Journal of Safety Engineering 2012, 1(1): 1-6
DOI: 10.5923/j.safety.20120101.01

Evaluation of Safety Improvement in Iranian Railway Level Crossings

Jabbar-Ali Zaker[1,*], Ali-Asghar Sadeghi[2]

[1]School of Railway Engineering Iran, University of Science and Technology
[2]Department of civil engineering, Ferdowsi University of Mashhad

Abstract Increasing railway level crossing accidents during nineties, made the railway to analyse the situation. The primary investigation showed that; despite having very few level crossings, unfortunately, the number of accidents is 4 times greater than the average in European countries for every 100 crossings. Hence alongside the data gathering from crossings, steps were taken towards elaborating short term and long term planning and implementation of management network. Now, after five years from the execution of this plan, the crossing safety situation and the resulted enhancement is described in this paper. Studies show that; in spite of growing rail & road traffic the number of accidents have fallen tremendously.

Keywords Level Crossings, Railway Accident, Hazard Risk Index, Safety

1. Introduction

Crossing locations of railways with roads (level crossings) are amongst the most eventful points on the transportation network. At these points, due to passing the rail & road vehicles with two distinguished mechanism, the right of way is given to the rail vehicle because its braking distance (depending on their weight and speed) is several hundred times longer than that of road vehicles. Usually some superstructure arrangements are made to keep the road traffic fluent at during the safe periods. Also suitable alarming system is provided for road vehicles in order to prevent possible accidents. In view of the fact that the level crossing equipments, vary due to the intensity of traffic, roads classification, geometry of the crossing and so forth, the right type should be determined[1]. Different countries seek to improve the geometry of their fixed installations, warning systems etc. Finland is amongst the countries which is considered to have safer crossings than desired level, and had managed to reduce its rail road accidents in the past few years[4]. In this paper, while measures taken by Iranian Railway are investigated, results and effects of such procedures in reducing road accidents are described.

The state owned Iranian rail network has 8460 km of rail. Over 85% of the rail network have single track. On this network we have about 24 million passenger trips and carry about 32 million tons of freight yearly(2007).

The total number of level crossings on the whole rail network is 264 (Table 1). On the state owned rail network, we have 264 level crossings and 586 grade separated crossings (248 bridges and 338 underpasses).

Since 1995 about 44 level crossing accidents with about 7 fatalities have occurred yearly. During 2002 occurred 48 level crossing accidents, 12 of them at active and 22 at passive level crossings and 14 of them in other points (unofficial level crossings). The number of fatalities was 4 and injuries 10. During the last year we had 22 accidents in level crossings. 5 people were killed and 13 injured in those accidents[5].

The goal for level crossing safety work is to close certain level crossings and to improve the safety at the remaining crossings. The numerical aim set by Iranian railways for the maximum number of level crossing accidents is 25 in a year. This goal has not been reached during the last four years.

The removal of railway level crossings is slow. About 15 – 20 level crossings have been changed to grade-separated crossings yearly. The remaining crossings are mostly open, private road crossings on the rails with a low traffic volume. Especially for those crossings the low cost measures (i.e. upgrading track superstructure in crossing area and completely equipping crossings to warning signals) to improve traffic safety are needed. This paper summarizes the findings of the research study conducted by Author in Way and Works Department of Iranian railway. It covers the following areas:

- Identifying key problems experienced by people, drivers and track experts at rail crossings;
- Reviewing international experience in providing safe passage for people and vehicles at rail crossings;
- Identifying solutions and actions to improve safety.

* Corresponding author:
Zakeri@iust.ac.ir (Jabbar Ali Zaker)
Published online at http://journal.sapub.org/safety
Copyright © 2012 Scientific & Academic Publishing. All Rights Reserved

2. Condition of Level Crossings in Iranian Railways

Primary Survey on the number of existing level crossing in Iranian Railway shows that Iranian Railway has distinctive situation compared to railways of other countries (table 1)[7].

Table 1. Track length and number of level crossings in 10 countries (in 2008)

Countries	Track length (A)	Number of level crossings (B)	Ratio B/A
USA	212400	253129	1.19
Iran	8460	264	0.03
Belgium	3518	2409	0.68
Finland	5850	4956	0.85
France	31200	19831	0.63
Germany	35858	26980	0.75
Ireland	1919	1976	1.03
Netherlands	2806	3006	1.07
Norway	4077	5090	1.25
UK	17052	8323	0.49

Its safety can be feasibly improved by sufficient investment. Generally, a suitable index defined to consider accidents in level crossings as the number of accidents happened in 100 level crossings, which in reference[7] the average accidents in past 12 years in Iranian Railways crossings obtained 9.8, which is approximately four times more compared to European countries[7]. By considering safety improvement measures; it reduced to 8.33 in 2009.

This table shows that the ratio level crossings numbers to track length in Iran is the lowest compared to the other countries. The analysis of such a figures shows that this is because constructing overpass or underpass is comparatively cheaper than automatic systems. In Iran there is just one level crossing with automatic barrier constructed, for instance. The result of technical and economical survey of constructing this barrier shows that the cost of converting small level crossing to unlevelled one with underpass construction is about %200 of automatic barrier cost. For this, during past years many of them converted to unlevelled one instead to be equipped to automatic system.

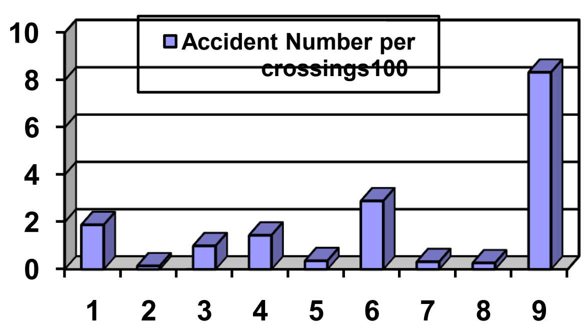

Figure 1. Number of accidents per 100 crossings in European Countries and Iran: 1- Belgium; 2- Denmark; 3- France; 4- Germany; 5- Great Britain; 6- Netherlands; 7- Norway;8- Sweden and 9 – Iran (in 2008)[5]

In addition to the number of accidents used an index in statistical analysing level crossing safety, another international index named "accidents rate" is also used, which is defined as dividing the number of accidents in million / train / km passing level crossings of every country. Figures (2), (3) and (4) shows the rate of train – km of the country, number of accidents and the rate of accidents for a seventeen-year period.[5].

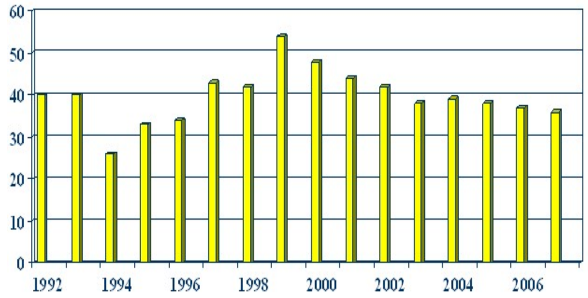

Figure 2. Surveying accident numbers in Iranian railways level crossings

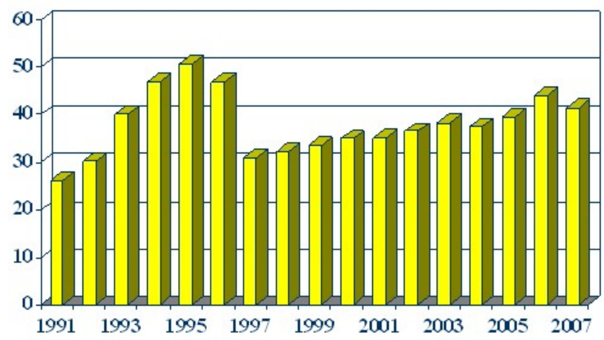

Figure 3. Train – km (in million) of Iranian Railways for a 15 years period

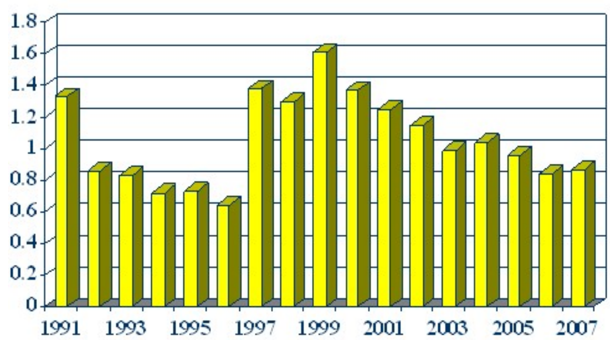

Figure 4. Rate of train – km of the country, number of accidents and the rate of accidents for a seventeen-year period

The first inventory report was finished in the winter of 1999. Separate reports are prepared for each inspected railway districts. Based on the road gradient measurements, the crossing times for different vehicle types are calculated. Then, suggestions are given for measures to improve safety at level crossings on a line. These suggestions are made on the basis of crossing time calculations and sight distance measurements. There are three classes of measures: immediate (e.g. the clearing of vegetation from the sight areas or the imposition of restrictions on the types of vehicle allowed using the crossing), short-term (e.g. the installation of half-barriers or removal of a level crossing by the construction of a compensatory road) and long-term.

Table 2. Comparison figures of observed accidents with that of forecasted by formulas

-	No. accidents during the year 2003-2008 in 100 crossings	Pbody Demickle formula	Culmann Stewart formula	US.DOT formula	Canadian forecast formula	Gitleman Herkert formula
-	9.40	7.56	44.31	8.49	15.23	114.54
Priority number	-	2	4	1	3	5

3. US. DOT Accidents Forecast Formula

Accidents forecast formula was elaborated by the US transportation department in early 80's, for anticipation of limitations and primary type models[6]. US. DOT, formula is a complex and comprehensive formula composed of three equations:

$$A= (k) (EI) (DT) (MS) (MT) (HP) (HL) (HT) \quad (1)$$

$$B = T_0/(T_0+T)*(a) + T/(T_0+T)*(N/T) \quad (2)$$

$$\left.\begin{array}{l} A= \{0.6500B\} \text{ for crossing with passive warning instruments} \\ A= \{0.5001\ B\} \text{ for crossing with flashing lights} \\ A= \{0.5725B\} \text{ for crossing with barriers} \end{array}\right\} \quad (3)$$

Each parameters of the formula (1) provides a crossing characteristic listed in the check list of US federal railway. These parameters are statically important and had been calculated by non-linear regression[6].

Description of formula (1);

A: primary annual accidents forecast at one crossing.

K: constant.

EI: indicative characteristic of crossing rail & road existing traffic.

MT: Number of main lines.

DT: number trains in day light.

HP: Asphalted or non-asphalted road factor

MS: Headway

HT: road classification factor,

HL: number of lanes.

Equation (2), adjusts the number of accidents forecasted in equation (1) in order to reflect the real history of accidents at the crossings. In this equation:

N: number of accidents observed.

T: number of year.

T_0: weight factor of the formula. Where,

$T_0 = 1.0/(0.05+a)$

Equation (6) is a normal constant. Normal constants of US.DOT accident forecast formula, is determined by comparison of accident forecasted sample in recent years with number of observed accidents[7].

4. Ultimate US.DOT Model Factor Estimation for Iranian Level Crossings

By forecasting accidents for 100 crossing in Iran, during the years 2002-2006 by using equations (1) and (2) of US.DOT, and comparing them with the real events during the first six months of the year 1386 (for which the statistics have been available), normal constants can be determined for the Iranian crossings.

Six accidents have been occurred in 100 crossings in Iran during the first six months of the year 2007, out of which three at crossings with barriers and three at crossings without this installation. Total forecasted for the year 2007, using US.DOT equations (1) and (2), for crossings with barriers is 5.2107 and for non barriers crossings, 4.8477. Hence:

β×(No. of forecasted accidents in year 2007) =2×(No. of accidents observed in the first six months of the year2007). The number 2 in this equation is because only the first six months data has been available, and the assumption is that the second half shall have the same number of accidents.

$$2 \times 3 = \beta \times 5.2107 \Longrightarrow \beta = 1.1515$$

$$2 \times 3 = \beta \times 4.8477 \Longrightarrow \beta = 1.2377$$

This way US.DOT. (3) formula for Iranian crossings is recommended as follows:

$$\left.\begin{array}{l} A= \{1.1515B\} \text{ for crossing with barriers} \\ A= \{1.2377B\} \text{ for crossing without barriers} \end{array}\right\} \quad (4)$$

Table 3. Results obtained from chi2 calculations for accidents forecasting formula

	Pbody Demickle formula	Culmann Stewart formula	US.DOT formula	Canadian forecast formula	Gitleman Herkert formula
Chi^2	31.73	28.87	26.76	22.04	146.93
Priority number	4	3	2	1	5

Table 4. Results obtained from power factor calculations for accidents forecasting formula

PF (40%)	PF (30%)	PF (20%)	PF (15%)	PF (10%)	PF (5%)	
1.43 (2)	1.70 (1)	1.91 (1)	1.84 (2)	1.91 (2)	2.55 (1)	Pbody Demickle formula
1.38 (3)	1.56 (2)	1.59 (2)	1.84 (2)	1.91 (2)	1.27 (3)	Culmann Stewart formula
1.43 (2)	1.70 (1)	1.91 (1)	2.12 (1)	2.55 (1)	1.70 (2)	US.DOT formula
1.54 (1)	1.34 (3)	1.38 (3)	1.56 (3)	1.48 (4)	0.85 (4)	Canadian forecast formula
0.85 (4)	1.06 (4)	1.38 (3)	1.56 (3)	1.70 (3)	2.55 (1)	Gitleman Herkert formula

5. Long Term Plan

In long term plan, collecting managerial data and completing level crossing inventories (ID's) have been primarily carried out .In this stage ID's and figures of all level crossings collected for 12 districts separately for whole one year and classified in special formats after processing, so that updating of data could be possible simply. Then the most risky level crossing identified through these IDs and accidents happened. Moreover, the existing defects and insufficiencies in facilities and capabilities related to signals, communications, infrastructure and equipment related to level crossings identified and included in short term upgrading plan and their completion in implementation program. For identification, the most risky level crossings are those having more than one accident, more than one loss and more than one injured during study period.

In the past, level crossings were classified according to a simple risk index as follow:

IP= Number of trains passed per day*number of road vehicles crossed in one whole day (5)

However, this formula is no longer used due to variety of level crossings and existing other key parameters and does not give suitable results. Therefore, the author presents Hazard risk index calculation (IP) compatible with Iranian Railway level crossings, using the experiences of other countries. The index uses more parameters and factors and shows more suitable result in level crossings priority.[8]

$$IP=1/4(NRWV \times NRV \times \alpha_v)(\alpha k+NTL+KVR+AN) \quad (6)$$

In which following parameters have been used:

a) Number of rolling stocks: Number of train passed in 24 hours considered as a key parameter in determining risk and illustrated by NRWV.

b) Number of road vehicles: Number of passing road vehicles in 24 hours is considered as an important parameter in determining risk and illustrated by NRV.

In this study, to conclude heavy vehicles, tractors, road construction machinery effects, an effect coefficient is defined and calculated as follow:

$$NRV = NLV+ \alpha\, NHGV+ \beta\, NRCV+ \gamma\, NT \quad (7)$$

In which:

NLV- number of light vehicles

NHGV- number of heavy vehicles

NRCV- number of road construction machinery

NT - number of tractor

α =2 - effect coefficient of heavy vehicles

β =3 - effect coefficient of road construction machinery

γ =3.5 - effect coefficient of tractor

c) Effect coefficient of rolling stocks speed α_v :

d) Coefficient of road importance α_k

e) Number of track at level crossings (NTL)

Number of track at level crossings is another effective factor indicating the importance of level crossing conversion

f) Coefficient of sight distance for road (KVR)

Existing curves and other physical barriers in level crossings causes insufficient sight distance (both in rail and road) as a result increase risk of accident. Coefficient of distance effect defined considering given points and their effects appears in level crossing prioritizing and risk index.

g) Crossing angle coefficient(AN)

6. Level Crossing Management System

The Iranian Railway organization has also created a so-called "level crossing management system". According to this system once the inventory work and report have been completed, a person will be assigned responsibility for each railway district. This person is responsible for ensuring that the sight areas at level crossings remain clear. They are also responsible for replacing damaged traffic signs and perform other small tasks.

7. Safety Improvement Measures and Their Implementation in Short Term Plan

To increase safety in level crossings, a comprehensive definition of level crossings, equipment, superstructure material & components, communication systems, rail/road signals and etc. was, primarily, given. Considering given comprehensive definition, level crossings IDs given for all level crossings in 12 districts, separately. It is followed by the defects/deficiencies of all level crossings. It is expected that, by a six months plan, all of the defects / deficiencies will be removed.

To change the type of level crossing is one of the important actions to be taken. Considering speed increase in some routes, rail/road traffic increase, double-tracking some tracks, fundamental survey on changing the type of crossing and its components settled as a serious move in Iranian Railway plan.

It should be noted that the executive problems and existing difficulties in converting level crossings involved as the main criteria to change the type of crossing. The fundamental actions to be taken in order to enhance safety in level crossings in short term are as follow:

7.1. Electrifying Level Crossing Mechanical Barriers

Electrifying barriers at crossings with mechanical barriers to accelerate road closure by guards was another important step which took place at 25 crossings. At first a number of mechanical barriers were electrified as experimental samples. Though it was tried to keep also the mechanical capability of being remote controlled at a time of emergencies. A year long monitoring of these crossings shows that; at these 25 crossings no accidents have occurred and with the help of the road guards a relative safety of these crossings have been achieved. It should also be stressed that special signs have been erected at these crossings to inform the drivers of such installations which in turn has been quite effective.

7.2. The installation of Intelligent Barriers

A manual mechanical barrier was converted in to intelligent one as a sample. In this project an intelligent system recognizes the approach of the train to the crossing zone (from a distance of 5 km for the speed of 120 Km/h) and lowers the barrier lever. In case of any obstruction at the crossing, alarms and warning lights go in to action to warn the danger. No events have been recorded at this crossing neither.

7.3. Upgrading Superstructure in Level Crossing Areas

Improvement on superstructure at crossing location in order to accelerate the clearing of the crossing and the comfort for road vehicle passage and to eliminate any possibility of stoppages by heavy goods vehicle while crossing the track, are other important steps scheduled in the railway plan to take place. During the past three years 20 crossings have been upgraded, but there is no suitable method of evaluation to measure the degree of effectiveness in the safety of these crossings.

7.4. Installing Road Warning System

Road warning installations such as red flashing lights and sound alarming systems play an important role in raising the safety at the crossings due to the alarms giving to the drivers and increase their awareness in order to stop within the permissible zone. Video recording of 20 selected crossings shows that; most of drivers react positively to the warning installations and stop their vehicles with extra care, so much so that even at crossings with no barriers, as soon as they hear the alarm that warns them off, they stop at a safe distance and wait for the approaching train. During 72 hours of consecutive video recording no dangerous move has been observed.

7.5. Training Level Crossing Men and Their Retraining Annually

Many road guards could not react promptly during emergencies and save the vehicles from certain dangers due to their forgetfulness of their leanings. One of the serious measures in the 3rd five year social and economical development plan of Iran in rail section was to train the road guards and retrain them annually. Despite all the difficulties with regard to this issue, it took place in the form of mobile. The effect of this step was not also easily evaluative but as a whole it has been quite effective.

7.6. Increasing Barriers Distance from Track Axle

In order to provide sufficient space on either side of the track to accommodate the vehicles in emergencies, the 17m axle distance of 2 sample crossings were increased to 20m. Due to this change and giving alarms to the drivers, no accidents have been registered (in the period of investigation) at these crossings.

7.7. Installing Double Lane Roads Physical Separators

In one crossing concrete separators was install as a sample and it was monitored for 72 hours. Investigations shows that; these physical separators cause more order at a time of crossing and less dangerous diversion moves by drivers was observed. The advantage of this work was in having a half barrier and therefore the control of the traffic by the road guard was easily achieved.

7.8. Separating Road Heavy and Light Vehicle Traffic in Level Crossings

In practice heavy traffic crossings, especially those with heavy goods vehicles are amongst the most dangerous crossings. In Iranian railway heavy traffic crossings are to be converted in to underpasses. In order to evaluate the behaviour of the drivers as an example; the heavy goods vehicles were separated from cars. In one of these crossings the road was divided in to two slow and fast lane from a distance of 200m by physical concrete barriers. No accidents have been reported in this crossing and early investigations show facilitating traffic and fast clearing of the crossing.

7.9. Equip the Crossings

In order to equip the crossings, serious steps were taken as follows：

- Installing road/rail signals
- Installing speed reducers in defined points
- Adding barriers up to footpath and bicycle path
- Adding typical strips to warn drivers to reduce speed
- Installing speed reducers in 20m distance or wide speed reducers with 5m with near to stop line
- Installing overhead signals

8. Conclusions

Due to the statistics of accidents in Iranian railway level crossings and the increasing trend of train-kilometre and number of road vehicles, 4^{th} five year plan was compiled. In this paper while investigating the past five year's accidents, the effect of each measure together with its monitoring of the crossing was examined. The results of the evaluations indicate improvement in safety situations of crossings. It should be emphasized, in the continuation of these measures, there is additional appraisal results stated as follows:

1. Level crossing accidents in terms of train/kilometre had likely descending trend.
2. Level crossings prioritizing in terms of hazard index have shown better & realistic results. Therefore more dangers level crossings have been recognized and included in level crossing conversion into unlevelled crossings (fly-over) plan.
3. Safety improvement methods with low costs included in short term plan and it is expected that by the end of 2013, 30% level crossing accidents will be reduced compared to 2006.
4. Analyses of level crossing accidents show that, car-train accidents have increased along railway lines in special areas, not in level crossings. Because of that, it is

necessary to study for establishing new level crossings in such areas.

5. More than 8.6% of accidents have happened in ports and it is necessary to pay attention to this points.

REFERENCES

[1] Anila M, Kallio M. (2000) "Safety of railway level crossings on the track between Toijala and Turku", Technical Research Centre of Finland, Research Report, pp.539-576.

[2] Finlex (2002) Database of Finnish Acts[http://www.finlex.fi].

[3] Horst R. & Bakker P. (2004)" Safety measures at railway level crossings and road user behaviors " CD- proceedings of 8th international Level Crossing Symposium, Sheffield University.

[4] Pajunen K., (2004) "Low cost measures at Finnish level crossings" CD- proceedings of 8th international Level Crossing Symposium, Sheffield University.

[5] RAI (2010) Annual Report of Iranian Railway Accidents.

[6] Woods M., (2004) "Development of a program of level crossing research to Improve railway Safety in Great Britain" CD-proceedings of 8th international Level Crossing Symposium, Sheffield University.

[7] Zakeri J. A. (2004) "Iranian railways strategies for reducing risks of accidents in crossings" CD- proceedings of 8th international Level Crossing Symposium, Sheffield University.

[8] Zakeri J. A., (2006) "Safety Improvement Measures Based on Level crossing Inventories", CD- Proceedings of the World Congress on Railway Research, Canada.