© 2019 IJSRSET | Volume 6 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology
DOI : https://doi.org/10.32628/IJSRSET196518

Safety Demonstration and Risk Management at Rail-Road Level Crossing at Addis Ababa Light Rail Transit Network

Adoh Lucky Ugochukwu[1], Mutswatiwa Lovejoy[2], Akello fiona Mercy[3]
[1*]African Railway Centre of Excellence, Addis Ababa University, Ethiopia
[2,3]African Railway Centre of Excellence, Addis Ababa University, Ethiopia

ABSTRACT

Safety and security are among the major basic needs for the public in daily life and transportation plays a crucial role in satisfying this need. According to the World Health Organization (WHO) data, estimates of 1.2 million people worldwide died as a result of road traffic injuries in 2013 and it is estimated that road traffic injuries will be the 6th leading cause of death by 2030. Among the various types of road traffic injuries, accidents between trains and road vehicles are the deadliest and are associated with high cost of accidents. As Railway transportation continues to be an important piece to the overall national transportation puzzle in Ethiopia and as congestion continues to increase on the nation's roadways, commuters continue to flock to public transit as an alternative transportation mode. In Addis Ababa Light Rail Transit, there are over 20 level crossings, this represent a significant safety hazard to both road and rail users. In this paper, we used safety demonstration by complete system analysis to carry out safety demonstration for level crossing at Addis Ababa Light Rail Transit, and Failure mode effect analysis was used for identifying the potential hazards associated with the system and their root causes. Hazards associated with Addis Ababa Light Rail Transit level crossing are identified and classified, and results showed that 41% of the hazards are caused by Human errors, technical problems has 32%, non-compliance with standard operating procedures takes 18% and 9% are caused by other factors. Our Failure mode effect analysis result shows that safe redesign of the level crossing, management and operation of level crossings can reduce risks, and frequent orientation of road vehicle users to always give attention to traffic signal in level crossing can reduce the number of fatal and serious incidents and collisions.
Keywords : Addis Ababa Light Rail Transit, Hazards, Level crossing, Railway transportation, Safety

I. INTRODUCTION

Railway transportation have played a major role in developing civilizations around the world. From ancient Greece to modern-day America, railroads have changed the way humans travel and work. In the last two centuries, the Railway has changed radically, not only in terms of design and manufacturing processes but also in terms of its role in socio-economic development of a nation.

Safety is a major public concern in our daily life. Annually, thousands of people lose their lives due to road accident. Among the various types of road accident, accidents between trains and road vehicles are the strongest and most expensive accidents (Dehhkam & Eslami, 2017) [1].

As Railway transportation continues to be an important piece to the overall national transportation

puzzle in Ethiopia and as congestion continues to increase on the nation's roadways, commuters continue to flock to public transit as an alternative transportation mode. In particular, rail transit has been shown to provide many benefits to a regional transportation system. Safety of both passengers and employees is a major concern for transit agencies. Typical safety concerns for rail transit vary greatly depending on mode, location, climate, age of system, and various other factors. In general, the public often interact with rail transit at two primary locations. The first is at grade crossings, whether they be a pedestrian crossing or a roadway crossing. The second is at rail station platforms, which can vary from low level to high level. Passenger safety at rail stations can be a significant concern for rail transit operators [2].
Berrado [3] opined that railway safety is even more questionable at road rail level crossing (LC) where the number of fatal accidents has been significant over the years. A major concern is to understand and remove the risks in railway operations in general and at Level Crossing in particular.

A Railroad level crossing is an intersection where a railway line crosses a road, or in some situations an airport runway. In AALRT, there are over 20 level crossings, this represent a significant safety hazard to both road and rail users. Data gotten from AALRT shows that there are about 119 level crossing accidents in the North-South line and about 61 in the East-West line including 15 collisions between 2015 to April 2019 which gives a total of 180 accidents since inception. Statistics from AALRT has it that up to majority of accident and/or incidents at railway level crossings is caused by driver error. This is largely attributable to inattention, driver distraction, risk-taking, and disobeying or lack of knowledge of the road rules and sometimes suicide. In almost every case that the motorist failed to stop and give way to the train at the level crossing and that there was little the train driver could do to prevent the collision or minimize its effects.

The aim of this paper is to carry out safety demonstration and risk management at Rail-Road level crossing in Addis Ababa Light Rail Transit. In this paper, we shall carry out safety demonstration by complete system analysis for LC in AALRT and Failure mode effect analysis (FMEA) will be used for identifying the potential hazards associated with the system and their root causes. Hazards associated with AALRT LC will be identified and classified.

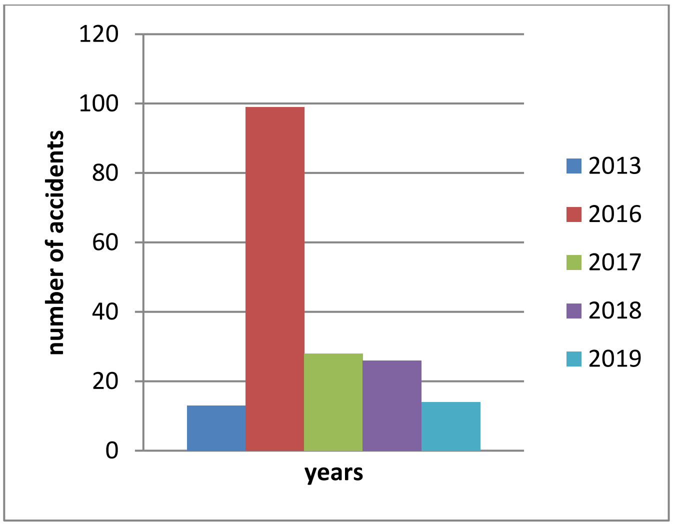

Figure 1. Accident occurrence in AALRT level crossing

Figure 2. Hazards associated with Rail-Road level crossing at AALRT

II. METHODS AND MATERIAL

2.1 Safety demonstration strategies

There are three safety demonstration strategies:

1. By complete system analysis and risk evaluation

2. By using safety evidence of an existing system as a reference.
3. By using technical standards as a reference.

For this paper which uses Addis Ababa Light rail transit (AALRT) level crossing as a case study, safety demonstration by complete system analysis and risk evaluation will be used because experience and analysis data is not available for approach 2. The table 1. below shows the phases of safety demonstration by complete system analysis at LC AALRT.

Table 1 : Phases of safety demonstration by system analysis and risk evaluation

Phases	Description
Phase 1 concept	The level crossing is an intersection where a railway line crosses a road. Basing on the collected data, AALRT switches are most affected by error caused by the road users.
Phase 2 System definition	According to the gathered data, the reliability of AALRT level crossing is 50.2 failures/year, Availability is 78.1% and maintainability is 2 days This means it risky not to pay critical attention to the safety of the level crossing.
Phase 3 Risk assessment	1. Not mitigating the identified hazards consequently leads to; Accidents/ collision at level crossing The above can be caused by human's errors, technical failure and non-compliance with standards.
Phase 4 System requirements	1. traffic police must always be on site 2. there should be regular check up on the signaling systems at level crossing
Phase 5 Apportionment of system requirements	1. Level crossing is usually affected human errors and technical failures 2. There should be a barrier created to prevent road drivers from gaining access to the level crossing area when a train is on the track 3. also traffic police should always be available
Phase 6-10 Design, implementation And manufacture	Same as the existing level crossing being used at AALRT.
Phase 11-13 Operation & maintenance performance modeling and decommissioning	1. Maintenance time should be reduced to 1 or 0.5 day , 2. The signaling equipment should be regularly maintained and checked. 3. Road vehicle drivers should be intimated regularly to pay attention to the traffic signals at level crossing. Decommissioning of the level crossing at AALRT is not really necessary but key attention must be given to human errors and how to avoid them at level crossing

2.1.1 RAMS calculation

Reliability

Number of years, from Sept, 2015 to April, 2019 = 3 + (3/12) + (4/12) = 3.583 years

Reliability, λ Number of failures in a given time = $^{180}/_{3.583} = 50.2\ failures/year$

Failure rate = 4.2 failures/month or 0.14 failures/day

Mean time between failure (MTBF) = $\frac{1}{\lambda} = \frac{1}{0.14}$ = 7.14 days

Availability

$A == \frac{MTDF}{MTDF+MTTR} = \frac{7.14}{7.14+2} = 0.781\ or\ 78.1\%$

Maintainability

Maintainability is estimated in terms of Mean Time to Repair (MTTR)

From the AALRT safety records,

MTTR = 2 days

Safety

The safety of AALRT was estimated using Safety Integrity Level (SIL) [4].

Table 2. Safety Integrity Level (SIL) [4].

THR (h^{-1})	SIL
$10^{-9} \le THR < 10^{-8}$	4
$10^{-8} \le THR < 10^{-7}$	3
$10^{-7} \le THR < 10^{-6}$	2
$10^{-6} \le THR < 10^{-5}$	1

Risk associated with collision (with road vehicles or pedestrians on the level crossing)

Risk = hazard frequency X Severity = $\frac{180}{24\ x\ 365}\ x\ 0.00005 = 0.10274\ x\ 10^{-7}\ h^{-1}$,

which lies under SIL 3 which implies a higher-level risk is associated with the system and a higher-level protection must be put in place to prevent or reduce this risk.

2.2 Safety demonstration method

Probabilistic methods of safety demonstration was used because most of the risk associated with level crossings are due to human errors and they are very unpredictable.

Average number of daily passenger on AALRT = 20000

Average number of trains per day = 66

Average number of road vehicles per day = 3000

Number of level crossings in AALRT = 16

Probability of collisions occurring at the crossing/year

$$= \frac{collision/year}{number\ of\ train\ x\ number\ of\ road\ vehicle\ per\ year} = \frac{15/3.583}{365\ x\ 66\ x365\ x3000} = 1.59\ x\ 10 - 10$$

Collision/day = 2.1 x 10^{-5} (0.2 collisions in 1 million) which is fairly high

2.3 Hazard and Risk management Process for Level crossing of AALRT

Different authors [5]–[9] have defined risk in different perspectives. Risk has been defined both qualitatively and quantitatively. Pitblabo [9] defines risk qualitatively as the potential of loss or injury resulting from exposure to hazards. A hazard being considered as source of danger that is not associated to the likelihood with which that danger will actually lead to negative consequences. Quantitative definitions of risk associate hazards with their probability of nuisance to the people and the environment. Risk is defined to be a set of events, each of which having a probability and a consequence [3]. This quantitative definition to risk aims to estimate the degree or probability of loss related directly to the occurrence of hazards or potential failures of a system. An organization faces essentially three different types of risk to its operations, namely internal risks [3], i.e. those associated with activities and locations for which the organization is solely responsible, external risks.

Hazard identification is often seen as the heart of risk management [3]. The successful accomplishment of this task is critical since if one omits some potential hazards, it could result in severe human loss and infrastructure damage and in a misevaluation of risk. Many hazard identification techniques (Stewart & Melchers, 1997) [10] have been developed in various disciplines. There are several techniques for hazard identification; Structured group discussions / brainstorming, 365º analysis – multi-view/multi-dimensional, Cascade from multi-fatality to single death to injury hazards , Check lists, Hazard and operability studies (HAZOPs), Hazard identification studies (HAZIDs), Failure mode and effects analysis (FMEA), Failure mode, effects & criticality analysis (FMECA), Fault trees, Event trees, Task analysis but for this paper, HAZID was used in identifying hazards.

2.3.1 Risk/Hazard identification and classification

Risk associated with Level crossing in AALRT

- ✓ Error by the Train operator
- ✓ Track Defects
- ✓ Presence of objects on the track
- ✓ No Warning signals Installed
- ✓ Failure of Train to read traffic signal correctly
- ✓ Faulty Warning Signals
- ✓ Train system failure

Hazard Classification

Out of all the identified hazards, 41% are caused by Human errors, technical problems has 32%, non-compliance with standard operating procedures takes 18% and 9% are caused by other factors according to AALRT level crossing data collected. The figure 2 below shows the classification of hazards at AALRT.

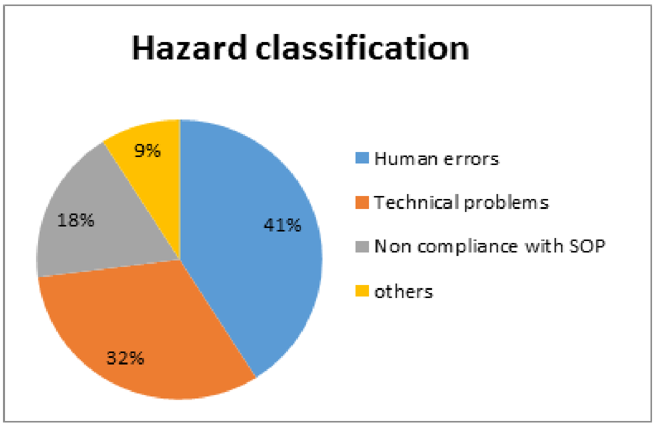

Figure 3. Hazard Classification for AALRT

III. RESULTS AND DISCUSSION

3.1. Risk Analysis, evaluation and treatment

Failure mode effect analysis (FMEA) was used for identifying the potential hazards associated with the system and their root causes.

Steps in FMEA

1. Determine the types of potential failure
2. Determine the effects of potential failure
3. Determine the causes of potential failure
4. Determine the detection method of potential failure
5. Determine the risks priority number, RPN
6. Development of preventive action plan

Table 3: Frequency and severity classification [3]

Score	Frequency Class
1	Very unlikely
2	Remote
3	Occasional
4	Probable
5	Frequent

Score	Severity Class
1	Minor
2	Major
3	Critical
4	Catastrophic

The table4. below gives the FMEA technique carried out on the AALRT level crossing

Table 4. Frequency and severity of level crossing defects due to root causes

S/N	Failure modes	Potential cause	Potential effects	frequency	severity	Detection	RPN
1	Presence of obstacle on the track	No ultrasonic sensor on train to detect the obstacle	Collision	3	4		15
2	No signal detected	Faulty warning signal	collision	2	5		10
3	Failure of Train to read traffic signal correctly	Faulty warning signal, train system failure	Accident/collision	4	4		16
4	Failure of Train operator to read traffic signal correctly	Driver has lost control of the train, driver not seeing properly, driver over speeding	Collision/ death/injury	2	4		8
5	Track defects	Loosen sleepers, cyclic top, track twist, track buckle, crossing derailment	Derailment, collision	2	5		10

Table 5. Frequency and Severity classification of risk

	Severity				
Frequency	5	4	3	2	1
5	25	20	15	10	5
4	20	16	12	8	4
3	15	12	9	6	3
2	10	8	6	4	2
1	5	4	3	2	1

1 - 9 can be managed and monitored
10 - 15 ought to be reduced or transferred
16 – 19 should be avoided
20 - 25 should be given immediate action

From table 4 and table 5 above, it shows that the risks which are occurring frequently such as collision have high severity and high cost of accident hence they are presented by high risk or relatively high risk in the matrix above. Mitigation measures have to be put in place to reduce the severity of those accidents.

3.2. Development of preventive action plan/ management of risk

Safe design, management and operation of level crossings can reduce risks, and frequent orientation of road vehicle users to always give attention to traffic signal in level crossing can reduce the number of fatal and serious incidents and collisions. In order to reduce the likelihood and severity of accidents and at AALRT level crossing, the following should be considered.

- ✓ Promoting replacement of level crossings with grade-separated crossings, structural improvements, and improvement of grade separation facilities for road drivers.
- ✓ Regular orientation of road drivers to always give priority to trains at level crossings.
- ✓ Improving level crossing maintenance facilities and implementing traffic regulations
- ✓ Implementing other measures to ensure safe and smooth traffic at level crossings

IV.CONCLUSION

In this paper, we have carried out safety demonstration by complete system analysis for level crossing in Addis Ababa Light rail Transit and Failure mode effect analysis (FMEA) have been used for identifying the potential hazards associated with the level crossing system and their root causes. Hazards associated with AALRT LC was identified and classified and results showed that 41% of the hazards are caused by Human errors, technical problems has 32%, non-compliance with standard operating procedures takes 18% and 9% are caused by other factors. According to our FMEA result, risks which are occurring frequently such as collision which have high severity and which leads to high cost of accident Mitigation measures was to be put in place to reduce the severity of these accidents. Some of the measures are safe redesign of the level crossing, management and operation of level crossings can reduce risks, and frequent orientation of road vehicle users to always give attention to traffic signal in level crossing can reduce the number of fatal and serious incidents and collisions.

V. REFERENCES

[1]. B. Dezhkam and S. M. Eslami, "OPEN ACCESS A review of methods for highway-railway crossings safety management process," vol. 12, no. 5, pp. 561–568, 2017.

[2]. D. Anderson, "Improving Safety of the Platform-Train-Interface Through Operational and Technical Mitigation Strategies," 2015.

[3]. A. Berrado, "A Framework for Risk Management in Railway Sector: Application to Road-Rail Level Crossings," Open Transp. J., vol. 5, no. 1, pp. 34–44, 2011.

[4]. Wika, "SIL? PL? What is the probability of failure of a safety function? - WIKA blog," 2014. Online]. Available: https://blog.wika.com/knowhow/sil-pl-probability-failure-safety-function/. Accessed: 21-Sep-2019].

[5]. A. Gorod, B. Sauser, and J. Boardman, "System-of-Systems Engineering Management: A Review of Modern History and a Path Forward," Syst. Journal, IEEE, vol. 2, pp. 484–499, Jan. 2009.

[6]. D. Cooley, "DIPAK K. DEY, JUN YAN, EDS. Extreme Value Modeling and Risk Analysis: Methods and Applications. Boca Raton: CRC Press," Biometrics, vol. 73, pp. 1057–1058, Sep. 2017.

[7]. L. George, "What Every Engineer Should Know About Reliability and Risk Analysis," Technometrics, vol. 36, pp. 226–227, Mar. 2012.

[8]. I. Kozine, "Probabilistic Risk Analysis. Foundations and Methods By Tim Bedford and Roger Cooke. Cambridge University Press, UK, 2001, 408 pages, ESBN 0 521 77320 2," Risk, Decis. Policy, vol. 6, no. 3, pp. 207–207, 2001.

[9]. R. Pitblado, "What Every Engineer Should Know About: Risk Engineering and Management John X. Wang and Marvin L. Roush Marcel Dekker Inc., 2000 264 pp, £75.00 ISBN 08247 9301 3," Process Saf. Environ. Prot. - Process SAF Env. PROT, vol. 78, p. 416, Sep. 2000.

[10]. M. Stewart and R. E. Melchers, Probabilistic Risk Assessment of Engineering Systems. 1997.

Cite this article as :

Adoh Lucky Ugochukwu, Mutswatiwa Lovejoy, Akello fiona Mercy, " Safety Demonstration and Risk Management at Rail-Road Level Crossing at Addis Ababa Light Rail Transit Network, International Journal of Scientific Research in Science, Engineering and Technology(IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 6, Issue 5, pp.103-109, September-October-2019. Available at doi : https://doi.org/10.32628/IJSRSET196518
Journal URL : http://ijsrset.com/IJSRSET196518