

Safety and risk analysis at railway crossings of north-south Addis Ababa light rail

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Abstract

Purpose – Railway-level crossings (RLCs) are the point of intersection between rail and road users and are therefore hotspots of road-rail user conflict and catastrophic collisions. The purpose of this study is to assess the risks associated with RLCs and suggest probable reduction measures. Through questionnaires and visual inspection, the authors identify the safety risks, hazards and hazardous events at some railway crossing of Addis Ababa light rail transit (AA-LRT) north-south (N-S) route. The identified risky events are then categorized based on As Low As Reasonably Practicable (ALARP) principle and generic risk ranking matrix. The authors then examine existing safety management measures at railway crossing and assess the need for additional safety management. Five major crossings on the 16.9 km (10.5 mi) N-S line, starting from Menelik II Square to Kality, were considered for the study. This study is carried out by data collection from about 145 stakeholders and the application of statistical data and risk analysis methods. The major findings of this study and the recommendations for improvement are suggested.

Design/methodology/approach – The research followed a case study approach. Through questionnaires and visual inspection, the authors identify the safety risks, hazards and hazardous events at some railway crossing of AA-LRT N-S route. The identified risky events are then categorized based on ALARP principle and generic risk ranking matrix. Collected data was then analyzed using SPSS to deduce relationships.

Findings – The study findings reveal human factors as the greatest cause of accidents, injury or death. About 22% of hazards identified by category are human factors, whereas 20% are because of technical

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Authors wish to thank the African Railway Center of Excellence and employees of Ethiopian Railway cooperation (ERC) for the support offered during the study.

Funding: No funding was received for this research.

Conflict of interest: The authors declare no conflict of interest.

Informed consent statement: Informed consent was obtained from all subjects involved in the study.

Author contributions: Jackson Sekasi: Conceptualization, methodology, software, validation, formal analysis, writing – original draft, review and editing. Habeeb Solihu: Conceptualization, methodology, writing – review and editing, visualization. All authors have read and agreed to the published version of the manuscript.



problems. Intolerable risks stand at 42%, whereas the tolerable risks are at 36% according to risk classification results as per the ALARP model. Because the process of risk management is a long-term cycle, its importance should not be missed at any time.

Research limitations/implications – Because of design considerations of RLCs and the difference in generalized human behaviors for people of a given region, the results are limited to AA-LRT RLCs. This study opens a discourse for detailed evaluations, qualitative and quantitative analysis into the categorized identified hazards. There is also room for additional research into the performance of RLCs aimed at formulating standard necessary features that should be included on RLCs for proper risk control especially in emerging economies.

Originality/value – The research paper is original and has not been submitted for consideration to other journals.

Keywords Risk analysis, Railway safety, Addis Ababa light rail, Railway, Railway-level crossings, Safety risk assessment

Paper type Research paper

1. Introduction

Because of ongoing urbanization and industrialization coupled with a population boom, the African continent is experiencing transportation challenges. To meet these challenges, the establishment of large-scale transport services is needed in almost all major cities. This has given birth to a railway renaissance, because the current transportation challenges can only be handled by railways. Railways are the safest and the most economical ground transport means for commuters (An *et al.*, 2013). Addis Ababa city, with support from the Federal government of Ethiopia, has responded positively to the above challenges by putting railways at the forefront of all transport modes. For example, the construction and operation of the light rail transit service in Addis Ababa under the Ethiopian Railway Corporation (ERC) has been highly successful in addressing the urban transportation issues of commuters.

Railway systems also have their own risk and safety issues. According to An *et al.* (2013), risk in the railway industry can be defined in relation to accidents and incidents leading to fatalities or injuries of passengers and employees. Among several possible hazards, level crossings are very important hazard potentials in any railway system. This paper focuses on the hazard potentials of railway crossings in some parts of the railway tracks in Ethiopia.

A grade or level crossing is defined as an intersection between a roadway and a railway at the same elevation or grade (Liang *et al.*, 2017; Yang *et al.*, 2017; Michalik *et al.*, 2019; Keramati *et al.*, 2020; Zhou *et al.*, 2020). Safety is a core issue in railway operation (Liang *et al.*, 2017) and in terms of rail transport safety, grade crossings have created serious conflicts among rail and road transport (Yang *et al.*, 2019; Havârneanu and Ma, 2020). They have some of the most complicated road safety concerns because of the amalgamation of road vehicles and rail infrastructure and the mixture of trains together with train services (Tey *et al.*, 2011). Any of the railway-level crossings (RLCs) can be a hotspot for collisions between users and vehicles of both road and rail, which can lead to property damages, injuries, fatalities and traffic delays that correspond to enormous economic losses “and even the release of hazardous materials” (Chadwick *et al.*, 2014). Such accidents persistently present a significant burden to society in terms of human and financial expenses (Larue and Wullems, 2015), and therefore, these collisions are a source of concern to railway authorities and the public at large (Zhang *et al.*, 2018; Saccomanno, 2019).

Safety and risk problems at RLC can be grouped into railways and highways. Railways represent components such as the level crossing, rolling stock and the track, whereas highway components include the vehicle, pedestrians, road furniture and road segments. All the above are representative risk components at RLCs in regard to their functionality and characteristics.

More than 20 level crossings that exist on Addis Ababa light rail transit (AA-LRT) represent a significant safety hazard to road and rail users combined (Ababa *et al.*, 2019). Many studies concerned with a range of issues on RLCs safety levels have been done in different countries (Hu *et al.*, 2010). At RLCs, accidents originate from either a single factor or from a combination of many other factors. Collectively, the two broad categories of origin for such collisions are unintentional error and intentional violation (Liang *et al.*, 2017). The problem would be solved by physically separating roads that intersect with railway tracks. However, this is farfetched as such arrangements are costly and would drastically impact the mobility of the people affected. This, therefore, implies that this is not a viable venture and direction.

In most cases, collisions at level crossings happen because of several reasons like lack of awareness of pedestrians or drivers about an approaching train, misjudgment of its arrival at the crossing as indicated by the following figures: Figure 1 choose to ignore warning signals like in Figure 2 or intentionally evade the barriers intended to safeguard pedestrians against accidents and risky occurrences (Victorian Auditor-general, 2010). In Figure 3, we have uncoordinated movement at an RLC. This kind of noncompliant behavior together with the failure to detect the crossing or train or a poor time-to-arrival estimate causes accidents at crossings (Landry *et al.*, 2019).



Figure 1.
Pedestrians crossing
in front of an
approaching metro at
Adey Abeba RLC,
photo taken on
January 27, 2020, by
the author



Figure 2.
Traffic officer trying
to stop pedestrians
and drivers by
showing them an
approaching metro at
Sebategna RLC,
photo taken on
January 27, 2020, by
the author

This study has been motivated by the fact that RLC risk and safety is among the most critical and pertinent issues in the railway industry that calls for an instant improvement. In the context of Addis Ababa city, where congestion continues to increase on the nation's roadways and commuters continue to flock to public transit as an alternative transportation mode, the safety and security of all passengers have to be ensured and improved at all times. Several accidents and fatalities have been reported in various RLCs of the AA-LRT in the past. A systematic study on the hazard potential and safety issues is essential to plan and execute actions to improve the safety and risk at RLCs.

The rest of the paper is organized as follows. Section 2 presents the literature review related to the risk and safety issues at rail-level crossings. Section 3 presents the research methodology followed in this paper. Section 4 shows the results of the study, and Section 5 presents conclusions and recommendations of the study.

2. Literature review

International Organization for Standardization defines safety as the release from unacceptable risks, a risk being a combination of harm probability and gravity of the harm. Risk implies the chance of occurrence of an unwanted event together with the consideration of the magnitude of loss that will result from such an event (Hadj-Mabrouk, 2019). It includes events that affect safety (fatalities, injuries of passengers or employees, serious material damages) or transportation stability (delay).

As an integral part of the railway system, railway crossing provides a means of passage at points where the rail/road routes cross each other thereby playing an essential role in the urban rail operation. Grade crossings are locations on the railway system where the railway track intersects with the road, and these locations present a high risk of collision because of the potential of conflict between roadway traffic and trains.

RLCs safety is just a piece of an enormous brick of transport safety within the transport system block. It is a major public concern in our daily life (Beanland *et al.*, 2018). Annually, a lot of individuals succumb to death as a result of road accidents. Considering several road accident types, those that occur among rolling stock and road vehicles are regarded to cause the greatest impact in the form of financial losses and also the toughest of all accidents. Thus, the operation safety and risk management of these crossings are very crucial and draw much consideration from city government administration and other stakeholders. According to Dezhkam and Eslami (2017), safety is a major public concern in our daily life.



Figure 3.
Uncoordinated
movement of vehicle
and people at
Sebategna RLC,
photo taken on
January 27, 2020, by
the author

If we are to improve the RLC safety, the important issue is to know how traffic accidents happen and their potential impacts and study how they can be avoided. [Fan et al. \(2016\)](#) further argues that according to accident or risk analysis, level crossing accidents usually result in many casualties and property losses. Generally, the risk level of transportation is evaluated by two indices, including accident frequency and severity. Overall, there is a considerable decrease in grade crossing accidents around the world mainly because of the provision of active traffic control equipment at RLCs ([Liu et al., 2015](#)). For example, [Mok and Savage \(2005\)](#) argue that the number of collisions and fatalities at rail-highway intersections in the USA has declined significantly over the past 30 years, despite considerable increases in the volume of rail and highway traffic.

In Ethiopia, from the data collected, total grade-level crossings crashes have been 22 in five years as shown in [Figure 4](#).

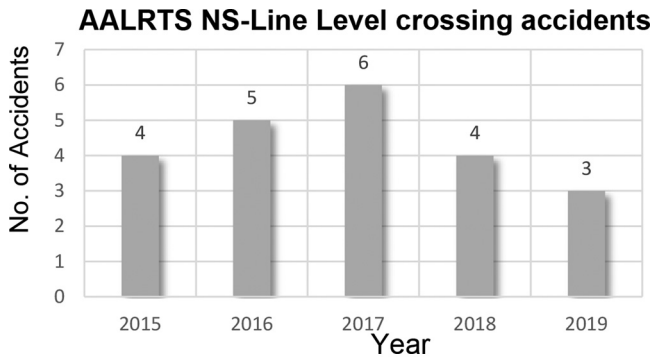
In India, as per records of Indian railway, 66% of fatalities with deaths because of accidents at crossings have hovered around 300 for almost a decade, now with 40% of the train accidents occurring at level crossings ([Edla et al., 2020](#)). Here, level crossing collisions are more frequent and consequently more severe, because they involve injuries and death to many both rail and road users as well as property damage and transportation delays.

Also in five years from 2001, it is approximated that more than 400 accidents that resulted in 125 mortalities and 153 injuries took place at close to 630 RLCs in Taiwan. According to the board of transportation safety in Canada, each year from 1992 to 2001, an average of 47 people lost their lives as a direct result of grade crossing ([Saccomanno, 2019](#)).

The European Union annually records over 300 deaths resulting from collisions at level crossings ([Laapotti, 2016](#)). During the years 2008–2012, 59 level crossing accidents (of which 37 were collisions with motor vehicles) occurred on the Swedish railway network in all rail operations except for the metro and tram ([Jonsson et al., 2019](#)). Perhaps, a more generalized indication of the level crossing collision events in some countries that form the European Union is shown in [Figure 5](#). It can be seen that the RLCs safety-level records of Great Britain rate extremely higher compared to any other country in Europe.

It can be seen from the above that RLC incidents are a serious concern because of the fatalities, injuries and property damage, and productivity losses that they cause and, more severe than at other locations.

Such occurrences lead to economic hardships and financial constraints to government agencies and railway authorities mainly because of disruptions in service delivery and the damages caused to trains, track, equipment and delays in train movement ([Soleimani et al.,](#)



Source: Grey Literature

Figure 4.
Number of accidents
that have occurred on
RLCs of Addis-
Ababa Metro

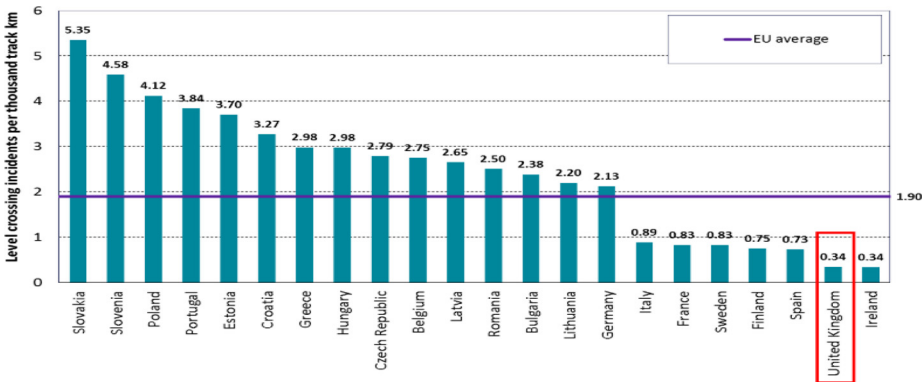


Figure 5. Number of level crossing incidents per thousand track kilometer

Source: Network Rail 2015

2019). Nevertheless, traffic engineers have made great efforts to improve safety at rail track-road intersection points (Hao *et al.*, 2016).

On types of RLCs, they can be public or private based on who is responsible for their maintenance.

On classifications, RLCS are generally classified according to the protection systems with which they are equipped. If based on warning systems, they can be either passive or active crossings. Passive crossings use static warnings devices like stationary stop signs, whereas active crossings are controlled by automatic warning systems using flashing lights. A huge quantity of RLCs is classed as “passive” level crossing types, implying they do not have automatic warning systems and safe crossing is the responsibility of the road users.

The primary method of operation for the passive crossings is through users observing whether it is safe to cross, which in most cases increases, which in turn increases human factor-based risks.

The last major classification of RLCs is the railway-controlled crossings. For such RLCs, the crossing train or motor vehicles are under the control of a railway staff or signaller who closes and opens the crossing aided by the transmitted railway signal (Evans and Hughes, 2019). The mechanism of operation is that the signal is interlocked to the railway movement. In this way, it is impossible to allow train passage except when the level crossing is completely shut off to road users (Evans, 2011). Modern railway-controlled crossings use CCTV, have obstacle detection technology, and use lifting full barriers.

2.1 Definition of key terms and concepts

2.1.1 Preliminary hazard analysis. Preliminary hazard analysis (PHA) is a semi-quantitative risk analysis method that is mainly used at the system level. PHA is intended to recognize potentially risky and hazardous events that exist within the “transport system and its interfaces” with a view of establishing means on how to manage and control these events (Hadj-Mabrouk, 2019).

2.1.2 As low as reasonably practicable As low as reasonably practicable (ALARP (Jones-lee and Aven, 2011) approach/model is about weighing the risk against the sacrifice needed to further reduce it (Hurst *et al.*, 2018). It means that risks should be reduced to the lowest level possible to minimize their consequences in terms of costs, delays, damage and fatalities.

3. Methods and materials

3.1 Research design and study population

The paper, in a transformative way, builds on AA-RLT level crossings as a case study to fulfill the study objectives. [Hollweck \(2016\)](#) suggests that any research in the form of a case study has a functional and legitimate role in doing evaluations, which is part of the research objectives. Case studies are an adequate research strategy for complex phenomena that cannot be studied outside their context and for providing an in-depth investigation ([Abdul Rasid et al., 2014](#)).

This study was conducted at level crossing across the north-south (N-S) line of AA-LRT. The five selected RLCs included level crossing at Piasa, a signaled level station between stadium and Meshwlekya stations, level crossing at Adey Abeba, level crossing between Saris and Abo junction stations and RLC 30 m away from Sebategna train station. The N-S line of AA-LRT has 17 stations in total with some of these ground stations being used as a level crossing for pedestrians and passengers. However, some level crossings are located at various other locations.

The study is executed by interaction with a selected sample of people. The target population of the study was 300 people and the readily accessible population was 145 people. These included eight employees of ERC, 57 train passengers, 30 security personnel overseeing the level crossings on behalf of the government and 50 readily accessible community members around the RLCs.

3.2 Sampling techniques and procedures

Sampling in the form of both probabilistic and non-probabilistic sampling techniques was used in the study.

This was through the use of semi-structured questionnaires that the researchers administered to railway passengers and pedestrians that they found during the study. Purposive and convenience sampling was done on ERC employees especially those who disburse tickets, the rail guards found at the same level crossings and local people who own businesses like shops that are close to the level crossings and who spend much of their day-to-day business near the RLCs considered in the study. Because purposive sampling can provide adequate representation and balance of knowledge and experience ([Zuofa and Ochieng, 2017](#)), it was considered an appropriate approach to adopt. Convenience sampling involves the researcher choosing respondents because they are at the center of the study, are readily available in terms of time, are accessible and are willing to take part and contribute to the study ([Young, 2015](#)).

Even though probability sampling is extremely honored as regard scientific merit, samples taken at one's convenience are regarded as a standard within developmental science ([Jager et al., 2017](#)).

3.3 Data collection instrument

The instruments used to collect data were questionnaires, observations and topics and document analysis. A structured questionnaire was prepared to capture primary data that could be used for safety and risk analysis of some selected RLCs along the N-S line of Addis Ababa Light Rail Track. Questionnaires are categories of data collection instruments developed in an either soft or hard copy made up of questions and several guidelines that allow respondents to fill in answers (data), which are later collected and analyzed by the researcher ([Pouline, 2013](#)).

The questionnaire used was initially developed in English and later converted to Amharic, which is the majorly used language in Addis Ababa. It captured respondents'

biodata under Section A together with details of the specific RLC, whereas Section B was used to capture relevant technical data together with five levels of service agreement. The levels of satisfaction and operation agreement were arranged to include strongly agree as to the top and first, whereas strongly disagree was the fifth and last. In between, we had three other levels arranged in the order agree, neutral and disagree. The four subsections of Section B of the questionnaire included availability of safe protection system, reliability of the safety system, environmental factors and human factors/activities.

3.4 Data collection methods

Quantitative data collection from respondents was by use of questionnaires (Silvius and Nedeski, 2011) as they are good at showing the happenings at a time. These are information-collection methods used frequently in mixed-method research that draws on quantitative and qualitative data sources and assessment. Documentary analysis was also used to review available written records on the risk analysis of level crossings and this was through a systematic and consistent procedure.

3.5 Validity and reliability

According to Mohajan (2017), validity and reliability are fundamental concepts in evaluating the functionality of research tools and instruments that any valuable research study has to consider. Validity implies whether data is what a researcher says it is, measures what the researcher says it measures or shows what the researcher says it shows, whereas reliability – whether data derived from one sample of the population would also be derived from another sample of the same population if the same techniques and instruments were used again (Young, 2015). Reliability and validity have been ensured in two distinct ways to improve the credibility of the study results. First by using an expert in risk and safety management to test, check and approve the questionnaire and second, by requesting permission from respondents to record the interviews will increase.

3.6 Data analysis

Data collected were analyzed and processed using IBM SPSS statistics 25 together with MS Excel 2016. The analysis adopted thematic, descriptive and multivariate statistics with the analysis focused on the risk and safety environment at selected RLCs with a view of delivering on the objectives of the study and set specific questions. Descriptive statistics gave us information such as frequency counts, percentages and mean. Thematic analysis provided relations on study objectives, whereas SPSS was used for data analysis to deduce meaningful and acceptable study results.

3.7 Safety demonstrations methods

The three safety demonstration strategies available are complete system analysis and risk evaluation, using safety evidence of an existing system and technical standards as a reference. PHA is about identifying the likely risks that may exist in a study environment, evaluating their nature and tendency to occur, analyzing the severity and impacts of these risks in case they occur and devising means to reduce, control or eliminate the gravity of these consequences (Habib Hadj-Mabrouk, 2017). In this work, a PHA was first carried out at the level crossing. All probable hazardous and risk events, intended or unintended that might contribute to accidents, were ranked based on their severity and thereafter, we identified necessary measures to combat the hazards and related supplementary actions.

The PHA provided a hazard assessment that was broad, but not detailed. The ALARP principle was also used on this occasion as per Figure 6.

The interaction of several factors around the RLC was used to identify the complete set of hazards immediate to the level crossings. The study also reviewed the operational specifications and considered all the environmental factors around the level crossing. We took into consideration the interaction that happens between people and the RLC interface. The study identified several hazards that can be classified into one of the five categories, namely, hazards because of the human factors (A), hazards related to the environment of the level crossing that affects the visibility of the level crossing users (B), hazards related to technical problems (C), hazards because of non-compliance with standards (D), hazards related to other factors (E) and the sixth category (F) includes hazards related to other environment factors as shown in Table 1.

4. Results and discussions

The study results are twofold and they focus on the perceived assessment of categorized safety risks and hazards from 144 questionnaire respondents as well as a risky ranking matrix, which is a product of the ALARP principle of the identified 50 hazards (Table 1) exiting at AA-RLC N-S. Biodata characteristics revealed less important data even when they were included in the analysis together with all the different collected data. Through SPSS and Excel data analysis, the results and discussions in the form of figures and tables are presented as follows.

4.1 Availability of safe protection systems

Seven aspects that indicate the presence of a safe protection system (Figure 7) were provided to the respondents and requested to present their level of service agreement toward the aspects at the RLCs. The questions included the presence or use of automatic barriers, mechanical barriers, warning signals, magneto phones, flagman is always at the crossing, stop signs are available at crossing in both tracks and availability of safe board in a national and international language. Figure 7 shows the most populous responses with warning signals having 89.8%. It is evidenced that there is a lack of magneto phones, automatic barriers and absence of flagman at RLC with respective percentages. The provision of automatic barriers such as gates has been neglected and is at 12%. Gates are taken to be superior in preventing train-road user collisions at RLCs than “other traffic control devices at crossings such as flashing lights, bells and signs” (Liu and Khattak, 2017, 2018).

Hazard Frequency	Rank	Severity/ Consequence classification			
		4 (Extreme)	3 (High)	2 (Medium)	1 (Low)
Frequent	5	20	15	10	5
Probable	4	16	12	8	4
Occasional	3	12	9	6	3
Remote	2	8	6	4	2
Very unlikely	1	4	3	2	1
Negligible Risk		Tolerable Risk		Intolerable Risk	

Figure 6. Most popular responses for the availability of safe protection system

No	List of identified hazards at the RLCs of N-S AA RLT route	
1A	People collides with train because of alcohol and drugs	6A
2A	Drivers misjudge arrival of train at RLC	7A
3A	Drivers forgetting the signals	8A
4A	Low level of public discipline	9A
5A	People deliberately avoid the barriers designed to protect them	10A
11A	Vandalism occurred at RLC	12B
13B	Restricted visibility of the incoming train (large turn angle or angle of the road)	14B
15B	Vehicle damages the electric barrier because the driver never saw the barrier	16B
17B	Adequate light during night at RLC	18B
19C	Non-activation of the detection system and train alarm does not work	20C
21C	Technical malfunction of vehicles so that it stops in middle of the railway track while a train is coming to RLC	22C
23C	Lack of adequate space for emergency exit during danger	24C
25C	Light signals are not working and do not alert the pedestrians in some stations	26C
27C	RLC signal and warning equipment like barriers damaged	28C
29D	Improperly closed railway gates when the train passes through the level crossing	30D
31D	Absence of road warning and signals especially near or at the RLC	32D
33D	Non-compliance to road traffic regulations by drivers	34D
35D	Non-compliance to railway standards by ERC	36D
37E	Attention blindness and poor knowledge of road rules	38E
39E	Signal transmission gives proceed light while the section is occupied	40E
41E	Lack of flagman and/or police officer on duty at the RLC	42E
43E	Drivers are unaware of an approaching train	44E
45E	Disobeying instructions from the police officer controlling the RLC	46F
47F	Cleaners for removal of obstruction	48F
49F	Animals such as dogs and donkeys are often found crossing the RLC as train approaches	50F

Table 1.
List of identified hazards at the RLCs of N-S AA RLT route

4.2 Reliability of the safety system

Eight individual variables presented in Figure 8 that depict the reliability of the safety system were clustered together and respondents presented their level of service agreement toward the questions at the RLCs. Safety system reliability can be gauged about its results, and several questions to invoke this included number of accidents occurred per year is less than five, number of deaths and injuries is less than five, no accident at all, sometimes the signal system fails, adequate lightning during the night, trains horns are produced on approaching the crossing, number of crossing is less than four and the vehicle driving speed is not exceeding 50 mph. Trains produce horns as they approach the RLC at 95.8%, and this brings some relief to the reliability of the system. However, accidents that cause bodily injuries and death occur more often. The number of accidents that occurred per year less than five is at 13.2%, whereas the number of deaths and injuries less than five at 9.0%. This implies more death and accidents occur throughout the year and action has to be taken to reduce the occurrence of accidents. One important revelation during our interviews was that many accidents go unrecorded especially at night but these involve vehicles and pedestrians.

4.3 Environmental factors

Five environmental aspects whose levels of service agreement were considered included good drainage system at the crossing, cleaners for removal of obstruction, weather condition does not affect drivers, animals like dogs are often found crossing the tracks and adequate space for escaping during the emergency. As presented in Figure 9, 34.2% of respondents strongly agree that animals are often found crossing the tracks are, and 62.4% strongly agree that cleaners are available to remove obstructions at RLCs.

Figure 7.
Most popular responses for the availability of safe protection system

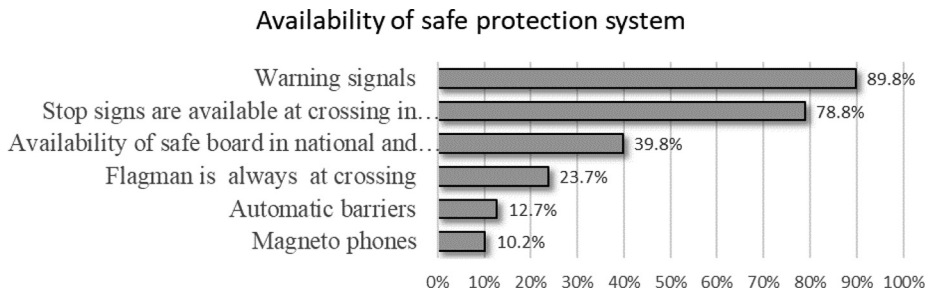
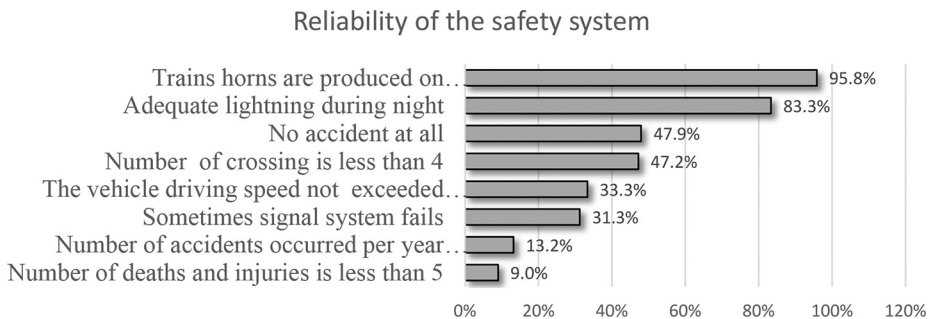


Figure 8.
Most popular responses for the reliability of the safety system



4.4 Human factors/activities

As Figure 10 shows, five human factors relevant to RLC safety, driver’s characteristics are always good, drivers care about the signal system at the crossing, pedestrians care about warning signal at the crossing, women have a stronger sense of obligation to traffic laws more than men and no vandalism occurs at the RLC, were considered. From Figure 10, it can be seen that pedestrians who care about warning signals at RLC are at 30.5%, and driver’s characteristics always good is low at 31.2%. This implies these two aspects need improvement with much emphasis to be put on sensitizing both the pedestrians and drivers. This is mainly necessary because previous research identified road user behavior as a noticeable factor that increases the risk of trains-road users accidents at RLCs (Larue and Naweed, 2018; Larue et al., 2020).

4.5 Level of agreement analysis results

Table 2 presents the result of findings from descriptive statistics analysis of individual hazard variables based on frequencies and percentages. As an example of findings for a single selected variable. These are results for flagmen always at RLCs. About 65.3% of the respondents strongly disagree with the aspect. Only 19.4% strongly agree, 1.4% agree, 4.9% gave a neutral response

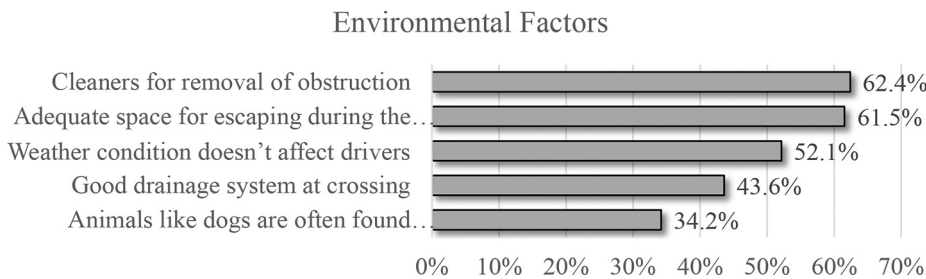


Figure 9. Most popular responses for environmental factors

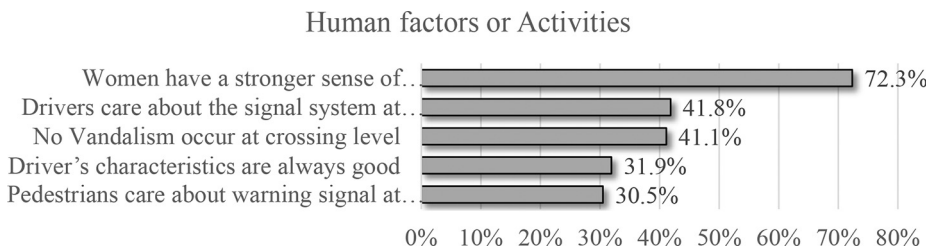


Figure 10. Most popular responses for human factors or activities

Level of agreement	Frequency	Valid %	Cumulative %
Strongly agree	28	19.4	19.4
Agree	2	1.4	20.8
Neutral	7	4.9	25.7
Disagree	13	9.0	34.7
Strongly disagree	94	65.3	100.0
Total	144	100.0	

Table 2. Flagman always at RLC, results from SPPS data analysis

and 9.0% disagree. When we combine the 65.3% and 9.0%, it gives a 74.3% level of disagreement. This implied that the crossings are rarely with flagmen. The risk is high.

For the aspect of train horning when approaching the RLCs, it is interesting to note the agreement given by almost all respondents. Almost 95.8% strongly agree, whereas 4.2% strongly disagree. The result implies trains always horn to ensure safety. The combination of strongly agree at 64.6% and agree at 5.6%, which sums up to 70.1%, is a strong indication for the existence of stop signs at the sides of both tracks.

Although the assessment focused on all aspects as presented in the questionnaire explained before, special interest goes to the following aspects that present a great risk because of analysis results and as visually and physically witnessed during the study. On consideration of the presence of automatic barriers, 45.8% are neutral, 26.4% strongly disagree and 7.6% disagree, whereas 10.4% strongly agree. The authors wish to state the absence of automatic barriers at all RLCs visited as well as mechanical barriers whose percentage is 19.4% strongly disagree, 7.6% disagree and neutral at 49.3%, whereas strongly agree is at 23.6%.

Magneto phones is at 68.1% strongly disagree, 5.6% disagree, 18.1% neutral and 8.3% strongly agree. Pedestrians care about warning signals the crossings is at 37.5% strongly disagree, 7% disagree, 15.3% neutral, 16.7% agree and 29.9% strongly agree. This implies that pedestrians need to take much care about warning signals.

4.6 Category of hazards identified

During our study, we identified a set of 50 hazards that exist at the selected railway crossings and these have been ranked by percentages and grouped according to the category as shown in Table 3. Hazards in the category of human factors and technical problems are high at 22% and 20%, respectively. Although this does not necessarily mean that they pose the greatest risk, but occupying a majority percentage is a wakeup call for authorities to closely analyze these categories so that any posed risks, risks emanating from these can be controlled before they can lead to accidents, injury and death. Also, hazards in the other category which stands at 18% have to be examined and prevented from turning into risky events.

We ranked the identified hazards using the risk ranking matrix (RPN) procedure basing on risk frequency as well as risk severity and categorized them based on the ALARP principle as explained. From this, the results in Table 4 show that 42% of the risks are

Table 3.
Percentage of
hazards identified by
cause category at
Addis Ababa N-S
RLCs

No.	Hazard category	Number of hazards identified	(%)
1	Human factors	11	22
2	Technical problems	10	20
3	Other factors	9	18
4	Non-compliance with standards	8	16
5	Visibility factors	7	14
6	Environmental factors	5	10

Table 4.
Risk classification in
percentages basing
on the ALARP
principle

No.	Risk category	RPN range	(%)
1	Intolerable risk	20–12	42
2	Tolerable risk	11–7	36
3	Negligible risk	6–1	22

intolerable, 36% are tolerable and 22% is negligible. The intolerable risk category demands immediate action from stakeholders and further consideration.

5. Conclusions and recommendations

5.1 Conclusions

Because RLC are points of intersection that present conflict between rail and road traffic, the following conclusions can be drawn from the study. The study findings reveal human factors as the greatest cause of accidents, injury or death. About 22% of hazards identified by category are human factors, whereas 20% are because of technical problems. Intolerable risks stand at 42%, whereas the tolerable risks are at 36% according to risk classification results as per the ALARP model. Because the process of risk management is a long-term cycle and its importance should not be missed at any time. All steps that constitute the risk management practice must be followed, risk identification not being enough for improving safety and reducing risk or accidents on RLCs. 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 ERC and the population.

5.2 Recommendations

This research draws upon its findings to propose the following recommendations, which the ERC has to put in place to lower risks and better safety at AA-LRT level crossings and crossing and upgrades to improve level crossing safety performance of AA-LRTS.

- An enhanced risk control strategy that involves mechanisms like building bridges, implementing railway-controlled crossing, installation of railway gates to prevent pedestrians and vehicles from crossing the track, giving priority for mitigating accidents caused by human factors and technical problems. For any planned evaluation, a quantitative risk assessment is recommended to make a qualitative one (low cost).
- Human factors being one of the high contributing factors of high risky events on AALRT, education through massive sensitization of traffic users including drivers and pedestrians about traffic discipline and requirements and the culture of good rail-road transport.
- To continuously monitor the emergence of safety risks through applying quantitative evaluation methods for major risk together with qualitative risk assessment methods with the consideration of computer-based program can be considered for AA-LRT.
- Other level crossing upgrading measures such as road underpass or overpass at RLCs with high traffic movements (volume) like Adey Ababa and Sebategna for the future AA-LRTS.

6. Limitations and future research

Because of design considerations of RLCs and the difference in generalized human behaviors for people of a given region, the results are limited to AA-LRT RLCs. The study opens a discourse for detailed evaluations, qualitative and quantitative analysis into the categorized identified hazards. There is also room for additional research into the

performance of RLCs aimed at formulating standard necessary features that should be included on RLCs for proper risk control especially in emerging economies.

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