or any wire connections were to fail or if a rail was broken, a clear signal would not be displayed.

2.4. Types of Railway Level Crossing System

RLC can be defined as an intersection of a road and a railway on the same level. All level rail/road intersections (grade or level crossings) are provided with either active or passive protection. There are two types of RLC system: active and passive. Active RLCs have signals and boom gates which operate automatically when a train is approaching and it is the application of warning devices to warn road users of the approach of the train when the train is a minimum time from entering the road-rail intersection, whereas passive RLCs have signs, pavement markings. The analysis of operational level crossing risk was carried out on the basis of the active and passive level crossing types as defined per European Railway Agency (ERA) for the purpose of defining common safety indicators [17]. Similarly the European Railway Agency

(ERA) classified the level crossing in to two groups: active RLC (group A) and passive (group B).

Figure 8: the level crossing types classified by ERA [17].



It defines an active level crossing as a level crossing where the crossing users are protected from, or warning of, the approaching train by the activation of devices when it is unsafe for the user to cross the level crossing. In the case of an automatic active level crossing (A.1 in fig 8), these devices are activated by approaching train. Manual active level crossing (A.2), are activated by humans when there is no railway signal interlocked with control train movements.

In case of passive level crossing (B in fig 8), there is no warning system and/ or protection system showing when it is unsafe for the user to cross the level crossing.

Chapter Three
Risk Management Process

3.1. Risk Management Process

Risk management is part of broader SMS and links through key inputs and outputs such as measuring, or assessing risk and developing strategies to manage it. Strategies includes transferring the risk to another party, avoiding the risk, reducing the negative effects of the risk, and accepting some or all of the consequences of the particular risk. It is a process by which the management assesses the risks, determines the control measures, and takes the appropriate measures to reduce such risks. It is stated that in ideal risk management, a prioritization process is followed whereby the risk with the greatest loss and the greatest probability of occurring are handled first and the risk with lower probability of occurrence and lower loss are handled later (kokash & Andrea 2006, p.11) [8].

Risk Management is a five step process:

1 – Establish the context

2 – Identify the risks

3 – Analyze the risks

4 – Evaluate the risks

5 – Treat the risks

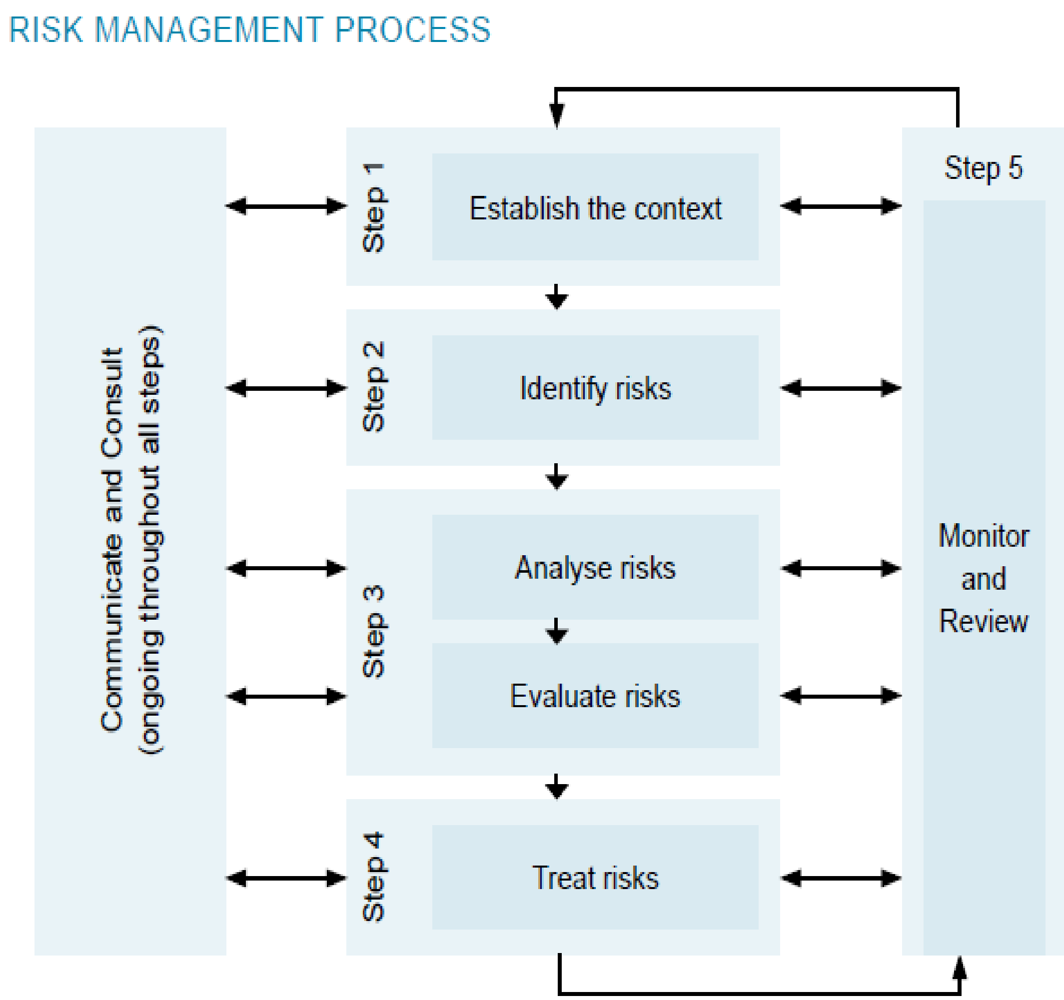


Figure 9: flow chart of a generic risk management process [18]

1 – Establish the context

Before risk can be clearly understood and dealt with, it is important to understand the context in which it exists. It includes the risk management context, develop criteria, and define the structure. It also refers to the organizational context – the objectives, core activities and operations of the system.

2 – Identify the risks

The purpose of this step is to identify what could go wrong (likelihood) and what is the consequence (loss or damage) of it occurring which often seen as the heart of risk management.

Key questions to ask include:

- What can happen? List risks, incidents or accidents that might happen by systematically working through each competition, activity or stage of your event to identify what might happen at each stage.
- How and why it can happen? List the possible causes and scenarios or description of the risk, incident or accident.
- What is the likelihood of them happening?
- What will be the consequences if they do happen?

Step 3 – Analyze the risks (& evaluate)

- This involves analyzing the likelihood and consequences of each identified risk and deciding which risk factors will potentially have the greatest effect and should, therefore, receive priority with regard to how they will be managed. Risk analysis consists of determining the consequences and their probabilities for identified risk events taking in to account the presence (or not) and taking the effectiveness of any existing controls. The consequences and their probabilities are then combined to determine the level of risk. However, in some instances, such as where the consequences are likely to be insignificant, or the probability is expected to be extremely low, a single parameter estimate may be sufficient for a decision to be made.
- Risk evaluation involves comparing the level of risk during the analysis process with previously established risk criteria, and deciding whether risks can be accepted. It also means the process of the evaluation of risks resulting in hazards, the consideration of the completeness of current control measures and the decision on the risk acceptance. If the risk falls into the low or acceptable categories, they may be accepted with minimal further treatment. These risks should be monitored and periodically reviewed to ensure they remain acceptable. If risks do not fall into the low or acceptable category, they should be treated using one or more of the treatment options considered in step 4.
- In the evaluation stage minor risks may be screened out and more attention will be routed towards risks with the highest expected risk value.

If all the consequences and frequencies of hazards have been identified then quantitative definition of risk can be used to estimate risk:

$$R_i = P_i \times C_i,$$

Where; R=Risk

P= probability of hazard

C =consequences of hazard

Table 4– Likelihood or probability of occurrence scale [14]

Rating (score)	LIKELIHOOD (PROBABILITY) The potential for accidents or risks to occur in a year
5	Almost certain: frequent, will probably occur, and could occur greater than 1 times per year (probability or chance of occurrence is greater than 90%)
4	Very Likely: high probability, likely to arise once per year (probability or chance of occurrence is 61% to 90%)
3	Possible: reasonable likelihood that it may arise 1 times over a five-year period (probability or chance of occurrence is 41% to 60%)
2	Unlikely: probable, could occur 1 to 2 times in a ten year period (probability or chance of occurrence is 10% to 40%)
1	Rare: very unlikely but not impossible, unlikely or 1 times over a ten year period (probability or chance of occurrence is less than 10%)

Table 5– Loss or damage impact scale [14]

Rating (score)	POTENTIAL IMPACT In terms of the severity or financial loss of the consequences in a year
5	Catastrophic: death or permanent disability, or several severely affected and contains greater than 10 million dollar
4	Major: serious injury requires hospital treatment, most objectives threatened, or one severely affected or contains (1 million to 10 million dollar)
3	Moderate: injuries requiring medical treatment and contains (100,000dollar to 20 million dollar)
2	Minor: minor treatment (easily treated), i.e. first aid only required and contains (10,000 to 100,000) dollar
1	Negligible (insignificant): very small impact, injuries requiring no treatment, or first aid and contains less than 10,000dollar

➢ Risk Matrix Caution

- Discuss and review with supervisors and employees- is risk understood? Does every one agree on assessment?
- Review and research loss history from risk register,
- Do a reality check- could the severity be greater? Could the exposure be more frequent?
- Matrix only gives a relative way to set priorities and rank risk order considering the probability and impact of a single risk.

Generally, each risk is rated on its probability of occurring and impact on an objective if it does occur. The organizations threshold for low, moderate, or high risk determine whether the risk is scored as high, moderate, or low for that objective.

In the risk evaluation step, the existing risks are classified and decisions are made regarding the tolerability of the existing risk, i.e. As ALARP principle that the risk of any system with serious quencequences Interms of human loss and injury is kept to a level as low as reasonable practicable (ALARP).

Step 4 – Treatment and control the risks

Risk treatment involves identifying the range of options for treating the risk, evaluating those options, preparing the risk treatment plans and implementing those plans. It is the fourth step, where action plans are determined in response to the identified risks and mechanism to control those risks are put in place.

Step 5 – Monitor and review

It should be noted that risk management process may well require regular monitoring and review especially when applied with dynamic systems which may change over time. As with communication and discussion, monitoring and review is an ongoing part of risk management that is integral to every step of the process. Review is an integral part of the risk management treatment plan.

3.2. Railway Safety Management System (SMS)

Safety management system (SMS) is one of the major challenges in the broader management of safety and risks of rail operation. It is an important issue in all critical safety sectors including rail industry and regarded as an important means of improving safety in all safety culture. An SMS is an organizations formal arrangement, through the provision of polices, resources and processes, to ensure the safety of its work activity [19]. An effective SMS helps the organization to identify and manage risks effectively. It allows an organization to demonstrate its capability in achieving the safety objectives and in meeting regulatory requirements.

Rail safety management is constantly aiming to improve overall safety of rail infrastructure, in particular rail road crossings. This involves identifying research problems with in the broader rail safety and risk assessment and managing complexities of railway level crossings across many situations and locations. It is a systematic, explicit and comprehensive system to managing safety risks. It also helps to address safety issues before they lead to an incident or accident provides management with the ability to deal with accidents and reduces losses and improves productivity. The basic safety management process is generally accomplished with major elements of events and functions such as:

- A safety issue/ concern is raised, a hazard is identified or an accident happens,
- The concern/ event is reported or brought to the attention of management,
- The event, hazard, or issue is analyzed to determine it cause or source,
- Corrective actions, control or mitigation is developed and implemented, and
- The corrective action is evaluated to make sure it is effective. If the safety issue is resolved, the action can be documented and the safety enhancement maintained. If the problem or issue is not resolved, it should be re-analyzed until it is resolved.

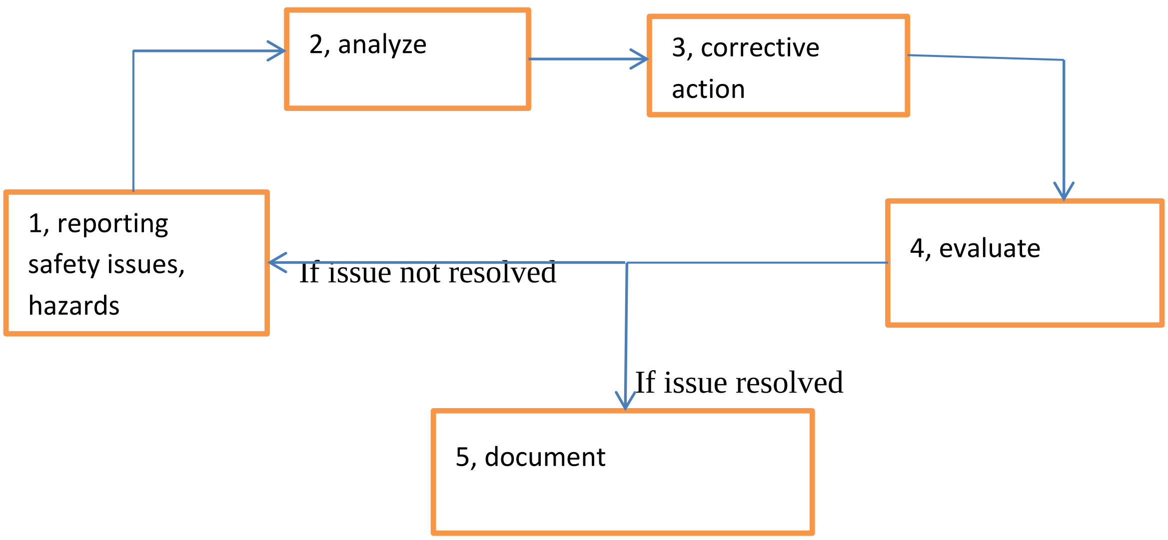


Figure 10: the basic safety management system process [7]

Railway safety is a critical part of rail operation in all over the world. RLC are the interface between roads and railway tracks and as site as the potential site for vehicle-train collisions and incidents [7]. United Nations (2000, p.1) states that each year, accidents at level crossing is not only cause the deaths or serious injuries to many thousands of road users and railway passengers but also impose heavy financial burden Interms of interruption of railway and road services and damage to railway and road vehicles and property [18].

This leads to the following phenomenon:

- Many billions of dollars are paid in medical cost and disability payments,
- Capacity of operations and productivity is decreased,

- Heavy loss of life and human suffering,
- Inconvenience caused to the people injured, to others and to the environment.

Rail SMS is important in insuring the rail safety. It provides a complete, systematic and optimal way of controlling and managing rail safety risks to achieve desired safe outcomes in sustainable way.

Safety at level crossings is important issue for road users, train passengers, train drivers. RLC accidents are amongst the most complex issues in rail operations, due to its multi reactions dealing with at least two mode of transport and surrounding environment. The function and characteristics of those components and their corresponding elements contribute to risk at RLC locations. In rail safety engineering factors associated with RLC accidents are human errors (both rail and others), engineering infrastructure, and RLC surrounding environment. The risk of accidents at level crossings depends on their configuration, the volume of pedestrians and vehicle traffic traversing the crossing and rail traffic. The only way to eliminate risk at level crossing is to close it.

3.3 Tools & Techniques for Risk Analysis

Risk analysis normally includes the estimation of the range of potential consequences that might arise from an event, situations or circumstances, and their associated probabilities, in order to measure the level of risk. However, in some instances, such as where the consequences are likely to be insignificant, or the probability are expected to be low, single parameter estimation may be sufficient for a decision to be made. Methods used in analyzing risk can be qualitative, semi-qualitative and quantitative.

3.3.1. Qualitative Risk Analysis

Qualitative analysis/approaches do not use absolute variables value, but instead it qualitatively evaluates the influences of each variable in the risk. Experience, expertise and competence of the person conducting the risk assessment are the most important when taking a qualitative approach. The qualitative assessment results are usually descriptive, and do not imply an exact quantification of risk. The qualitative assessment often provides support for further investigation of quantitative, but can also provide information needed for risk management. The risks are assessed qualitatively; however, in order to interpret the results easier, variables, as well as the assessed risk, will be quantified. In contrast to qualitative risk assessment, in this case numeric values are not absolute but relative. Risk quantification and repeated reinterpretation of this numerical value are all direct cause for result uncertainty. A qualitative assessment is formal being preferred to quantities for several reasons as follows;

- there are insufficient data to make a quantitative assessment;
- there is no mathematical competence to assess risk;
- Appears to more accessible and more easily understood by policy makers and others.

Qualitative risk analysis is the application of methods for ranking the identified risks according to their potential of effect as combination probability of occurrence of event and severity of impact. It is one way of determining the importance of addressing the specific risks and guides risk response measures. It is also a method which defines consequences, the probability and the level of risks by significance levels, high medium and low may combine the probability and consequences and evaluates the resultant level of risk against the qualitative criteria.

3.3.2 Semi-Quantitative Risk Analysis

Semi-quantitative methods use numerical rating for consequences and probability and combine them to produce a level of risk using a formula. Scales may be linear or logarithmic or may have some other relationship, and the formula can also vary.

3.3.3. Quantitative Risk Analysis

Quantitative risk analysis estimates practical values for consequences and their probabilities, and produces value of the level of risk in specific units defined when developing the context. Full quantitative analysis may not always be possible or desirable due to insufficient information about the system or activity being analyzed, the lack of data, the influence of human factors, etc. or because the effort of quantitative analysis is not warranted or required. In such circumstances, the comparative semi-qualitative or qualitative rankings of the risks are effective.

The quantitative approach to risk assessment is based on exact numerical values. in this case, fuction variables has precise values. The fuction values are displayed in monetary units.

3.4 Hazard Identification Methods

- With respect to production characteristics of AALRTS, the identification is carried out by place, work and equipment. In detail, all kinds of hazards shall be identified completely, e.g. unsafe conditions existing in the workplace, potential in the work and remained by the equipment, unsafe human behavior and industrial hygiene (work environment), emergencies and other hazards of relevant parties.
- The "work process/procedure – equipment-staff analysis method" shall be adopted for the hazard identification. In detail, divide equipment and facility maintenance and commissioning activities, etc. in specific working procedures, divide traveling and passenger transportation activities, etc. in specific work flow, and identify unsafe conditions of equipment and facilities, unsafe conducts of people, industrial hygiene (working environment), emergencies and various hazards of relevant parties respectively with respect to people's activities in the work procedure/process, facilities and equipment, work environment and energy input-output;
- Reference Methods:

Direct Observation method:

By means of data search, site observation, interview and questionnaire, hazards are analyzed. There are two methods mainly:

- Comparison and Experience Method

Compare with relevant standards and examination tables or depend on the observation and analysis ability of analyzers to identify and evaluate hazards by virtue of experiences automatically.

- Analogy Method:

Use the same or similar work condition experience and data to analog and analyze hazards

Table 6: the probability” and “consequence” evaluation method [19]

			Risk ranking matrix R =P×C						
			1	2	3	4	5	6	7
			Extremely minor	Minor	General	Serious	Very serious	Major	Extraordinarily major (Catastrophic)
Physical safety	Number of death		——	——	——	1 person	2-3 persons	3-9 persons	Above 10 persons
Property loss	Direct economic loss		——	——	1-5 million	5-10 million	10-50 million	50-100 million	100 million and above
9	Weekly frequency	≥100 times/year	R3	R2	R1	R1	R1	R1	R1
8	Monthly frequency	30-100 times/year	R4	R2	R2	R1	R1	R1	R1
7	Quarterly frequency	10-30 times/year	R4	R3	R2	R2	R1	R1	R1
6	Yearly frequency	1-10 times/year	R4	R3	R2	R2	R2	R1	R1
5	Frequency per 10 years	0.1-1 time/year	R4	R4	R3	R2	R2	R2	R1
4	Frequency per 100 years	0.01-0.1 time/year	R4	R4	R3	R3	R2	R2	R2
3	Rarely occurrence	0.001-0.01 time/year	R4	R4	R4	R3	R3	R3	R2
2	Very rarely occurrence	0.0001-0.001 time/year	R4	R4	R4	R4	R3	R3	R3
1	Extremely rarely occurrence	0.00001—0.0001 times /year	R4	R4	R4	R4	R4	R4	R4

Where ; AA-LRTS enterprise standards:

- R1 stands for “high risks”/dark red.

- R2 stands for "relatively high risks"/red.
- R3 stands for "normal risks"/yellow color.
- R4 stands for "acceptable risks"/green color.

3.4.1 Identification and Evaluation Steps

- Organize relevant members of the department to launch the identification work, and clarify the identification area and involved production activities and people.
- Select an appropriate identification method according to characteristics of hazards.
- Determine the hazard distribution, category, potential reason and consequence, etc.
- Make a preliminary evaluation on risk levels: evaluate the probability of the injury and damage caused by a hazard and the consequence severity, determine the original risk level of the hazard according to the risk evaluation matrix, prepare control measures, evaluate the residual risk after the measure is adopted, and specify the person in charge of the hazard control.
- The original risk levels are R4 and above, fill the Hazard Risk Evaluation and Application, and submit it to the superior for approval. If the original risk is R3/R4, it shall be checked and approved by each department, and also the Hazard Register shall be filled and submitted to Security Department for recording. If the original risk is R1/R2 or the hazard involving R1/R2 risks is changed, it shall be approved by each department, and the Hazard Register shall be formed, submitted to AALRTS Risk Management Committee for review and then to the General Manager of AALRTS for approval. For R1/R2 hazards of each department, the department shall lead and organize the review and report them to Security Department for R1/R2 hazards across departments, Security Department shall lead and organize the review.

- Department shall transfer the R1/R2 hazard evaluation result to each department, as the basis for the establishment of the target, management scheme, operation control procedures and emergency response plan, and also specify the department in charge of controlling hazards at all levels.
- department shall evaluate its hazards at least once per year, check, supplement, organize and conclude the original hazard list, submit the Hazard Register to Security Department and indicate "New", "Level Change" and "Cancel" in the remark column.
- AA-LRTS announces R1 and R2 Hazard Register of AALRTS once per year. Each department shall organize an evaluation according to the emergency and hazards discovered during the safety inspection, organize the evaluation, and update and distribute the Hazard Register and R1 & R2 Hazard Register in 15 work days after approval [20].

3.4.2. Hazard Risk Control

Risk control is the processes, by which risks are continuously monitored and their conformity to the acceptable level of risk. The general principle is that appropriate and systematic control measures shall be selected according to the difference between the risk evaluation result and risk level and the cost benefit principle.

The occupational safety and health target shall be set, the safety and technical hardware equipment and facilities shall be implemented so as to improve the safety performance according to the economic condition of AALRTS. The target shall focus on the continuous improvement of staff and passenger safety and health protection measure, so as to realize the emergency prevention.

See the table below for control measures for the selection of risks of different levels:

Table 7: control measures for the selection of risks of different levels [20]

Level	Severity	Description	Control measure	Control level
R1	High (Catastrophe)	High risks	1. The Occupational Safety & Health Management Plan shall be established according to the cost benefit principle and considering the feasibility of the technical plan. 2. Thorough control measures shall be selected and the control measure management plan shall be established and implemented. 3. Running control procedures shall be established and revised by classification. 4. The emergency preparation and relevant procedures shall be established/revise and also prepared if necessary; 5. The Dynamic Following List for Hazards shall be established.	AA-LRTS
R2	Relatively high	Relatively high risks	1. Existing control measures shall be used continuously and reinforced mightily. 2. If the risk reduction meets the cost benefit, the new control measure shall be adopted. 3. High-risk hazards can be involved in the management plan if necessary and the Occupational Safety & Health Management Plan shall be established. 4. The Dynamic Following List for Hazards shall be established.	Each department /branch
R3	Normal (Normal)	Normal risks	1. Existing control measures shall be used continuously and reinforced. 2. If the risk reduction meets the cost benefit, the new control measure shall be adopted.	Each department /branch
R4	Acceptable (Minor)	Acceptable hazards	Existing control measures shall be used continuously and new control measures may not be adopted.	Shift

Chapter Four

Proposed Methodology of Risk Management

4.1. Methodology

The design of the level crossing system, for the case of Addis Ababa Light Rail Transit system type and placement of components and full data of all systems, is obtained from CREC. That is risk management of accidents at level crossings for AA-LRT system will be achieved by collecting data of accidents from ERC, CREC and from LRT projects of other countries. In addition the data collection also includes, literature reviewing of different books, assessment of level crossing safety performance and safety measures in some countries, review of the essential and effective safety, measures and priorities for level crossings and finally by direct observation of the operation of level crossing system of AA-LRT. The structure forming the research design steps are presented in figure below.

The proposed methodology is in a flow chart describing a risk management process in a research. A functional definition of risk management is the complete process of understanding risk, risk assessment, and decision making to ensure effective risk controls are in place and implemented. Risk management begins with actively identifying possible hazards leading to the ongoing management of those risks estimated to be acceptable. The various steps given on the generic structure of risk management process are briefly explained below.

- Planned reviews: This is a management function in which reviews are conducted to provide the data needed to monitor operations or develop new project design. This is the data base for an effective safety and loss management system. It would include incident investigation in addition to regular data collected. The objective in this step is to be active, so that gathering the data and doing development analysis in combination with statistical analysis will keep the company out of the difficulty.
- Identification of hazards: One of the importance's of doing such a planned review will be the identification of hazards and concerns or issues. A company's management team will receive the data and, in the judgment of the team, will determine what needs to be considered by means of risk analysis. There are varieties of tools available for hazard analysis, like as HAZOP (hazard and operability analysis), what-if analysis…etc.

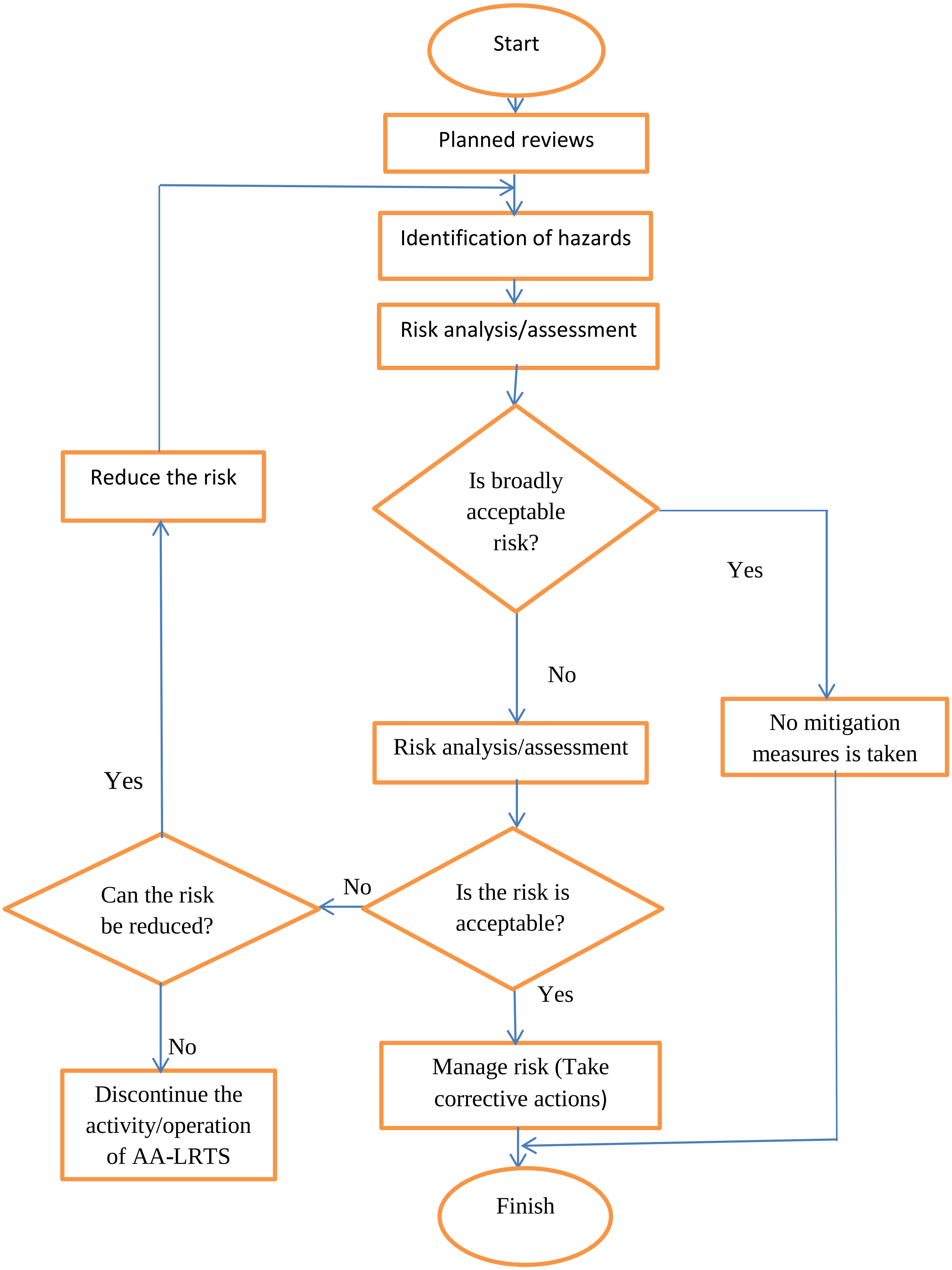


Figure 11: flow chart of the methodology adopted in the research [21]

- Risk analysis/assessment:

  Similarly, there are many tools available to help with risk analysis and assessment. Risk analysis involves gaining an understanding of risk components-probability and consequences. Probability pertains to failure of systems, humans, equipment etc., and in many instances is readily quantifiable. Once the probability and severity of consequences are known, the risk estimated, risk assessment is conducted to determine whether the risk is acceptable or not.

- Is the risk acceptable:

  The management's process uses a risk matrix describing what a low-level risk (acceptable), medium-level risk (acceptable with certain conditions), and high-level risk (unacceptable). The low-level risks are usually acceptable without any further management involvement or design additions. With respect to medium-level risk, management needs to be actively involved to ensure the risk is kept under control; it is worthwhile nothing here that management's responsibilities come to the front as managers are assuming responsibility to accepting the risk.

- Manage risk:

  Once a risk is determined to be acceptable, it must be managed. This is arguably the most important step in the process as the responsibility has now been taken for assuming the risk and preventing any undesirable incidents from occurring. Safety management systems are recognized and accepted worldwide as best practice methods for managing risks. Once a risk is accepted, it does not go away; it is there waiting for opportunity to happen unless the management system is actively monitoring company operations for concerns and taking proactive actions to correct potential problems.

- Can the risk be reduced:

Often there are ways to reduce risks once its level is to be determined unacceptable. The term inherent safety is used to imply methods which will eliminate or reduce risk by tackling the underlying hazards themselves (by substitution of less hazardous material; khan & Amyotte,

2003) [22]. Additionally, further controls, management systems, proactive features, and the like can added to reduce the risk to acceptable level.

- Reduce the risk:

  If the proposed risk reduction measures are possible, then necessary changes must be made to equipment, procedures, and hazardous inventories, etc. It is important to note that once a change is made, the risk management cycle is once again used to evaluate possible new hazards and risks. Changes in engineering processes often create additional potential problems that can unintentionally (and perhaps unknowingly) lead to increased operational risk.

- Discontinue the activity:

  A very important step is to recognize when the risk is too high. Management needs to be strong on this and the right decision. Discontinuing an activity because the risk is unacceptable is the key decision because it says that companies will not do something which is unsafe, damages the property, and disturbs the safe operation and cause loss of life. At this stage, the operation is not permitted or not allowed and it is mandatory for concerned management to make decision on reducing the risk to acceptable level. On the risk management processes risk reduction measures would be implemented, and the risk management cycle repeated to ensure that no new hazards have been introduced, and that the residual risk is being effectively managed. If the risk was deemed to be unacceptable even with the recommendations are fully implemented, then the activity would be discontinued until such time (if ever) that it could be carried out with an acceptable level of risk.

4.2. Modeling Hazard Results with Cause Category of AA-LRT

In order to identify the complete set of hazards surrounding the AA-LRT level crossing of both the E-W and N-S lines under study since Sep. 2015 to Sep 2016, then considering different hazard factors like human factors, engineering infrastructure or track design factors and others..

Table 8: A sample of hazards identified for the AA-LRT under study

Hazards
improperly closed railway gates when the train passes through the level crossing
Drivers forgetting the signals
Low level of public discipline
Road traffic light and interlink with level crossing warning system, near stations
attention blindness and poor knowledge of road rules
People collides with train because of alcohol and drugs
Animals, donkeys try to cross when train approaches level crossing
Road vehicles coming over the RLC where barriers on the other side have been closed
Poor road surface state causing the crossing of vehicles difficult
The railway gates are not working at some level crossings
Technical malfunction of vehicles that it stop in middle of the railway track while a rain is coming to RLC
Poor maintainace of level crossing
Restricted visibility of road signals by the drivers (due to the presence of physical obstruction)
Barriers take too much time to close
Some vehicles cross the level crossing while the train is near by
Absence of road warning and signals especially near the stations
Light signals is not working and do not alert the pedestrians in some stations
Signal transmission gives proceed light while the section is occupied
Light truck destroy the railing machine
Private car damage the electric barrier because the driver not seeing the barrier
Interruption of signal, since it is stroked by private car
Basement of distance measuring pole injured by government car
Signal equipment damaged by private car
OCS protector damaged by government bus
Signal barrier damaged by private car at the level crossing
Approach behavior (high speed) of both vehicle drivers and pedestrian to RLC

After several study and direct observation periods, we identified 26 potential hazards which lead to accidents. The pi-chart in figure below illustrates the distribution of hazards identified by the cause category. According to this chart the hazard categories, “human factors'' and “technical problems”, with respectively 57% and 35% of the overall AA-LRTS system hazards identified, are the two major hazards that can lead to an accident at the AA-LRT level crossing . While, according to pi-chart the hazard categories “environmental factors” and “other factors”, with each 4% of the overall AA-LRTS system hazards identified, are the two minor hazards that can lead to an accident at the AA-LRTS. A detailed analysis of “human factors'' and “technical problems”, categories was needed to understand and identify which actors (people or subsystem parts) are responsible for majority of them and to state if some actions can be undertaken by appropriate authorities to reduce their impact, as a future step for AA-LRTS.

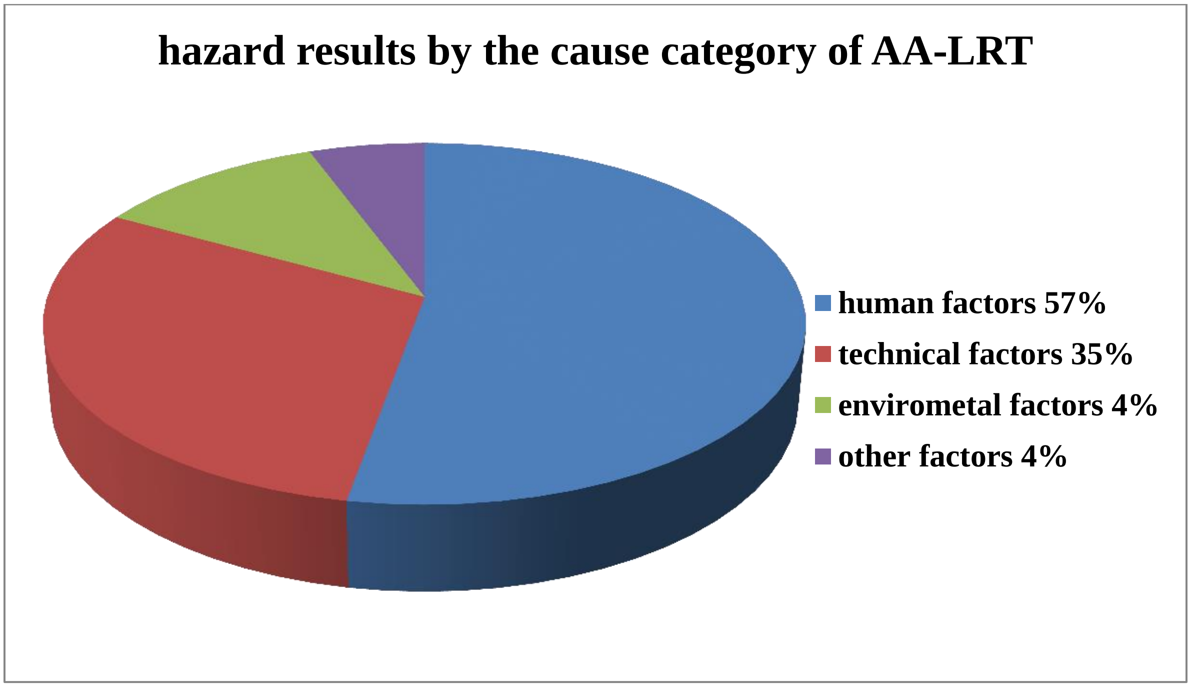


Figure 12: hazards identifications results classified by cause category of AA-LRT.

The next logical step is to take actions to remove hazards with potentially intolerable risk which is with high probability of occurrence and high impact or consequence/severity. These actions should target human actions and technical problems which has high frequency and high severity.

Table 9: AA-LRTS Traffic Accidents record since Sep.2015 to Sep. 2016 [20].

Location	Accident Type	Plate Number	Final Result
NS14 CK10+700	Private car destroy the fence		Compensated
EW10 CK13+180	Private car destroy the fence		Escaped
EW12 CK11+960	Private car destroy the fence		Under process
EW6 CK18+115	Private car destroy the fence		Escaped
NS7 CK16+700	Minibus destroy the railing machine		Under process
EW12 CK11+920	Private car destroy the fence		Escaped
NS6 CK17+750	Private car destroy the fence		Escaped
EW3 CK7+500	Private car rear-ended dump truck		Under process
NS22 CK5+300	Private car destroy the fence		Escaped
EW4 CK18+940	Private car destroy the fence		Escaped
NS8 CK16+542	Private car destroy the fence		Escaped
NS6 19+CK960	Private car destroy the fence		Escaped
EW2 8+100	Light Truck destroy railing machine		Under process
NS10 CK14+225	Private car destroy the fence		Escaped
EW11 CK13+725	Private car destroy the fence		Escaped
NS15 CK11+860	Private car destroy the fence		Under process
NS7 CK16+860	Light Truck destroy railing machine	3-43983 3-13281	Under process
EW1 CK6+156	Private car destroy the fence		Under process
EW5 CK11+810	Private car destroy the fence		Under process
NS25	Private car destroy the fence		Under process
NS7 CK16+710	Private car destroy the fence	3-29167 A.A	Under process
EW7	Private car destroy the fence		Under process
NS8	private car damage electric barrier	3-29167 A.A	Under process
EW5 CK11+710	Private car destroy the fence		Under process
NS22 CK5+320	Private car destroy the fence		Under process
NS25	Private car destroy the fence	1-30335	Under process
NS9	Private car destroy the fence	14971	Under process
NS11	Private car destroy the fence	3705	Under process
NS9	Private car destroy the fence	3-15443 A-A	Under process
EW5	Government car damage fence and signal device also interrupted operation time	Defense- 04864	Compensated(473,132ETB)
NS7	private car on reflector stone	3-74538	Not damaged
NS8	private car pushed protector fence of the pol	3-01846	Not damaged
NS25	private car destroy the colon	3-46094 ET 3-16586 ET	Compensated(1000 ETB)
NS7	Private car destroy distance measurment wire	3-78150/01923 ET	Not damaged

NS26	private car damage the colon	2-76587 A.A	Compensated(1000 ETB)
NS25	private car damage the colon	3-35219 A.A	Compensated(5000ETB
Ns23	private car damage the fence	3-55525 A.A	Compensated(18,000ETB
Ew7	private car damage the fence	2-A 20545	Compensated(36,007 ETB)
NS 26	Anbesa bus damage concrete fence	3-76251	Not damaged
NS8	private car damage the fence	chanse no JTDKV 12350325126	Compensated(2,000 ETB)
NS12	Government car damage the fence	4-22404 E.T	Compensated(1,000ETB)
NS 10	private car damage railway hand rail	3-28463 O.RO	Compensated(14,788ETB)
NS11	private car damage railway hand rail	3-55739 E.T	Escaped
NS 6	Government car damage the fence	4-21129	Compensated (33,043.50ETB)
NS 7 (next to level cross)	Private car damage the fence	3-41470 E.T	Under process
On NS 27 (giorgis)	Elevator basement concrete scratched	3-121320 S.P	Compensated (10,435ETB)
Between NS 6 and 7	Railway fence damaged		Escaped
EW 14 (bambis)	Railway fence damaged	117-003- C.D	Compensated (24,210ETB)
NS 15 (meshualekia)	Railway fence damaged	2-72710 A.A	Compensated (22,700ETB)
EW 9(megenayga)	Private car scratched the railway concrete fence	2-87437 A.A	Not damaged
NS 7 (level cross)	private car damage distance measurment pol concrete basement	3-34905-03-09562 E.T long vehicle	Escaped
NS8(saris abo)	Railway fence damaged	3-69588 E.T 3-20488 long vehicle	Compensated3,950(ETB)
NS 8 (level cross)	Anbesa bus damaged distance measurment pol concrete basement	3-73698 A.A	Compensated15189(ETB)
Between NS12 and 13	Railway fence damaged	2-70440 A.A	Compensated(38,837ETB)
Between EW 7-8(gurd Shola 1and 2)	Railway fence damaged	UN2006	Under process
Between NS14-15 (meshualekia)	Railway fence damaged	2-40593 A.A	Compensated(31,082ETB)
Between EW 13 and EW 14 (bambis)	Railway fence damaged	2-46070 A.A	Compensated77,612(ETB)
EW 1 (Hayat)	Vehicles distance measuring wire damage	3-649600 E.T	Compensated13,820(ETB)
EW 1 (Hayat)	Ticket office damaged	48341 A.A	Compensated(48,550.21ETB)
Between NS14-15 (riche)	Railway fence damaged	2A-79282 A.A	Under process
Between NS 14-15 (meshualekia)	Railway fence damaged	2-11578 A.A	Compensated(31,945ETB)
EW 5(Civil service)	Railway fence damaged	2-A03663 A.A	Compensated (1,318ETB)
NS 10 (Kadisko)	Private car damage railway hand rail	3-A08495 A.A	Compensated(10,292 ETB)
EW 14 (bambis)	Railway fence damaged	2-A70027 A.A	Compensated (3,918ETB)
NS7(Abo)	Anbesa bus damage railway fence	3-77154 A.A	Compensated (2,784ETB)
Between NS 21 and	Railway concrete guard fence scratched	3-77312 A.A	Compensated (1,610ETB)

22(sebateyga-abn)			
EW8(gurd shola 2)	Railway plastic guard fence scratched	3-11461 -3-04132 E.T Long vehicle	Compensated (2,241ETB)
NS9(level crossing)	Signal equipment damaged	3-A29832 A.A	Compensated (59,882ETB)
EW2 (meri)	Railway concrete guard fence scratched	3-27094 A.A	Compensated(1,610ETB)
between NS 22 and 23	Railway plastic guard fence damaged	1-07961 A.A	Compensated (2,486ETB)
EW 3	Railway plastic guard fence damaged	3-73458 E.T	Under process
Between NS 22 and 23	200mm PVC pipe damaged	3-81410 A.A	Compensated (3,738ETB)
EW20 station	Hand rail the marble foundation damaged	3-20151 O.R	Compensated (10,729ETB)
NS 6 (gumruk)	Manhole damaged	3-07809/3-04631 E.T	Compensated (10,508ETB)
Between NS6-7	Railway plastic guard fence damaged	esp.- 237 A.A	Compensated(12,729ETB)
Between EW6-7	Railway plastic guard fence damaged	2-A67258 A.A	Compensated(1,900ETB)
NS6-7	Railway plastic guard fence damaged	1-28404 A.A	Compensated(11,419ETB)
Between NS9-10	Railway concrete guard fence damaged	2-A63039 A.A	Not damaged
EW 3(Cmc)	Railway signal and communication material damaged	2 -A33524 A.A	Compensated(54,609ETB)
NS 12 station	Private car damage railway hand rail	2-A76241 A.A	Compensated(5,331ETB)
Between NS 22-23	Railway plastic guard fence damaged	3-33084 O.R	Compensated (31,704ETB)
Next to NS12 station	Railway plastic guard fence damaged	3-09676 O.R	Compensated (19,619ETB)
Between EW9-8	Railway plastic guard fence damaged	3-65299 A.A	Compensated (19,619ETB)
NS13-14	Railway plastic guard fence damaged by motorcycle	2-5294 A.A	Escaped
NS7(Abo) level crossing	The basement of distance measuring pole broken	3-46587/14095 ET	Compensated(1,000ETB)
EW3-4	Guard fence damaged	3-5344 A.A	Compensated(539ETB)
EW3	The concrete block fall	2-79889 A.A	Not damaged
Between EW9-10	Guard fence damaged	3-53132 E.T	Escaped
NS9(adey abeba)	Signal equipment damaged	3-16416 O.R	Compensated (24,054ETB)
Between NS 7-8	Guard fence damaged	3-36376 E.T	Compensated (27,197ETB)
Between NS 12-13	Guard fence damaged	1-16325 A.A	Compensated (4,230ETB)
NS 6(gumruk)	Guard fence damaged	3-44336/13229 E.T	Compensated (5,021ETB)
between NS 22-23	Guard fence damaged	1-14161 A.A	Compensated(9,961ETB)
EW14-13	Guard fence damaged	2A61060 A.A	Under process
EW13-12	Guard fence damaged	2A-28399 A.A	Compensated (49,364ETB)
NS13(temenja yazh)	Guard fence damaged	3A-04858 A.A	Compensated(9,976ETB)
NS 27(giorgis)	Fire extinguisher pipe damaged	2A-43184 A.A	Compensated(16,388ETB)
NS15(Meshualekia)	Signal equipment damaged	3-30769 O.R	Compensated (24,054ETB)
NS7-8(Saris)	Guard fence damaged	3-10370/3-03758 E.T	Compensated (9,221ETB)
EW7(Gurd shola)	Signal equipment damaged	3-74124 E.T	Compensated (21,815ETB)
EW 1(Ayat)	Guard fence damaged	2A-73445 A.A	Compensated (21,197ETB)

EW7-6	Guard fence damaged	2A-34672 A.A	Compensated (7,674ETB)
NS14-13	Guard fence damaged	2A-63998 A.A	Compensated (49,364ETB)
NS14-13	Guard fence damaged	2-4312 A.A motor cycle	compensated (8,292ETB)

4.3 Accident Types and Analysis of AA-LRTS

In this thesis study, due to small number of recorded accidents data on level crossing, we were considered the one year accident data of the whole railway system of AA-LRTS, even though; the study depends (focus) on only AA-LRTS level crossing.

According to the risk evaluation basis and criteria, in connection with the specific condition of AALRTS, the "probability and consequence combination analysis method" are mainly adopted in the evaluation process.

Accident type	Risk ID	Frequency/year	Impact (financial loss)/year
Private car damage guard fence	RD1	54/year	34,129 dollar
Signal equipment damaged	RD2	6/year	32,877 dollar
Fire extinguisher pipe damaged	RD3	1/year	819 dollar
The basement of distance measuring pole broken	RD4	5/year	1500.45 dollar
Railway plastic guard fence damaged	RD5	10/year	5,086 dollar
Railway concrete guard fence damaged	RD6	7/year	161 dollar
Manhole damaged	RD7	1/year	525 dollar
Private car damages railway hand rail	RD8	4/year	1970 dollar
Ticket office damaged	RD9	1/year	2528 dollar
200mm PVC pipe damaged	RD10	1/year	187 dollar

Elevator basement concrete broken	RD11	1/year	521.75 dollar
Private car damage the colon	RD12	4/year	350dollar
Private car damage electric barrier	RD13	1/year	Under process
Light Truck destroy railing machine	RD14	3/year	Under process

Table 10: Integrated "probability" and "consequence" evaluation method of Accidents for AA-LRTS.

Table 11: generic "probability" and "consequence" or risk ranking matrix

C/P	1(insignificant) <10,000 dollar financial loss	2 (minor) or loss (10,000 - 100,000) dollar	3 (major) (0.09-0.9)million dollar loss	4 (serious) (0.9-9)million dollar loss	5 (catastrophic) >9million dollar Loss
5 (frequent) >90% or >1/year	Medium	High	High	(Extreme) operation not allowed	(Extreme) operation not allowed
4 (very likely) 61-90 % or 1/year	Medium	Medium	High	High	(Extreme) operation not allowed
3 (possible) 41-60% 1/5 year	Low	Medium (acceptable)	Medium	High	High
2 (unlikely) 10-40% or (1 to 2)/10 year	Low	Low	Medium	Medium	High
1(rare) <10% or 1/10year	Low (broadly Acceptable)	Low	Low	Medium	Medium

According to as low as reasonable practicable (ALARP) principle and generic risk ranking matrix shown in table17 above, each of the identified accidents of AA-LRTS would be given a priority order to take control (mitigation) measures and to pay maximum funding for accidents with (unacceptable level) high risk which has high “severity” or impact and high “probability” as follows:

Generally, according to as low as reasonably practicable (ALARP) principle only two accidents (guard fence damage and signal equipment damage) are considered as intolerable, red condition (high risk) accidents, which cannot be justified or accepted except, in unexpected conditions. Therefore; we must first reduce them to acceptable level, document or register the risk and we must monitor and review it every time.

The other accidents are considered as tolerable risk (yellow condition), but risk mitigating measures should still be applied, provided that they are capable of practical application, document or register the risk and we must monitor and review it every time and the benefit to be gained exceeded the cost of their application. Tolerable risk, which can be accepted only if risk reduction is impossible or the cost of risk reduction is greatly, exceeds the benefits gained.
None of the recorded accidents are broadly acceptable, green condition (negligible) in AA-LRTS, which risk mitigation measures is not needed, but document or register the risk and we must monitor and review it every time.

4.4 Risk Control Strategies of Level Crossing of AA-LRTS

This research explains the prioritization of Strategies of risk control (mitigation measures) in accordance with those which: eliminate cause; prevent accident occurrence, and mitigate the consequences of accidents for AA-LRT. It also classifies control measures Interms of those related the level crossing itself and those related to physical environment of the crossing.

A list of possible control measures identified in my study which is recommended for AA-LRTS are as follows:

- Synchronizing (coordination) of train and road signal at RLC of stations,
- Establish interface agreement between track and road authority,

- Slowing down speed of both vehicle and train at approach of RLC,
- Reducing the train crossing/gate closing time by half, because the gate closes for long time before train approaches to level crossing,
- Giving awareness (educating) RLC users about RLC rules and accidents of RLC,
- Building bridges (over pass or under pass) at location of RLC,
- improve road surfaces over crossings,
- Replace all fixed warnings lights by flashing lights, or colored light to provide a visual indication to the user of whether, or not, it is safe; to cross, these may also be combined with audible alarm.
- strengthening of regulations against unsafe driving practices and road transport operations, e.g. bans on heavy goods vehicles at small crossings, increased penalties for violations,
- progressive abolition of level crossings through their integration with overpass or underpass between rail and road,
- Public service advertisements in the mass media (TV programme, Radio programme, Newspapers, etc.)
- Participation in traffic safety week and assistance for school and community education programme covering level crossing safety, and
- Presentation of lectures at short courses offered at driving schools and by driver licensing authorities for the renewal of driver’s licenses.
- Installation of barriers or gates to physically prevent vehicles or pedestrian users from crossing the railway.

Chapter Five

Findings and Discussion

5.1. Findings

Findings (outcomes) and discussions are described in this chapter. The findings in this research includes cause category and analysis of identified hazards of AAA-LRTS which leads to accidents if it was not mitigated from the beginning, analysis of one year recorded Traffic Accidents of AA-LRTS, finding priority order for treatment of the three level of risks based on ALARP and risk ranking matrix, and fatality rate, injury rate for three types of level crossing protection (railway-controlled, automatic and passive crossing), and the risk reduction mechanisms of other countries (UK, USA and Japan) experiences on level crossing risk reduction or generic safety risk management system will be familiarized to AA-LRTS.

A detailed analysis of "human factors'' and "technical problems", categories was needed to understand and identify which actors (people or subsystem parts) are responsible for majority of them and to state if some actions can be undertaken by appropriate authorities to reduce their impact, as a future step for AA-LRTS.

For the cases of one year recorded traffic accidents of AA-LRTS, only two accidents (guard fence damage and signal equipment damage) are considered as intolerable, red condition (high risk) accidents, which cannot be justified or accepted except, in unexpected conditions.

The other accidents are considered as tolerable risk (yellow condition) and none of the recorded accidents are broadly acceptable.

- On railway- controlled crossings, the accidents rates have declined.
- On automatic crossings, the accident rates are higher than on railway-controlled crossings and have not declined, even though the average crossing usages are similar.
- The safe operation of passive crossings and its accident rate is much lower than automatic crossings, primarily, because, not being public roads, their usage is lower.

Railway-controlled crossings are the best performing crossing type with falling fatal accident rates, minimizing the chance of Accident and will be recommended for the future AA-LRTS.

5.2. Discussion of Result

The discussion from the above result or findings is presented as follows:

According to as low as reasonable practicable (ALARP) principle and risk ranking matrix, most of the identified hazards and recorded accidents of AA-LRTS are caused due to human factors and technical problems, which has high frequency and high severity in the current AA-LRTS.

Generally, each risk is rated on its probability of occurring and impact on an objective if it does occur. Then using risk ranking matrix the organizations threshold for low risk (green condition), moderate risk (yellow condition/Acceptable level), or high risk (red condition/unacceptable level) determine whether the risk is scored as high, moderate, or low for that objective of the organizations. All the acceptable conditions are treated as a safe with respect to corresponding severity and probability value of risk or if the benefit obtained is greater than cost of risk reduction. On the other hand, the unacceptable condition represents a chance of collision between road and train traffic movement or high risk condition and naturally becomes the point of concern of AA-LRTS.

On the other hand, level crossing experiences from other countries shown that, railway-controlled crossings are best performing than automatic and passive crossings When we considered the balance between safety, cost and delay time, and falling fatal accident rates, ensuring safety to peoples, vehicles and train.

Chapter Six

Conclusion and Recommendation

6.1 Conclusion

This research identifies hazards and uses Qualitative Approaches which is (ALARP) of risk analysis of accidents of safety risks to railroad level crossings, characteristics of the crossing environments, and taken some treatment (mitigation) strategies or measures for AA-LRTS. Now it is important to determining the types of risk and evaluating their levels becomes increasingly higher and it is better to decide in the implementation of quick actions to shift from higher risk levels to acceptable lower risk levels of AA-LRT.

Risk management process is a long term cycle and its importance should not be missed at any time. All steps in the risk management process must be followed, risk identification not being enough for improving safety and reducing risk or accidents for AA-LRTS. Risk identification should be done with greater care, and all risks must be identified and treated carefully. Its results help managers to implement the most efficient control mechanisms that bring the greatest benefit to the Railway organization of AA-LRTS.

It is clear that the railway-controlled level crossings are relatively safe, and that may partially account for the good safety record at level crossings records in Britain and should be bests for future AA-LRTS.

For railway-controlled crossings, the trend in accidents per crossings per a year is significantly downward, but flat at passive crossings, and non significantly upward (as well as higher) at automatic crosings.

It is concluded that most of the accidents happened in AA-LRTS level crossings are due to driver behavior (human factors) and in fact that the majority of drivers did not search (look) for the train at passive crossings which shown the failure of passive crossing systems and low vehicle driver reaction to passive crossings.

6.2 Recommendation

This research must be considerable and additional control actions (participating in operation lifesaver, building bridge, implementing railway-controlled crossing, synchronization of signal at stations, by reducing railway gate closing time by half, giving priority for mitigating accidents caused by human factors and technical problems, etc.) must be taken by AA-LRTS rail industry to better safety at level crossing and upgrades to improve level crossing safety performance of AA-LRTS.

- If there is planned evaluation, quantitative risk assessment is recommended to make a qualitative one (low cost).
- Typically, for major (high) risks it is recommended to use of quantitative evaluation methods that provide and accurate estimation of the possible consequences. Qualitative risk analysis is rapid and cost effective means of establishing priorities for planning risk treatment and to perform quantitative risk analysis, for future AA-LRTS.
- The conclusion is that when a qualitative risk assessment is made, a great deal of work for quantitative assessment using computer based-program can be considered for the future AA-LRT.
- Other level crossing upgrading measures (road under pass or over pass) of level crossings with high traffic moment (volume) like as Ayat, torhailoch and saris for the future AA-LRTS.
- Besides to this, it recommended to do installation of barriers or gates to physically prevent vehicles or pedestrian users from crossing the railway.
- Finally, it is recommended that, AA-LRTS to apply all the possible strategies for risk management of accidents at level crossing and carefully using the experiences of other countries on railway level crossing protection systems and generic risk management process presented in this thesis.

References

[1] China railway group limited (2013 Jun.) “ERC construction agreements, certificate of engineering design”, No: A151000179 Jun 2013, pp. 1-12.

[2] Beard, M.J,Chawla H “Use of Risk Models and Risk Assessment for level Crossings by other crossings”, Research report by Arthur D. little on behalf of the Rail safety & standard Board,(2007).

[3] Kankan railway corporation limited, “cost effective system for railway level crossing protection’ ’Belapur Bhavan, plot No 6, sector- 11,CBD Belapur, Navi Mumbai- 400 614.

[4] “Major railway level crossing accidents”: http://en.wikipedia.org/wiki/list of level crossing accident, November 17, 2016, 5:35am.

[5] Caird, J. k., Creaser, J.I., Edwards, C.J., Dewar, R.E. (2002) “A Human factors analysis of highway-railway grade crossing accidents in Canada”. Fourth workshop on highway-railway grade crossing research Montreal, Quebec, Transportation development center, publication distribution services.

[6] Kirsi Pajunen, “traffic safety at railroad level crossing’’ VTT communities and infrastructure of Finland, June 2012.

[7] Amit Kumar, “Human Behavioral Aspects of Level Crossing Safety Special Reference to Indian railways’’, volume (6) n=Number (1), February 2012, ISSN 1995-665.

[8] Alikhani, A. 2009, “Proposed risk control in strategic management project for Qomrud river in Iran’’, international journal of energy and environment, volume 3, No. 3, pp. 112-121.

[9] EN 50126: “Railway application-The specification and demonstration of reliability, availability, maintainability and safety (RAMS)’’, CENELEC, 1999.

[10] P.R.Cheesewright, “Recent Developments in Risk Assessment in Rail”, paper presented at safety on euroupean railways conference, London, 4 December 1997.

[11] M. Rausand and A. Hoyland, “system reliability theory; Models, statistical methods and applications’’, Wiley: New York, 2004.

[12] Operations Lifesaver (2016). http:/www.operationlifesaver.ca/facts-and-stats/train-safety-faq/. February 17, 2017, 5:35am

[13] Level crossing; A guide for managers, designers and operators, Railway safety publication 7, office of Rail Regulation, December 2011(Para 2,155).

[14] FRA statistics, as reported on the operation lifesaver website, October 1999.E. Schneider, R. Slovak, and S. Wegele, "New and Conventional Measures for Quantifying Risk in Rail Transport", J, system safety, vol.41, no.1, February 2005.

[15] Indian railways country paper, "Scale and severity of railway level crossing accidents in India".

[16] Saccomanno, F., FU, L., REN, C., Miranda, L. (2003) "identifying highway-rail grade crossing black spots in Canada", phase 1 TP 14168E. Montreal Quebec, transportation development center, Transport Canada.

[17] ERA (European Railway Agency). "A summary of 2004-2005 EU statistics on railway safety". Source of data: Eurostat.

[18] Kokash, N. & Andrea, V. 2006, "Evaluating quality of web services: A Risk-Driven Approach'', Technical Report # DIT-06-093, University of Trento, Italy.

[19] Li Linyuan, "Hazard Identification and Risk Evaluation & Control Procedures" (Rev. A), AA-LRTS, August 2015.

[20] Operation Accident Management Regulations, Safety Department of AA-LRTS.

[21] Khan, F.I. & Amyotte, P.R. (2003). "How to make inherent safety practice a reality. Canadian Journal of Chemical Engineering", 81, 2-16.

[22] AA-LRT project, "signaling system ''vol. 1, page 9-11.