ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

EVALUATION OF COST-EFFECTIVE SYSTEMS FOR RAILWAY LEVEL-CROSSING PROTECTION

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CHAPTER 1: INTRODUCTION

Road/rail grade intersections are unique in the world of transport in as much as they present the only case of two different infrastructures placed under different responsibilities and travelled by vehicles with dramatically different performances which converge and meet during their normal operation. The result is that these intersections constitute high-risk spots for all railways in the world. The potential for accidents is made higher as the railways only control only half the problem. The other half, meanwhile, cannot really be said to be controlled by one entity as, even though traffic rules and road design standards supposedly exist, the movements of road users are not organised and monitored by one specific entity as rigidly as rail movements. The railway systems of the ESCAP region do not escape this general observation. Each year, accidents at level crossings not only cause the deaths of or serious injuries to many thousands of road users and railway passengers, but also impose a heavy financial burden in terms of interruption of railway and road services and damage to railway and road vehicles and property.

The great majority of these collisions are caused by the negligence, incompetence or incapacity of road vehicle drivers, who by and large operate their vehicles in environments in which safety consciousness is practically non-existent.

Since it is the railway which must bear the responsibility for ensuring that it is protected from the transgressions of road users (despite the fact that in many countries the law gives it priority of passage over road users), it is the railway which also has to shoulder most of the financial burden of providing this protection. Similarly, it is the railway, which has most of the responsibility for educating road users on the safe use of its level crossings.

Notwithstanding these responsibilities, it appears that many of the region’s railways are ill-equipped to be in a position to monitor level crossing safety effectively and to take both corrective and pro-active measures to improve the safety of their level crossing installations.

In view of this and, given the financial burden of accidents on the resources of the operating companies – in most cases government-granted subsidies – ESCAP, with generous financial assistance from the Government of Japan, launched the present study in 1999 with the objective of assisting railway administrations in the ESCAP region to improve railway safety through the provision of practical guidance/methodology to select cost-effective systems for level-crossing protection.

The study outputs were to:

(i) review the present status of level-crossing accidents in the ESCAP region;

(ii) present statistics, indicators, technology and problems relating to the systems adopted by the participating countries for level-crossing protection;

(iii) analyse various alternative systems for level-crossing protection; and

(iv) make recommendations pertaining to the selection of cost-effective protection systems.

To accomplish the above the following activities were carried out:

(i) assessment of level crossing safety performance and safety measures in seven selected countries of the region (Bangladesh, India, the Islamic Republic of Iran, the Philippines, the Russian Federation, Thailand and Viet Nam);

(ii) assessment of level crossing safety performance and safety measures in a selection of other countries which are advanced in their railway development and can possibly provide possible “best practice” examples of methods and practices for dealing effectively with the level crossing problem (these countries are: Canada, Belgium, France, Germany, Japan, the Netherlands, the United Kingdom and the United States);

(iii) evaluation of the requirements of a Safety Management Information System which adequately addresses the needs of railway managements for information on level crossing safety performance;

(iv) evaluation of the approaches to the application of Quantitative Risk Analysis (QRA) to establishing priorities for level crossing safety enhancement measures;

(v) explanation of suitable approaches to undertaking Cost Benefit Analysis of investments in level crossing safety enhancement;

(vi) review of the technical attributes of modern, cost effective systems for protection of level crossings as well as the criteria which can and should be applied to the selection of appropriate systems; and

(vii) recommendations of guidelines for adoption by the railway administrations of the region in managing the problem of level crossing safety on their systems.

Outputs (i) and (ii) relating to activities (i) and (ii) are addressed in Chapters 2 and 3 of this report, output (iii) relating to activity (vi) is addressed in Chapter 4 and output (iv) relating to activities (iii), (iv), (v) and (vii) is addressed in Chapters 4 and 5.

Railway safety is a crucial aspect of rail operation the world over, malfunctions resulting in accidents usually get wide media coverage even when the railway is not at fault and give to rail transport among the uninformed public an undeserved image of inefficiency often fuelling calls for immediate reforms. It is therefore hoped that the present study will help the railway administrations concerned strengthen their safety culture and develop the monitoring tools required by modern safety management.

CHAPTER 2: SCALE AND SEVERITY OF RAILWAY LEVEL CROSSING ACCIDENT PROBLEM IN SELECTED COUNTRIES OF THE REGION

2.1 General

This chapter surveys the level crossing safety problem in relation to the overall railway safety problem in certain countries of the Asia-Pacific region. The countries for which level crossing safety data were obtained are : Bangladesh, India, Islamic Republic of Iran, Philippines, Russian Federation, Thailand, and Viet Nam. Detailed data were requested and obtained from India, the Islamic Republic of Iran, the Russian Federation and Viet Nam while the data requested and obtained from Bangladesh, Philippines and Thailand were of a more general nature.

Major factors included in the analysis for individual countries include:

(i) *Level crossing safety record* – trend details for absolute numbers and rates per million train-km of level crossing accidents, fatalities, injuries and (where possible) property damage;

(ii) *Level crossing characteristics and effectiveness* – details and effectiveness of the types of level crossings and level crossing protection systems in operation, and planned for future operation;

(iii) *Administration of railway safety regulations* – responsibility for enforcement of safety (including level crossing safety) regulations and for investigation of accidents;

(iv) *Techniques used for evaluation of level crossing safety improvements* – technical and financial (including quantified risk analysis, where applicable);

(v) *Initiatives taken for level crossing safety improvement in recent years* – technical and non-technical (including pedestrian/motor vehicle driver education); and

(vi) *Impediments to safety improvement at level crossings.*

2.2 Level Crossing Safety in India

2.2.1 Summary

The Indian Railway network with a route length of 62,495 km has a total of 40,445 level crossings, or an average of one every 1.5 kilometres. Of this total, 16,132 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 with road warning signs, and 2,837 are simple open crossings with neither barrier protection nor fixed road warning signs.

In 1997/98, level crossing accidents constituted 65 out of a total of 420 accidents (or 15 per cent) of all types on the Indian Railway network. However, in the same year, level crossing accidents accounted for 42 per cent (134 individuals) of all fatalities and 18 per cent (179 individuals) of all persons injured in railway accidents on the network.

In one year surveyed, 80 per cent of all level crossing accidents occurred at crossings which were unmanned.

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 gates with a high level of usage by road and/or rail and not to construct any more crossings for unmanned operation. Subject to the availability of funds, level crossings which have reached a traffic moment (train movements x motor vehicle movements) of 100,000 per day or more are being replaced by the construction of road over or under-passes. However, these are very costly and only 50 per cent of the cost of their construction is being funded directly by the state government road authorities.

While the Indian Railways have contributed to motor vehicle driver and pedestrian education programmes, it is clear that these have had limited impact – perhaps a reflection of a lack of a safety awareness culture in India.

In future it is possible that the Indian Railways will have to embrace a fundamental policy change in relation to level crossing safety – one which might involve provision of automatic barrier and warning light/audible warning protection at some of the 24,313 unprotected crossings throughout India. With this possibility in view, the Indian Railways are pilot-testing train actuated barrier and road user warning systems for such applications.

2.2.2 Level crossing safety record

(a) Accidents

Level crossing accidents comprise a small but growing proportion of all railway accidents in India. In the last year for which data were available (1997/98) the total number of railway accidents in India was 420 and the number of recorded accidents at level crossings 65. The trend in level crossing accidents as a proportion of all railway accidents is shown in Table 2.1.

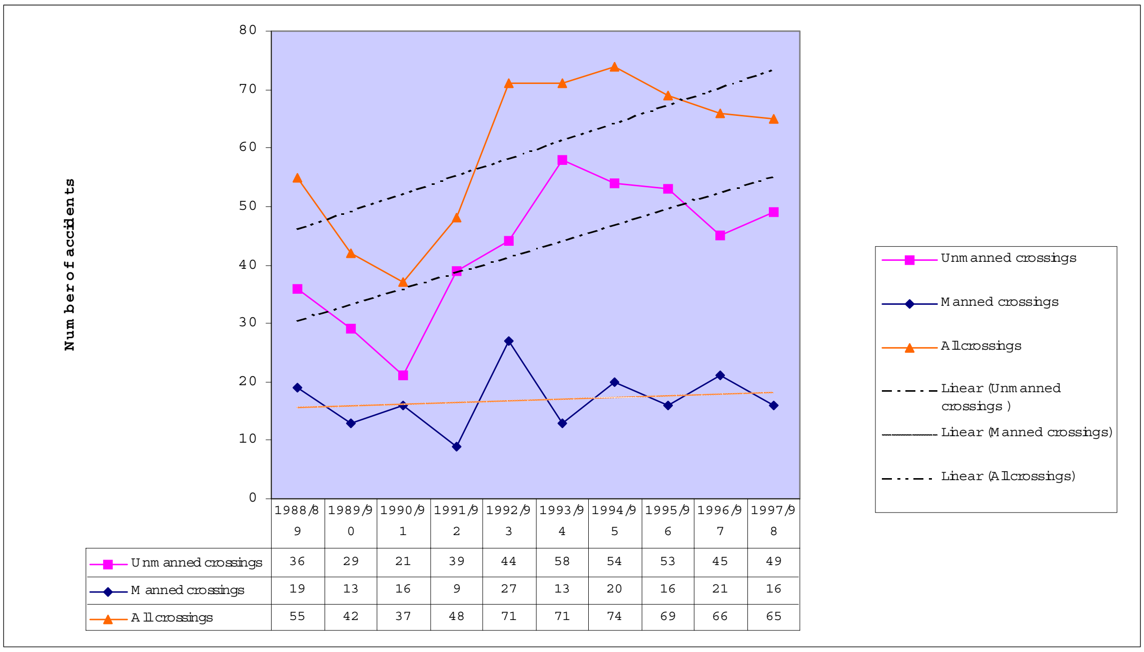
Table 2.1: Significance of and trend in level crossing accidents in India

Year	Total railway accidents (No.)	Accidents at level crossings (No.)	Level crossing accident %
1988-89	545	55	10.1
1989-90	541	42	7.8
1990-91	532	37	7.0
1991-92	742	48	6.5
1992-93	746	71	9.5
1993-94	675	71	10.5
1994-95	604	74	12.3
1995-96	440	69	15.7
1996-97	426	66	15.5
1997-98	420	65	15.5

Source: Indian Railways Country Paper.

Nearly two thirds of the total number of level crossing accidents occur at *unmanned* level crossings and this proportion has been increasing over the past decade as is shown in Figure 2.1.

Figure 2.1: Level crossing accidents in India, by type of crossing



	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98
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	48	71	71	74	69	66	65

Source: Indian Railways Country Paper.

(b) Fatalities

In 1996/97, fatalities in level crossing accidents comprised nearly 63 per cent of all fatalities in railway accidents in India, as is shown in Table 2.2. Although the share of level crossing deaths in all railway fatalities declined significantly in the following year (1997/98), over the decade it has shown a rising trend which is explained in part by increasing train speeds and in part by increasing motorization of rural communities. There is evidence to suggest that a majority of level crossing fatalities occur at unmanned (and therefore unprotected) level crossings in rural locations and involve slow moving farm vehicles driven by inexperienced drivers. There also appears to be a high number of accidents involving buses, *which would explain why the relatively low incidence of level crossing accidents results in a disproportionately high number of fatalities.*

Table 2.2: Significance of and trend in level crossing fatalities in India

Year	Total fatalities in railway accidents (No.)	Fatalities in level crossing accidents (No.)	Level crossing fatality %
1988-89	231	52	22.5
1989-90	239	51	21.3
1990-91	322	75	23.3
1991-92	235	104	44.3
1992-93	282	116	41.1
1993-94	369	168	45.5
1994-95	296	187	62.8
1995-96	589	138	23.4
1996-97	353	221	62.6
1997-98	316	134	42.4

Source: Indian Railways Country Paper.

(c) Injuries

With the exception of three years (1991/92, 1993/94 and 1996/97), over the past decade level crossing injuries have comprised a relatively constant proportion (about 20 per cent) of all injuries in railway accidents in India.

Table 2.3: Significance of and trend in level crossing injuries in India

Year	Total injuries in railway accidents (No.)	Injuries in level crossing accidents (No.)	Level crossing injury %
1988/89	736	134	18.2
1989/90	992	192	19.4
1990/91	888	175	19.7
1991/92	896	302	33.7
1992/93	908	222	24.4
1993/94	906	312	34.4
1994/95	676	159	23.5
1995/96	934	191	20.4
1996/97	610	264	43.3
1997/98	977	179	18.3

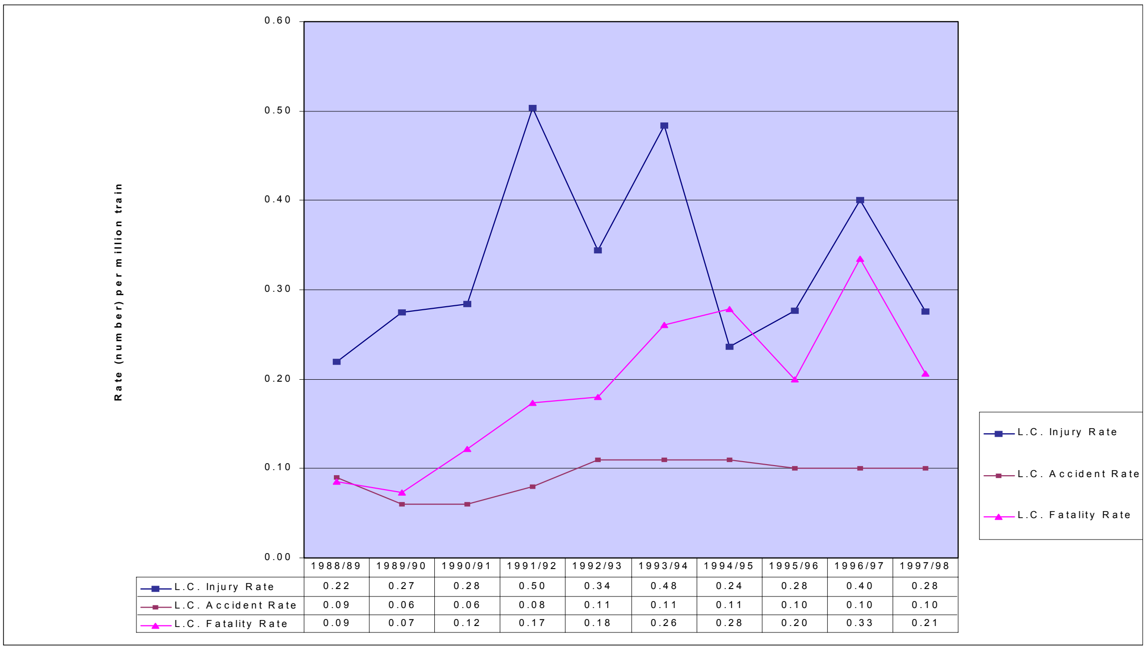
Source: Indian Railways Country Paper.

(d) Accident, Fatality and Injury Rates

In common with all types of railway accidents, accidents at level crossings and the deaths and injuries they cause can be expressed in terms of a rate per unit of railway traffic. The railway traffic unit most commonly used for this purpose is the train kilometre (expressed in terms of million train kilometres on a system-wide basis). This unit is also a measure of *risk exposure* for motor vehicles using level crossings.

Figure 2.2 shows the level crossing accident, fatality and injury rates for India during the past decade. These indicate stability in the accident and injury rates which in the case of the former remained almost constant at 0.10 per million train kilometres and in the case of the latter fluctuated around a long term rate of 0.35 per million train kilometres. By contrast, the level crossing fatality rate rose sharply, from 0.10 per million train kilometres in 1988/89 to more than 0.30 per million train kilometres in 1996/97, before dropping to 0.20 per million train kilometres in 1997/98. The factors mentioned in sub-section (b) above are mostly responsible for the rising trend in level crossing fatalities.

Figure 2.2: Level crossing accident, fatality and injury rates in India



	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98
L.C. Injury Rate	0.22	0.27	0.28	0.50	0.34	0.48	0.24	0.28	0.40	0.28
L.C. Accident Rate	0.09	0.06	0.06	0.08	0.11	0.11	0.11	0.10	0.10	0.10
L.C. Fatality Rate	0.09	0.07	0.12	0.17	0.18	0.26	0.28	0.20	0.33	0.21

Source: Indian Railways Country Paper.

2.2.3 Level crossing characteristics and effectiveness

(a) General characteristics

The Indian Railways network contains the greatest number of level crossings of any railway system in Asia. In general, the IR network has five different types of level crossings, these being: a manually controlled full width lifting barrier type; a mechanical full width swinging barrier type; a fixed warning sign without barrier type; an open type crossing, without barriers or warning signs; and a cattle crossing. The population of level crossings by type on the IR network is given in Table 2.4.

Table 2.4: Level crossings on the Indian Railways network, by type

Class of L.C.	***Type of L.C.***	***No on system***	***Brief description***
Manned	Special	296	Manually controlled full width lifting barrier. All crossings in category are signalled. Road regularly open. Carries road of minimum 7.5 metre width.
	A	1,406	Manually controlled full width lifting barrier. All crossings in category are signalled. Road regularly open. Carries road of minimum 5.5 metre width.
	B	3,858	Manually controlled full width lifting barrier/ mechanical full width swinging barrier. 1,918 crossings in category (50%) are signalled. Road regularly closed.
	C	10,509	Manually controlled full width lifting barrier/ mechanical full width swinging barrier. 1,879 crossings in category (18%) are signalled. Road regularly closed.
	Canal	63	Mechanical full width swinging barrier. Road regularly closed.
	Sub-total, manned	*16,132*	
Unmanned	C	20	Warning signal. Open crossing without barrier.
		20,508	Open crossing without barrier.
	Canal	948	Open crossing without barrier.
	D	2,837	Open crossing without barrier and without check rails (cattle crossing).
	Sub-total, unmanned	*24,313*	
Total		***40,445***	

Source: Indian Railways Country Paper.

Special, Class A and Class B level crossings essentially have the same type of equipment but are distinguishable from one another in terms of the types of roads they carry as well as their daily road and rail traffic density. Thus, Special Class crossings which mostly carry roads of National Highway standard are equipped with wider barriers than are Class A crossings, while Class A crossings will require wider barriers than Class B crossings, and so on. The top three categories, representing nearly 40 per cent of all level crossings on the IR system, have barriers which are fully interlocked with wayside signals. Normally, warning to train drivers of the need to stop before a Special-B Class level crossing is provided via distant signals placed at an interval of 1 kilometre from the crossing. A second distant signal is placed at a further interval of 1 kilometre from the first if train speeds exceed 120 km per hour. From the train driver’s perspective each interlocked level crossing is protected by a “Gate Stop” signal with a black “G” on a yellow disc. When a level crossing becomes obstructed, the gatekeeper is required to protect the gate with detonator signals. A problem which exists throughout the IR system is that detonators (which have a lifespan of 10 years) are often life-expired and unserviceable.

At non-interlocked, but manned, level crossings warning of the impending arrival of a train is provided by telephone to the crossing keeper by the station master of the nearest station. The crossing keeper will then exchange a private number with the station master to indicate that he has closed the barrier and that the station master may now dispatch the train.

Canal crossings are level crossings provided across canal service roads, used by Irrigation Authorities for inspection and maintenance of canals. The gates across these service roads are operated and locked by Irrigation Authorities who also keep the keys.

Significant features of the level crossing inventory data provided in the Country Paper for India are that the existence of “unofficial” level crossings on the IR system is not acknowledged and that 16,132 out of 40,445 level crossings on the system (or nearly 40 per cent) are manned. This high manning ratio may largely explain why the Indian Railways, at least on the surface, appears to have a relatively good level crossing safety record, although the quality of the data relating to level crossing accidents and casualties has recently been criticized by the Commissioners for Railway Safety and by the Railway Safety Review Committee.[1] During one recent year, some 90 per cent of all level crossing accidents were estimated to have occurred at unmanned, and therefore unprotected, level crossings. This contrasts with the situation in Western Europe where by far the great majority of accidents occur at level crossings equipped with automatic barrier protection (see Chapter 3).

As may be observed in Table 2.5, IR safety statistics indicate that half of all accidents at manned level crossings were caused by “open or improperly closed or secured gates”. The other main factors contributing to these accidents were negligence, irresponsibility or incapacity on the part of motor vehicle drivers. In an effort to prevent accidents caused by this factor, IR has adopted a plan to equip 1,063 level crossings with relay interlockings between now and the year 2003.

Table 2.5: Causes of accidents at manned level crossings,1993-94 to 1997-98

No	Causes	93-94	94-95	95-96	96-97	97-98	Total
1	Due to open or improperly closed or secured gates.	8	8	11	9	7	43
2	Road vehicles coming over the level crossings where barriers on the other side had been closed.	2	1	0	2	0	5
3	Road vehicles crashing into the lifting or swing type gates or breaking the lock and opening it.	1	4	5	5	4	19
4	Road vehicles breaking or opening the chains at level crossings closed by chains.	0	1	0	0	1	2
5	Road vehicles left at level crossings or infringing track.	0	0	0	0	0	0
6	Disregard of signals by drivers.	2	4	0	2	4	12
7	Non-issue of caution order to driver when gate telephone is out of order.	0	0	0	0	0	0
8	Other Causes.	0	2	0	3	0	5
Total		13	20	16	21	16	86

Source: Indian Railways Country Paper.

Another unique feature of level crossings on the IR system is that nearly 90 per cent of all protected (i.e. manned) level crossings, comprising those in Classes B and C, are normally closed against road traffic – that is, the barriers are only opened when there is a significant build-up of road traffic and are then closed again when the road traffic build-up is cleared. This procedure is rarely applied in other countries

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[1] *Report of the Railway Safety Review Committee 1998,* New Delhi, August 1999.

and may also partly serve to explain the relatively good safety performance of IR level crossings.

A negative feature of level crossing operating procedures on the IR system is that barrier closure time on some level crossings is unusually long. An inspection of level crossings in the Agra area during the ESCAP mission to India in October 1999 revealed that at one “Class A” level crossing the maximum time of closure of the crossing barriers was 8 minutes, with an average of 5 minutes. Such closure times are much longer than those which would normally be tolerated by road users and could well result in barrier breakthroughs by motor vehicles and pedestrians. Excessively long barrier closure times tend to be a feature of the Absolute Blocking and Tablet systems of safe working in that these systems require barriers to be closed immediately after a train’s departure from a neighbouring station. By contrast, typical barrier closure times encountered at mainline level crossings in Thailand and in Viet Nam were only of the order of 2 minutes.

The policy of the Indian Railways to replace Absolute Block with Automatic Block Signalling is therefore a major step forward, as for very little additional expense it can be expected to result in significantly shorter level crossing closure times with attendant benefits in terms of increased line capacity and a reduced risk of level crossing accidents and casualties as a result of barrier breakthroughs. The further move towards an ATCS (radio-based Advanced Train Control System) will produce even greater benefits, since it will allow crossing closure times to be adjusted in line with road traffic demand without compromising safety.

(b) Characteristics by zonal railway

The vastness of the country and its railway network has made regional autonomy in the management of this network essential. Consequently, the network is divided into nine operating regions or zones, each one having complete control over all aspects of railway operations on its territory, including safety. The characteristics and effectiveness of the level crossing systems in operation on each zonal railway may be gauged from Table 2.6 below.

It may be observed from this table that accident occurrences are much greater on the Southern Railway than on any other zonal railway, yet the Southern Railway is not significantly disadvantaged in terms of having a higher proportion of unmanned level crossings or a lower proportion of interlocked level crossings than any other zonal railway. The explanation of this difference might lie in the volume and composition of the traffic carried on this railway.

Table 2.6: Level crossing characteristics and performance, by zonal railway

Zonal Railway	No of Level Crossings	Proportion of Interlocked Level Crossings (%)	No. of unmanned Level Crossings	Proportion of unmanned Level Crossings (%)	Accidents at Level Crossings	Accidents at L.C./ 1000 L.C.	Accidents at L.C./1000 unmanned L.C.
Central R.	3,125	19	1,294	41	18	5.76	13.94
Eastern R.	2,264	22	987	43	10	3.06	10.13
Northern R.	6,748	18	3,517	52	75	11.11	21.32
North Eastern R.	4,038	7	2,585	64	42	10.40	16.24
Northeast Frontier R.	1,943	13	1,247	64	11	5.66	8.82
Southern R.	4,484	19	2,290	51	73	16.28	31.88
South Central R.	3,443	17	1,947	57	42	12.20	21.57
South Eastern R.	4,338	14	3,394	78	25	5.76	7.37
Western R.	7,098	10	4,128	58	49	6.90	11.87
Total	37,481*	15	20,389	54	345	9.20	16.92

Source: Indian Railways Country Paper.
* ***Note*** *that this total does not include cattle crossings (unlike the total shown in Table 2.4).*

2.2.4 Administration of railway safety regulations: role of the CRS

The Indian Railways Act assigns responsibility for any accident occurring at unmanned level crossings to the road user. This is also as per the provisions of the Motor Vehicle Acts issued by the State Governments. IR has traditionally not considered any fundamental policy changes with regard to unmanned level crossings where the density of traffic has been low. Two of the high level Rail Accidents Inquiry Committees, namely, the Kunzru Committee and Wanchoo Committee, have in the years 1962 and 1968 respectively, not recommended any fundamental policy changes and have also not recommended that IR takes over responsibility.

However, a system for independent investigation of railway accident has been adopted in India. This system involves the establishment of an office of Commissioner of Railway Safety (CRS) for each zonal railway. The CRS operates independently of the railway organization and actually reports to the Minister of Civil Aviation.

In essence, the functions of the CRS are similar to those of the Railway Inspectorate of the Health and Safety Executive in the United Kingdom in that the post provides an independent source of inquiry and advice concerning all railway safety matters. The CRS has three main functions, namely:

(i) inspection and operational certification of new railway lines;
(ii) operational certification of all new motive power and rolling stock; and
(iii) conduct of inquiries into railway accidents.

The last of these functions comprises 90 per cent of the workload of the CRS's. In general, the CRS will investigate an accident if it involves fatalities, property damage greater than 2.5 million rupees (or approximately US$ 57,000), or if the interruption to traffic is longer than 24 hours. The decision as to whether to conduct an inquiry rests with the CRS who may decide to delegate an inquiry to railway officers. If a judicial inquiry is subsequently ordered, the CRS is obliged to suspend his own inquiry.

While the CRS has the power to conduct an inquiry, to write a report and to make recommendations on each accident investigated, the executive authority for safety regulation resides with the operational managements of each zonal railway. Thus, these managements may decide to accept the recommendations of the CRS either in full or in part, or alternatively to reject them completely. In practice, however, the CRS works closely with the Executive Director Safety at the level of the Railway Board and with Chief Safety Officers at the level of the zonal railways.

Discussions with the CRS attached to the Northern Railway indicated that the role of the CRS has been effective in identifying a number of problems related specifically to level crossing safety. These include:

(i) a lack of information in official safety statistics about accidents involving pedestrians, at level crossings or elsewhere (it was estimated that in the Northern Railway these amounted to about 5-10 per day);

(ii) poor maintenance by the railways of the road approaches to level crossings carries with it the risk of vehicles being grounded on crossings and subsequently being struck by trains (such accidents were considered to be very frequent on the Northern Railway);

(iii) the inadequacy of manually operated swing gates on double track lines (due to the time taken to close these gates road users can enter the crossing from the “open side” and risk being caught in the middle); and

(iv) poor training and lack of professional competence among level crossing staff (the CRS’s have been active in promoting the recognition of crossing keepers as an occupational grade with a career path and a proper training syllabus).

2.2.5 Level crossing system evaluation techniques

Systematic evaluation of level crossing safety performance and of justification for upgraded crossing protection is carried out by the Indian Railways. In general, the Train Vehicle Unit (TVU) is used as the criterion for identifying which level crossings will have priority for upgrading. The TVU as it is known in India is identical to the Traffic Moment (TM) indicators as applied in other countries in that it results from the multiplication of the daily road traffic volume at a level crossing by the daily number of trains passing through that crossing. The TVU criteria applied in India are as shown in Table 2.7.

Table 2.7: TVU criteria for level crossing type

Item	*Daily traffic density/ traffic movement*	*Type of crossing indicated*
1	TVU < 6,000	Unmanned level crossing
2	6,000 ≤ TVU < 10,000	All unmanned level crossings to be manned on programmed basis
3	10,000 ≤ TVU < 100,000	Manned level crossings
4	TVU ≥ 100,000	Road flyover / overpass

Source: Indian Railways Country Paper.

Visibility is also a criterion used in order to identify those *unmanned* (and hence unprotected) level crossings which are to be given priority for manning. All unmanned level crossings are required to have a clear visibility for road users of 600 metres as observed by them at 5 metres from the centre of the railway track. Level crossings not having visibility to road/rail traffic up to the prescribed distance are considered hazardous and are manned by the Indian Railways at its cost. The combined TVU and visibility criteria used to establish priorities for manning of unprotected level crossings are set out in Table 2.8. Throughout the network, a total of 4,449 level crossings have been identified as having priority for manning.

Table 2.8: Criteria for manning of *unprotected* level crossings

Priority Category	**Description**	**Number on system**
1	Level crossings having more than 10,000 TVU	123
2	Level crossings having more than 6,000 TVU, but which are hazardous on account of restricted visibility	57
3	Level crossings where traffic density is less than 6,000 TVU but where buses and other motor vehicles ply regularly.	591
4	Level crossings with TVU less than 6,000 and restricted visibility, but where motor vehicles do not ply	2,537
5	Level crossings where visibility is adequate but traffic density exceeds 6,000 TVU	1,141
Total		4,449

Source: Indian Railways Country Paper.

Another criterion used to establish priorities for manning of unprotected level crossings is the relative importance of the railway line in terms of traffic density and maximum train speeds. Seven classifications have been devised with descending manning priorities, from Group A to Group E as shown in Table 2.9.

Table 2.9: Measures of the importance of railway lines used to establish level crossing manning priorities

Group A	Speeds of up to 160km/h
Group B	Speeds of up to 130km/h
Group C	Suburban systems in Bombay and Calcutta
Group D-Special	Traffic density is very high or likely to grow substantially in future and the sanctioned speed is 100km/h at present
Group D	Speed is 100km/h at present
Group E-Special	Traffic density is very high or likely to grow substantially in future and present sanctioned speed is less than 100km/h
Group E	Sections and branch lines with a present sanctioned speed of less than 100 km/h.

Source: Indian Railways Country Paper.

2.2.6 Level crossing safety initiatives

(a) Manning of unprotected level crossings

The current five-year plan (covering the period 1999/2000 to 2003/2004) provides for the progressive conversion of unmanned/unprotected crossings to manned/protected status. Depending upon the assigned category of each crossing, this will involve installation of warning signs or lights and boom barriers of various types as well as construction of a crossing attendant's workstation at prioritised locations. Details of this programme are given in Table 2.10.

Table 2.10: Annual plan of level crossing conversion to manned status

Year	No of level crossings proposed for manning	Route Group	Priority Category
1999~2000	391	A, B&C	I~IV
2000~2001	1,000	D-Special	I~IV
2001~2002	950	E-Spl, D&E	I~IV
2002~2003	967	E	I~V
2003~2004	1,141	A, B, C, D-Spl,D, E-Spl, E	V
Total	4,449		

Source: Indian Railways Country Paper.

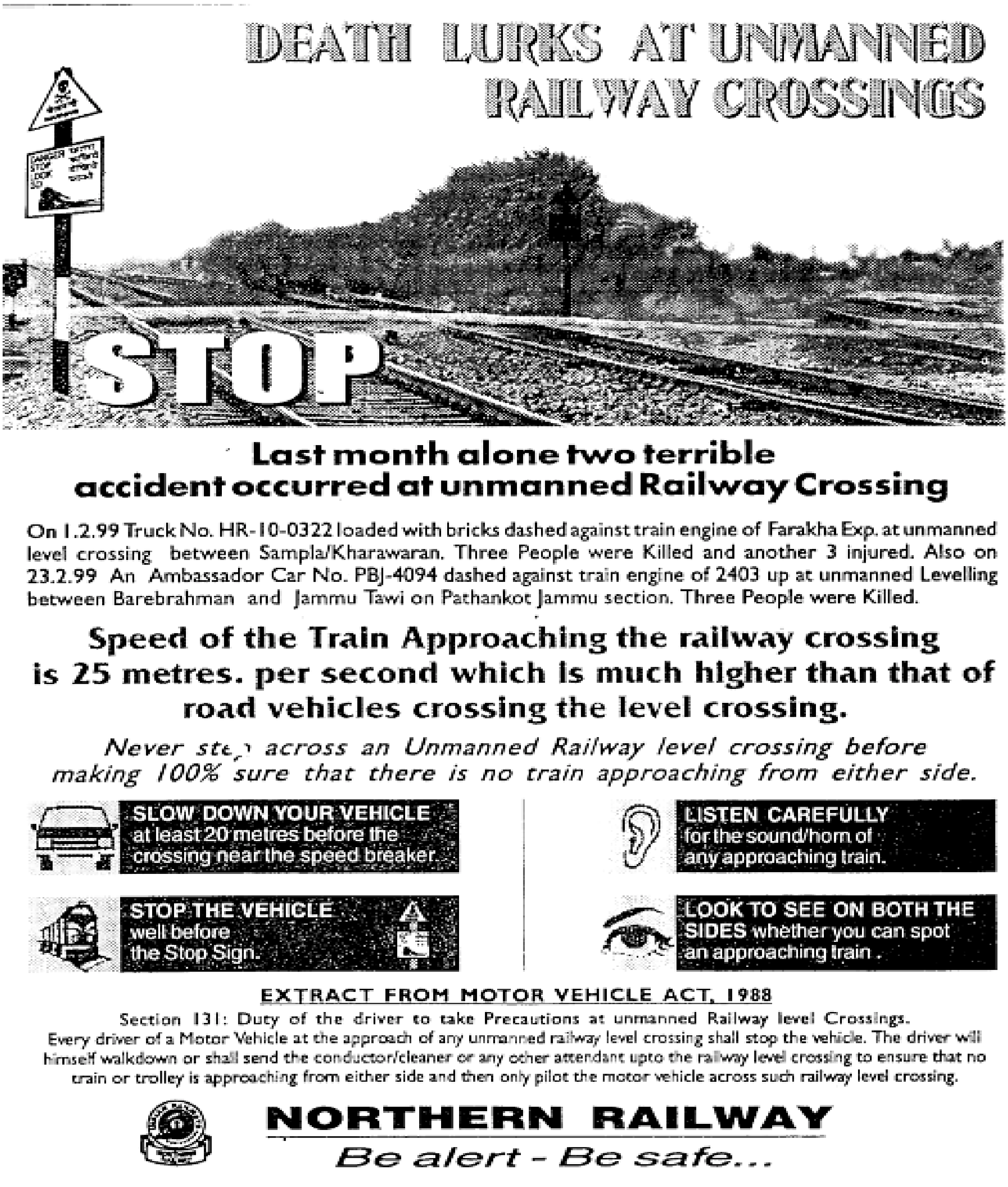
(b) Other level crossing upgrading measures

In addition to conversion of unprotected level crossings to manned status, the Indian Railways has a plan to grade separate or to relay interlock some of the more densely trafficked crossings on its network.

During the current five-year plan (1999/2000-2003/2004), it is proposed to interlock a total of 1,063 level crossings, while road under or over-passes are currently under construction at 339 locations throughout India. Owing to the high cost of these initiatives and (in the case of grade separation) to the necessity of sharing the cost with road authorities and/or private developers, progress has been slow.

(c) Road user education

The Indian Railways has only a very small budget for road user education but does make use of the mass media (mainly television and newspapers) to promote public awareness of the need for caution when using level crossings. One effective means of disseminating this message is the use of notice boards in *punjayat* (or local village) offices to display safety posters. Since residents of rural areas tend to regularly visit their *punjayat* offices, this initiative has the potential to reach a wide section of the community. One such poster used to promote caution by the public when using level crossing is shown hereafter.



DEATH LURKS AT UNMANNED RAILWAY CROSSINGS

STOP

Last month alone two terrible accident occurred at unmanned Railway Crossing

On 1.2.99 Truck No. HR-10-0322 loaded with bricks dashed against train engine of Farakha Exp. at unmanned level crossing between Sampla/Kharawaran. Three People were Killed and another 3 injured. Also on 23.2.99 An Ambassador Car No. PBJ-4094 dashed against train engine of 2403 up at unmanned Levelling between Barebrahman and Jammu Tawi on Pathankot Jammu section. Three People were Killed.

Speed of the Train Approaching the railway crossing is 25 metres. per second which is much higher than that of road vehicles crossing the level crossing.

Never step across an Unmanned Railway level crossing before making 100% sure that there is no train approaching from either side.

SLOW DOWN YOUR VEHICLE at least 20 metres before the crossing near the speed breaker.

LISTEN CAREFULLY for the sound/horn of any approaching train.

STOP THE VEHICLE well before the Stop Sign.

LOOK TO SEE ON BOTH THE SIDES whether you can spot an approaching train .

EXTRACT FROM MOTOR VEHICLE ACT, 1988

Section 131: Duty of the driver to take Precautions at unmanned Railway level Crossings.
Every driver of a Motor Vehicle at the approach of any unmanned railway level crossing shall stop the vehicle. The driver will himself walkdown or shall send the conductor/cleaner or any other attendant upto the railway level crossing to ensure that no train or trolley is approaching from either side and then only pilot the motor vehicle across such railway level crossing.

NORTHERN RAILWAY

Be alert - Be safe...

2.2.7 Level crossing safety impediments

Apart from a lack of adequate capital funds to upgrade level crossings, the main factors considered to be working against an improvement in level crossing safety in India are:

(i) *the lack of priority* given by road authorities to improving level crossing safety (no doubt explained by the fact that level crossing accidents represent an insignificant proportion of all road traffic accidents in India);

(ii) the *lack of funding priority* in the Indian Railways budget for level crossing improvement/upgrading (unlike the situation which applies in other countries of the region, level crossing accidents account for only a small proportion – only 15 per cent in 1997/98 – of all railway accidents in India);

(iii) *increasing disposable incomes and motorization* in India, leading particularly to an increasing incidence of level crossing accidents in rural areas where general levels of education and safety awareness are poor; and

(iv) the *predominance of Absolute Block and Tablet systems of safe working* on the less densely trafficked railway routes in India means that lengthy delays to road traffic at level crossings will persist for some time into the future, adding to the possibility of an increasing incidence of barrier breakthroughs at manned level crossings.

2.3 Level Crossing Safety in the Islamic Republic of Iran

2.3.1 Summary

The Iranian Islamic Republic Railways operates a route network with a total length of 5,995 kilometres. This network is subdivided into five main routes and thirteen operating regions or districts. Within this network there are 344 official level crossings of all types and 74 unofficial level crossings giving a total of 418, or roughly one crossing for every 14.3 route-km on average. Thus, overall, the network cannot be said to have a particularly dense concentration of level crossings.

The region with the greatest level crossing density is the Shomal region to the east of Tehran with 381 route-km and 85 level crossings, or one for every 4.5 route-km. At the other extreme is the Jonobesharg region in the southeast of the country, with 685 route-km and only 14 level crossings, or one for every 49 route-km.

Of the 344 official level crossings in the network, 217 (or 63 per cent) are equipped with road warning lights and barrier protection and the remaining 127 (37 per cent) are simple open crossings with no form of road warnings and barrier protection whatever.

To a large extent level crossing safety is a function of the number and density of level crossings on a rail system. The relatively low density of level crossings on the railway system of the Islamic Republic of Iran is reflected in small numbers of accidents, fatalities and injuries on this system. In 1998, accident, fatality and injury rates for the system respectively stood at 0.64, 0.11, and 0.17 per million train-km, demonstrating that the Islamic Republic of Iran has one of the better level crossing safety records in Asia and one which is indeed superior to that of more than a few developed countries.

The Iranian Islamic Republic Railways has a policy to eliminate as many of the level crossings as possible through *grade separation.* However, although about 47 level crossings have been nominated for replacement by road overpasses, the construction cost of these overpasses has so far proven prohibitive, and other cheaper forms of safety enhancement have been pursued. These have included: provision of cement barriers along railway lines (especially in the exit areas of cities), in order to prevent road users from crossing the tracks at other than the officially designated level crossings; installation of electrically operated barriers to replace mechanical barriers, thereby reducing the time for closure of crossings to road traffic; replacement of older level crossing staff by younger, fitter staff; and replacement of defective signs and other road warning devices with state-of-the art audible and visible warning systems.

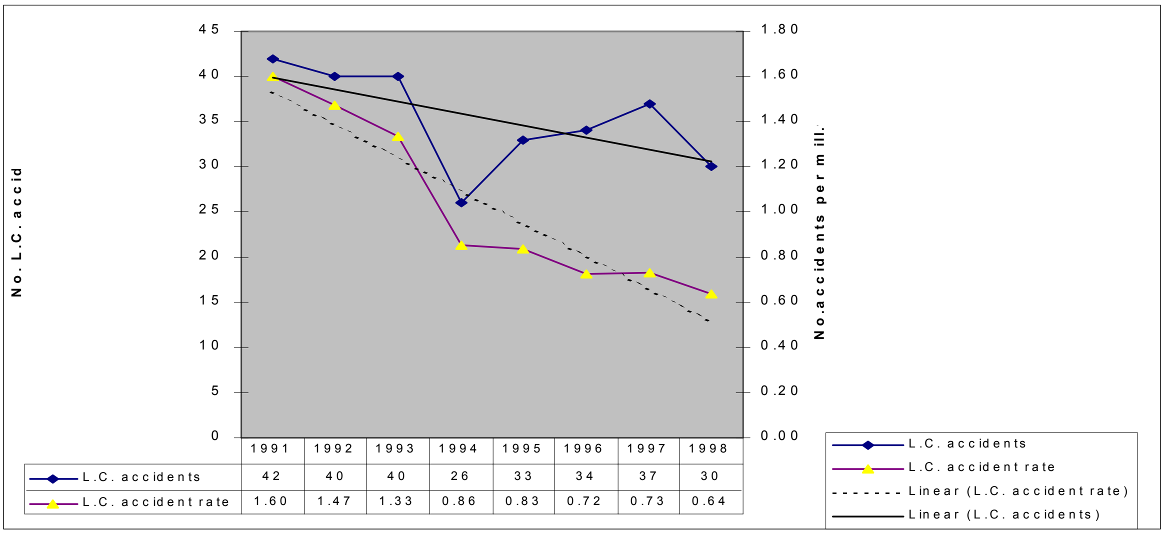
2.3.2 Level crossing safety record

(a) Accidents

Prior to 1997, data on railway accidents in the Islamic Republic of Iran were not available. Each region collected accident information in a form which suited its own requirements. However, data appear to be available on a consistent basis over the period 1991-1998.

Over this period, accidents at level crossings appeared to represent only 6-8 per cent of all railway accidents. As may be observed in Figure 2.3, the number of level crossing accidents during this period fell from 42 in 1991 to 30 in 1998, and the accident rate from 1.6 to 0.64 accidents for every million train-kilometres run.

Figure 2.3: Level crossing accidents in the Islamic Republic of Iran

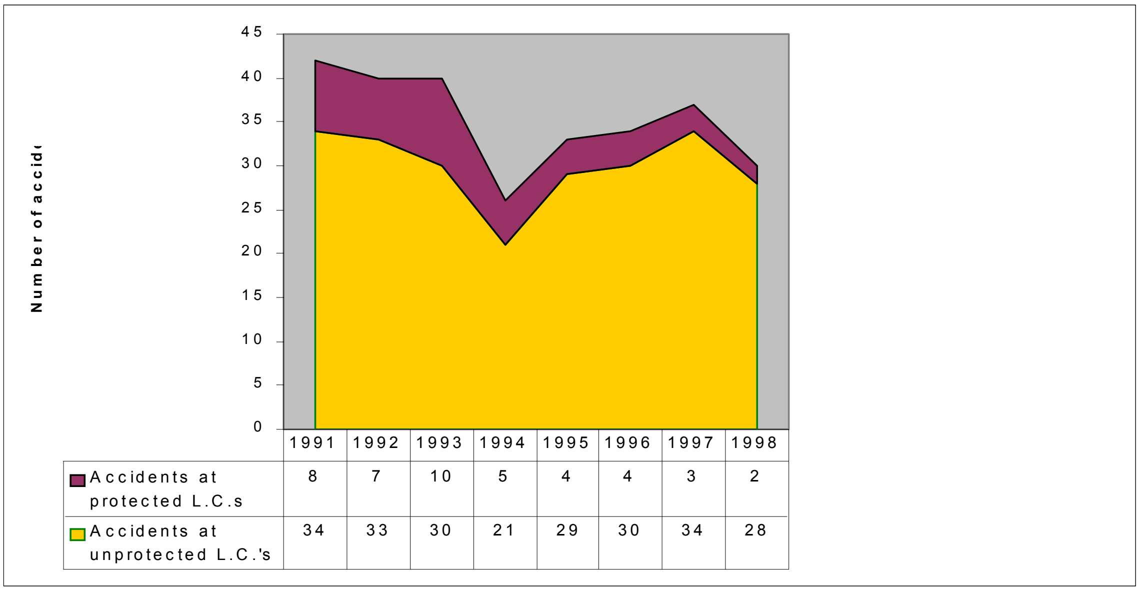


	1991	1992	1993	1994	1995	1996	1997	1998
L.C. accidents	42	40	40	26	33	34	37	30
L.C. accident rate	1.60	1.47	1.33	0.86	0.83	0.72	0.73	0.64

Source: Country Paper for Islamic Republic of Iran.

By far the greatest proportion (80-90 per cent) of the total number of level crossing accidents on the system occurred at unprotected level crossings, as is shown in Figure 2.4.

Figure 2.4: Number of accidents by type of level crossing in the Islamic Republic of Iran



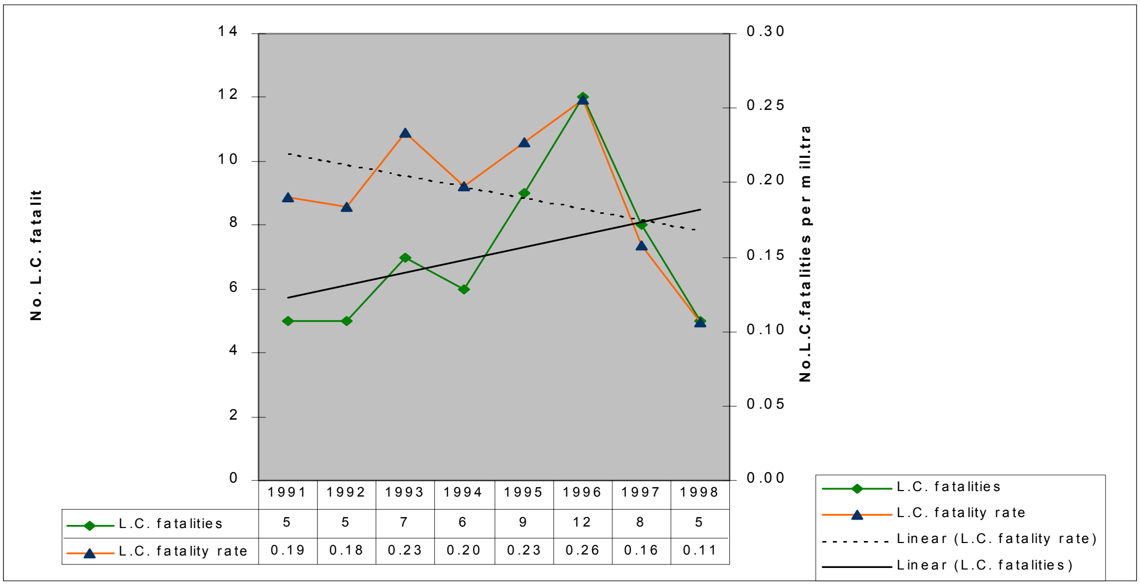
	1991	1992	1993	1994	1995	1996	1997	1998
🟪 Accidents at protected L.C.s	8	7	10	5	4	4	3	2
🟨 Accidents at unprotected L.C.'s	34	33	30	21	29	30	34	28

Source: Country Paper for Islamic Republic of Iran.

(b) Fatalities and injuries

Unlike accident occurrences, the number of persons killed (see Figure 2.5) and injured (see Figure 2.6) in level crossing accidents have been on a rising trend over the past 7-8 years, despite dramatic improvements in these statistics during the last two years of the review period (1997 and 1998). However, the fatality and injury rates corresponding with the absolute statistics have been declining steadily and at 0.11 persons killed and 0.17 persons injured per million train-km in 1998 compare quite favourably with many western countries.

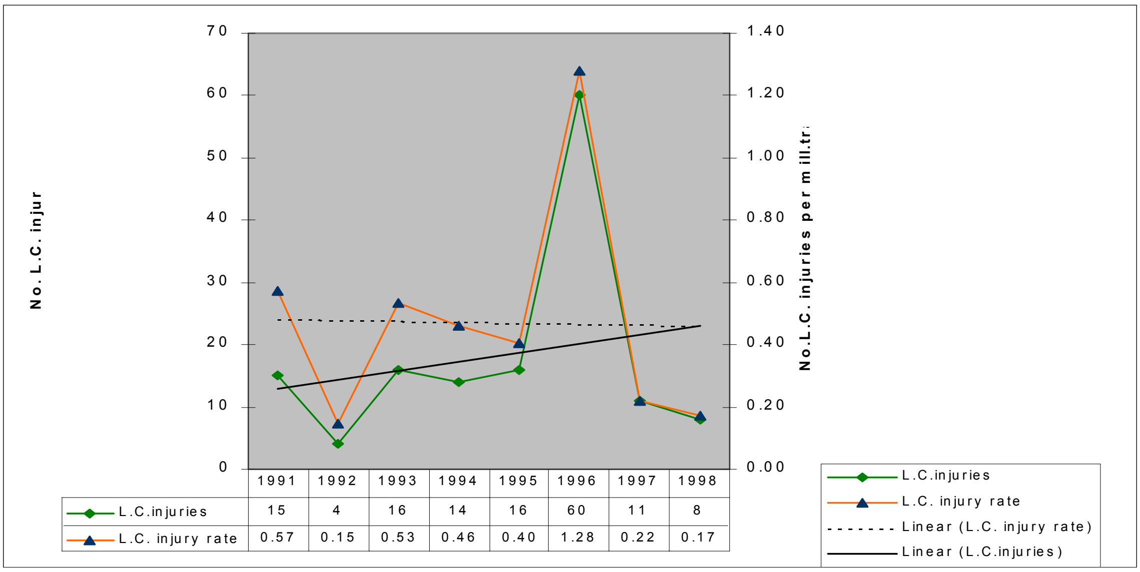
Figure 2.5: Level crossing fatalities in the Islamic Republic of Iran



	1991	1992	1993	1994	1995	1996	1997	1998
L.C. fatalities	5	5	7	6	9	12	8	5
L.C. fatality rate	0.19	0.18	0.23	0.20	0.23	0.26	0.16	0.11

Source: Country Paper for Islamic Republic of Iran.

Figure 2.6: Level crossing injuries in the Islamic Republic of Iran



	1991	1992	1993	1994	1995	1996	1997	1998
L.C.injuries	15	4	16	14	16	60	11	8
L.C. injury rate	0.57	0.15	0.53	0.46	0.40	1.28	0.22	0.17

Source: Country Paper for Islamic Republic of Iran.

2.3.3 Level crossing characteristics and effectiveness

Protected level crossings on the system of the Iranian Islamic Republic Railways are equipped exclusively with mechanically operated barriers. These are of two types: full width and half width lifting barriers (see Table 2.11).

In terms of the level of protection they afford, these barrier installations can be said to be safe, since accidents occurring at protected level crossings are clearly very few in number (only 2 in 1998). However, concern was raised in the country report that mechanical barriers may be incompatible with crossing closure times of short duration, since staff require more time to operate manually deployed barriers than they might if the barriers were electrically deployed. No information was provided on average crossing closure time for the system.

Table 2.11: Level crossing installations by type, Islamic Republic of Iran

Class	Type	Brief Description	Number on system	Associated Rail Signalling	Associated Road Signalling
Manual	Single Barrier (full width)	Mechanical full width lifting barrier	200	Fixed rail level crossing warning board	Fixed road level crossing warning board; flashing red light against road users.
Manual	Double Barriers (half-width)*	Mechanical half width lifting barrier	17	Fixed rail level crossing warning board	Fixed road level crossing warning board; flashing red light against road users.
Unprotected	-	Open crossing	127	None	None
Unofficial	-	Open crossing	74	None	None
Total			418		

Source: Country Paper for Islamic Republic of Iran.

* These are understood to be of the European design whereby half barriers are placed alternately across the road carriageway on either side of the track.

2.3.4 Administration of railway safety regulations

In the absence of any indication to the contrary in the country paper, it was assumed that the Iranian Islamic Republic Railways has sole responsibility for the administration of all safety regulations on its system.

In terms of its liability for human casualties and property damage resulting from level crossing accidents, the railway is not liable for compensation unless such accidents occur at protected level crossings *and* the railway has been deemed responsible by the courts system as a result of negligence on the part of its staff or of failure of its equipment. In such cases, the railway is required to pay compensation of up to US$ 10,000 for each person killed or injured, this amount being varied every year in accordance with Islamic Law. In common with most railways, the Iranian Islamic Republic Railways has absolute priority to operate within its own right-of-way, which is defined as the interval between boundaries fixed at 8.5 metres on either side of the track centreline. Road users are not permitted to encroach on this right-of-way except with the permission of the railway and at the appropriate crossings provided by the railway.

2.3.5 Level crossing system evaluation techniques (technical and financial)

The Iranian Islamic Republic Railways assesses level crossing upgrading priorities in relation to the following characteristics:

(i) location of the crossing;
(ii) rail and road traffic densities; and
(iii) width of the road crossing the rail tracks.

Thus, if a level crossing is within a city and has a wide road carriageway (e.g. double lane, dual carriageway), it will be equipped with double barriers either side of the tracks. If the level crossing carries a normal two lane road, it will be equipped with a single barrier either side of the tracks. If the level crossing is located outside a city and does not carry a main road, it will normally not be protected, i.e. it will have only fixed road warning boards at its approaches.

The Iranian Islamic Republic Railways is in the process of developing guidelines for use in assessing the case for upgrading its level crossing installations. While no official traffic density criteria yet exist as a basis for determining when and to what extent level crossings should be upgraded, a recent study by staff of the Railway Research Centre has indicated the following TM (Traffic Moment = daily number of road vehicles x daily number of trains) values for typical level crossings in each of the three categories in the system:

(i) *Class "a"* crossings. Minimum road vehicles per hour: 600
Minimum trains per day: 20
TM = 600 x 24 x 20 = *288,000*

(ii) *Class "b"* crossings. Minimum road vehicles per hour: 450
Minimum trains per day: 20
TM = 450 x 24 x 20 = *216,000*

(iii) *Class "c"* crossings. Minimum road vehicles per hour: 300
Minimum trains per day: 10
TM = 300 x 24 x 10 = *72,000*

It must be noted that the Iranian Islamic Republic Railways does not, as a matter of routine, take counts of road vehicles using its level crossings. Neither are these counts taken by the government agencies responsible for road construction and management. The above data were based on "one-off" counts of traffic using the busiest roads in each province.

Based on the above results of the Research Centre study, the railway proposes to establish criteria for the assessment of level crossings as follows:

Proposed level crossing assessment criteria, Islamic Republic of Iran

TM value	Indicated crossing type
TM < 72,000	No protection – simple fixed road warning signs at crossing approaches only
72,000 ≤ TM ≤ 288,000	Mechanical or electrically operated lifting barriers; fixed warning board and flashing warning lights against road users; fixed level crossing warning board against train drivers
TM > 288,000	Road overpass or underpass

Source: Country Paper for Islamic Republic of Iran.

It is government policy to replace level crossings with grade separated crossings wherever this may be justified by the frequency of accident occurrences and the combined volume of road and rail traffic at the crossing locations under assessment.

Responsibility for determining priorities and for undertaking grade separation and other level crossing upgrading works resides with the Deputy Minister of Railway Construction and Development.

The Deputy Minister's department will carry out economic evaluations of grade separation proposals taking into account the following factors:

- The *present annual value* (*PAV*) of the required investment in the grade separation works;
- Salary and maintenance cost of the level crossing to be replaced;
- Savings to road users resulting from reduced fuel consumption, vehicle depreciation and personal delay time; and
- Savings to the railway through elimination of speed restrictions.

It must be noted that these evaluations do *not* include allowances for benefits arising from reduced loss of life, injury and property damage, possibly because of the difficulty of identifying valid costs for these elements.

In the case of evaluations of major level crossing protection proposals, the major benefit assessed is the reduction of accidents at the level crossings involved. Again, such evaluations appear to exclude consideration of the benefits associated with reduced loss of life, personal injury and property damage, and are likely to be limited to the financial savings accruing to the railway in the form of reduced property damage and traffic disruption, as well as line capacity expansion resulting from removal of speed restrictions.

2.3.6 Level crossing safety initiatives

One of the major safety threats to the railway arises from the presence of unofficial level crossings which very often take the form of “distributed crossings” along a broad right-of-way frontage in the exit areas of cities. The Iranian Islamic Republic Railways has attempted to eliminate this problem by constructing concrete barriers alongside the railway tracks at some of the more critical locations.

2.3.7 Level crossing safety impediments

The Iranian Islamic Republic Railways has nominated the following factors as major impediments to the improvement of level crossing safety on its system:

(i) *Limited finance.* Construction of grade separated crossings is likely to cost anywhere between US$ 1 million and US$ 7 million per crossing depending upon the length of bridge spans required, while barrier protection and warning light installation is estimated to cost US$ 18,000 per crossing (suggesting a total of about US$ 3.6 million if all 201 of the existing unofficial and official, but unprotected, crossings are upgraded). The railway currently faces severe restrictions on its capital spending and indeed has no specific fund for level crossing improvement;

(ii) *Unfavourable social environment.* High risk level crossings tend to be located in the exit area of cities where the poor education and lack of personal discipline of local communities are factors in the high frequency of level crossing accidents;

(iii) *Problem of unofficial "distributed" level crossings.* As previously mentioned, the increasing usage of these unofficial crossings by local communities seeking to avoid delays at official crossings contributes to the high frequency of level crossing accidents on the margins of cities;

(iv) *Poor road signalling.* Installation of road warning signs at the approaches to level crossings is the responsibility of road construction/management authorities since these signs are located outside of railway rights-of-way. Many of these signs have deteriorated due to lack of adequate maintenance;

(v) *Inefficient and ill-trained crossing staff.* The use of older, less efficient and generally untrained crossing protection staff has been a factor contributing to some accidents on the system. The inability to replace these staff with younger, more efficient and trained personnel impedes safety enhancement at some crossing locations; and

(vi) *Careless and negligent motor vehicle drivers.* Lack of respect for road traffic rules is estimated to explain 40 per cent of all level crossing accidents in the Islamic Republic of Iran. The quality of driver education and qualification programmes available in the country may require re-evaluation and reform if this is to be eliminated as a major contributory factor.

2.4 Level Crossing Safety in the Russian Federation

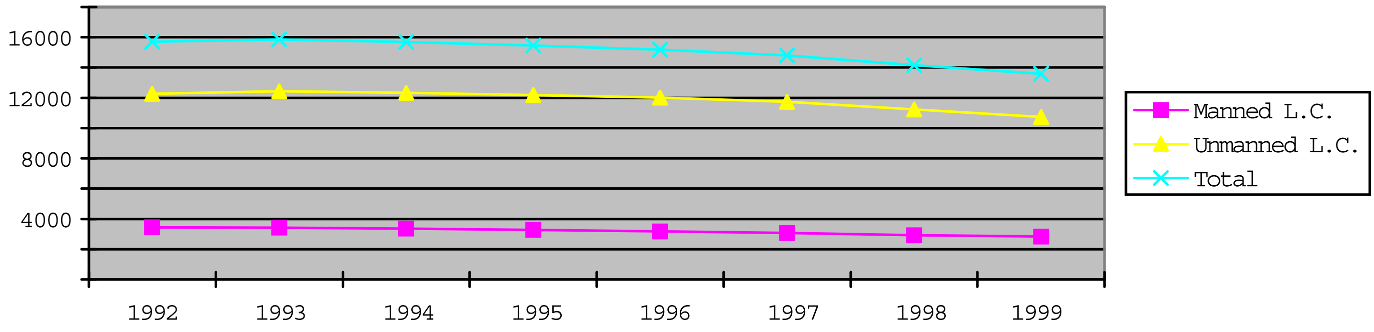
2.4.1 Level crossing characteristics and effectiveness

Data provided by the Russian Ministry of Railways (see Table 2.12 and the accompanying diagram) show that the number of level crossings in the Russian Federation has been declining steadily since 1992. The total number of crossings declined by an average of 2.1 per cent per year between 1992 and 1999, while the annual rates of decline during the same period for manned and unmanned level crossings averaged 2.7 per cent and 1.9 per cent respectively.

Table 2.12: Trend in level crossing numbers

	1992	1993	1994	1995	1996	1997	1998	1999
Manned Level Crossings	3,443	3,425	3,370	3,273	3,171	3,062	2,921	2,844
Unmanned Level Crossings	12,270	12,437	12,329	12,186	12,011	11,739	11,238	10,737
Total	15,713	15,862	15,699	15,459	15,182	14,801	14,159	13,581

Source: Ministry of Railways Country Paper.

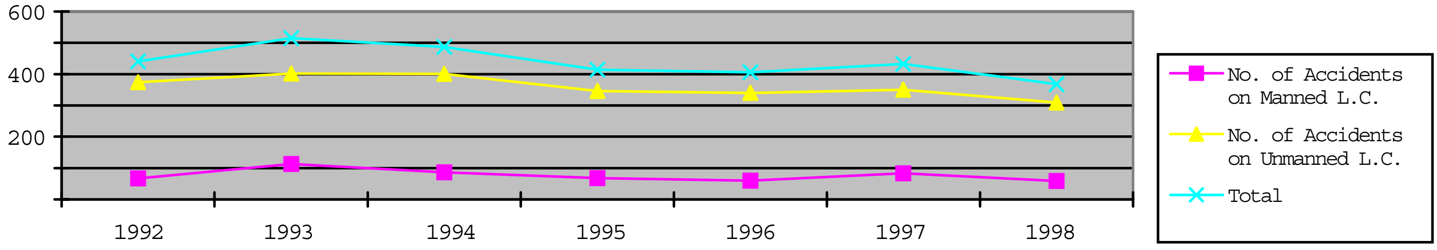


During the same period, the number of accidents at level crossings declined by an average of 2.6 per cent per annum, with the decline in the number of accidents at manned level crossings averaging 1.8 per cent per annum and at unmanned level crossings 2.7 per cent per annum.

Table 2.13: Trend in level crossing accidents

	1992	1993	1994	1995	1996	1997	1998
No of Accidents on Manned L.C.	67	113	86	68	60	83	59
No of Accidents on Unmanned L.C.	374	402	401	346	340	350	309
Total	441	515	487	414	406	433	368

Source: Ministry of Railways Country Paper.

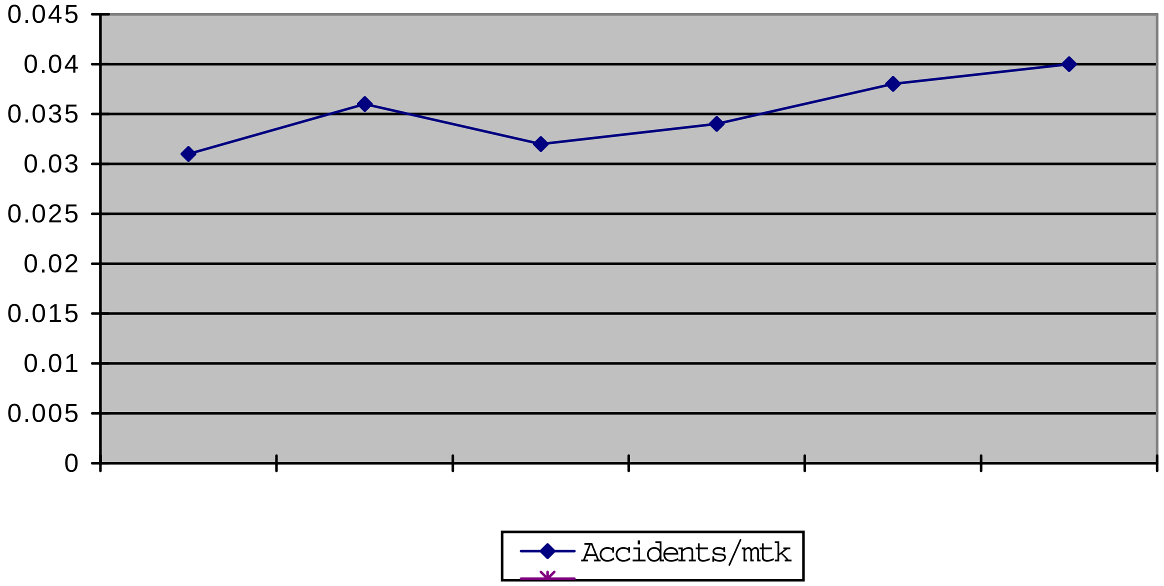


However, *accident rates* (i.e. accidents per million train-km) are increasing as shown in Table 2.14 and the accompanying diagram. The declining traffic task as reflected in the train kilometre trend was not matched by the decrease in the number of level crossing accidents.

Table 2.14: Trend in level crossing accident rates

	1993	1994	1995	1996	1997	1998
Million train-km	16,400	13,600	13,100	12,100	11,300	9,300
Accidents per million train-km	0.031	0.036	0.032	0.034	0.038	0.040

Source: Ministry of Railways Country Paper.



Details of the types of level crossings currently in operation on the railway system of the Russian Federation are given in Table 2.15, the trend in installations of each type of manned crossing is given in Table 2.16, and the trend in the numbers of each type of unmanned crossing is given in Table 2.17.

Trends in the numbers of manned crossings by type indicate that the numbers of all types of installations except types “B” and “H” have been declining over the past seven years. In particular, there was a steady reduction in the numbers of the most advanced “A” type crossing which, apart from being manned, is equipped with automatically operated barriers and full warning light protection against road and rail traffic. By comparison, over the same period, there was a decline in all types of unmanned level crossings, except type “J”, which now represents 40 per cent of all level crossings in the Russian Federation. Significantly, “B” type crossings, while equipped with automatically operated warning lights against road traffic, have no warning signals against train drivers.

Although there is insufficient evidence available, the decline in the “A” type crossing (averaging 3.2 per cent per annum), coupled with the increase in the “J” type crossing (averaging 2.3 per cent per annum) may have contributed to the deteriorating trend in level crossing accidents per million train-kilometres over the seven year period reviewed. It must also be noted that accident rates have increased ***despite*** a decline (averaging 4.2 per cent per annum) in the number of unprotected crossings on the system.

Table 2.15: Types of level crossings operational in 1999

Category	*Number on system*	*Manning status*	*Type of level crossing signalling system for road vehicles*	*Type of signalling system for railway transport*
A	1,170	Served by duty worker	Automatic barriers with automatic traffic light signal system.	Level crossing protection light. Signal provided but the automatic blocking system signals can also be used as crossing protection signals.
B	1,135	Served by duty worker	Semi-automatic barriers with automatic traffic light signal. Barriers are closed automatically and are opened by pressing button.	The signals for arrival and departure of trains at station are used for level crossing protection, but in reasonable cases, level crossing protection signals will be provided.
C	281	Served by duty worker	Electro pushbutton barriers with annunciator and manual light signal system.	Special signals with red and white alarm lights are controlled by the on duty worker.
D	67	Served by duty worker	Electro pushbutton barriers with annunciator signal system (no light system).	As above.
E	42	Served by duty worker	Mechanized barriers with annunciator and manual light signal system.	As above.
F	35	Served by duty worker	Mechanized barriers with annunciator signal system (no light system).	As above.
G	99	Served by duty worker	Mechanized barriers without annunciator or light systems.	As above.
H	355	Served by duty worker	Horizontal rotary Barriers only.	As above.
I	1,342	Not served by duty worker	Automatic traffic light signal system with blinking white light.	In reasonable cases on double track sections, special protection lights will be provided.
J	5,522	Not served by duty worker	Automatic traffic light signal system.	Not provided.
K	398	Not served by duty worker	Traffic light signal system using shunting signal with red and white lights as a protection.	Special signals with alarm lights are controlled by shunting or locomotive crew, or operate automatically.

Source: Ministry of Railways Country Paper.

Table 2.16: Trend in the numbers of each manned crossing type

Type of crossing	1992	1993	1994	1995	1996	1997	1998	1999
A	1,472	1,487	1,462	1,429	1,412	1,282	1,219	1,170
B	1,012	1,038	1,046	1,054	1,088	1,136	1,127	1,135
C	481	432	434	410	376	346	298	281
D	127	130	117	100	80	83	78	67
E	62	58	57	51	44	34	48	42
F	57	61	55	48	45	39	32	35
G	219	196	192	154	164	131	107	99
H	296	404	405	360	341	372	418	355

Source: Ministry of Railways Country Paper.

Table 2.17: Trend in the numbers of each unmanned crossing type

Type of crossing	1992	1993	1994	1995	1996	1997	1998	1999
I	2373	2092	2013	1869	1775	1642	1405	1342
J	4680	5435	5538	5695	5774	5752	5663	5522
K	517	564	562	520	453	454	441	398
No device	4700	4346	4216	4102	4009	3892	3729	3475

Source: Ministry of Railways Country Paper.

2.4.2 Level crossing evaluation system

The Russian Federation Railways has classified its level crossings in accordance with a matrix system, which relates the intensity of passing rail traffic to the intensity of passing road traffic within a 24 hour period. This system is described in Table 2.18.

Table 2.18: Level crossing classification in the Russian Federation

Intensity of rail traffic on mainline (total number of passing trains per day in both directions)	Intensity of road traffic (total number of passing vehicles per day in both directions)				
	Less than 200 inclusive	201-1000	1001-3000	3001-7000	More than 7000
Less than 16 inclusive, and also on all station and access tracks	4th Class	4th Class	4th Class	3rd Class	2nd Class
17-100	4th Class	4th Class	3rd Class	2nd Class	1st Class
101-200	4th Class	3rd Class	2nd Class	1st Class	1st Class
More than 200	3rd Class	2nd Class	2nd Class	1st Class	1st Class

Source: Ministry of Railways Country Paper.

The distribution of all the level crossings within this classification system is given in Table 2.19.

Table 2.19: Distribution of all level crossings, by traffic density class

Traffic density class	Manned, protected level Crossings*	Unmanned, unprotected level crossings**	Total
1	474	0	474
2	906	247	1,153
3	762	1,045	1,807
4	707	9,445	10,152
Total	2,849	10,737	13,586

Source: Ministry of Railways Country Paper.

* Indicates full barrier protection.

** Indicates no barrier protection.

The level crossing grading criteria adopted by the Russian Federation Railways *appear* to indicate that all crossings of the first traffic density class should in future be manned and that crossings of the 2nd to 4th traffic density classes should be unmanned and equipped with various types of automatic signal warning systems, but ***without barriers***.

This classification represents a departure from present practice in the sense that there is a higher percentage of protected crossing than would be indicated by the traffic density classification system, yet there has been a worsening of the accident rate over the seven year period reviewed.

However, the Ministry of Railways Country Report also indicates that "at present, obligatory requirements to the equipment of railway level crossings depending on their type on the Russian Federation Railways are not established. The specific choice of the equipment is determined by railways depending on conditions of operation; visibility of train and vehicle, traffic density of vehicles and trains, availability of electric supply for the equipment of level crossings with the level crossing signal system devices and other factors". From this it might be inferred that the Russian Federation Railways decide on the upgrading of level crossings from unprotected to protected status on a case-by-case basis and do not actually apply the criteria indicated in Table 2.17 above.

2.4.3 Level crossing safety impediments

The Russian Federation Railways has identified the following factors as the main causes of level crossing accidents:

(i) *low level of public discipline* and, as a consequence, mass violations by vehicle drivers of the rules relating to passing of level crossings;

(ii) *motor vehicle driver misjudgements* concerning road conditions and the approach of trains on level crossings;

(iii) *motor vehicle driver misjudgements* of vehicle speed and braking capabilities during the winter months;

(iv) *technical malfunction of road vehicles*;

(v) *non-compliance by highway authorities* with the standards of road maintenance at the approaches to level crossings;

(vi) *poor maintenance* of level crossing warning and protection devices; and

(vii) *human error* on the part of level crossing staff.

In accordance with these primary accident causation factors, the Russian Federation Railways has nominated the following as the remedial measures which should have priority for implementation in future throughout its railway network:

(i) improve road discipline of vehicle drivers and observance of law and order on level crossings;

(ii) improve reliability of devices operating on level crossings;

(iii) modernization and improvement of technical devices installed at level crossings;

(iv) introduction of improved methods for maintenance of level crossings;

(v) better organization of traffic safety control on level crossings;

(vi) accelerated grade separation of level crossings within the highest traffic density classification;

(vii) improvement of motor vehicle driver education programmes;

(viii) enhancement of training and qualification requirements for motor vehicle drivers and railway level crossing personnel;

(ix) refinement of level crossing classification system;

(x) improvement of materials informing the public about level crossing safety rules; and

(xi) giving greater priority to level crossing improvement in capital works budgets.

The difficulty with these remedial measures is that, by and large, they are abstract and do not focus on the apparent major factor contributing to a worsening of the level crossing accident rate, i.e. *a reduction in the number of manned, protected level crossings*. This is not to suggest that all crossings should be manned in future. However, it may be argued that there is a strong case for providing barrier protection at all but the least densely trafficked crossings. It must be emphasized that under present arrangements, none of the official unmanned level crossings, representing more than 50 per cent of the official crossings on the Russian Federation’s railway network, has any form of barrier protection whatever. In addition, there are another 3,475 crossings on the network without any form of warning or protection device. These are presumably designated by the Ministry of Railways as “unofficial” crossings, but no indication has been provided as to the traffic density of such crossings and of their status in the programme for level crossing improvement.

Finally, there is no indication that the Ministry of Railways has yet adopted a particularly efficient system for recording and disseminating level crossing accident statistics. An initiative to improve the dissemination of knowledge about level crossing safety performance is seen as an essential component of any policy to improve level crossing safety.

2.5 Level Crossing Safety in Viet Nam

2.5.1 Summary

The railway system of Viet Nam with a total route length of only 2,712 km has an estimated 4,842 level crossings, or an average of one crossing for every half a kilometre of route length. Thus Viet Nam has one of the densest level crossing systems in Asia, with more than three times the level crossing density of India.

Of the total number of level crossings, some 3,600 (or 75 per cent) are unofficial, i.e. not officially provided by Vietnam Railways and, by definition, have no form of protection against infringement by road users. Unofficial crossings combined with official, but unprotected, crossings comprise nearly 93 per cent of all level crossings in Viet Nam. This group has been estimated to account for 90 per cent of all level crossing accidents in Viet Nam. This report incorporates *estimates* for Viet Nam of accident, fatality and injury rates per million train kilometres. It was necessary to make these estimates as train kilometre statistics are not maintained, at least at the level of the railway headquarters. *Train-kilometre estimates were based on information supplied by the railway in respect of the number of trains and average distances run.*

Since accidents at level crossings represent nearly two-thirds of all railway accidents and account for more than 75 per cent of fatalities and more than 81 per cent of injuries in all types of railway accidents in Viet Nam, it becomes a matter of crucial importance to enforce new safety measures which can eliminate or minimize accidents of this type. However, the techniques available for automated level crossing protection are not affordable for Vietnam Railways and, given the relatively low cost of labour, it is likely that any safety enhancement programme would have to focus on extension of manual protection to currently unprotected crossings. Exceptions would be a limited number of crossings in Hanoi and Ho Chi Minh City, where both road and rail traffic volumes and potential time savings for road users would justify consideration of automatic protection systems with delay minimizing features.

To assist the process of prioritising measures to improve level crossing safety, it will be essential for Vietnam Railways to improve the system for safety data capture and to re-define the criteria used for determining which level crossings should qualify for grade separation or equipment upgrading. The present “Traffic Movement” indicator used to identify those crossings for which grade separation should be provided is only 20,000 per day, as compared with 100,000 per day in India. Further, road traffic counts are not taken as a matter of routine, or indeed *eve*r, and accident statistics are manually maintained only at the level of each of the three administrative divisions (usually called “Union Railways”). It is therefore impossible for headquarters staff to decide upon priorities when they have neither the ability to determine which level crossings have particularly poor safety records, nor the ability to determine the trend in road traffic density for individual crossings.

2.5.2 Level crossing safety record

(a) Accidents

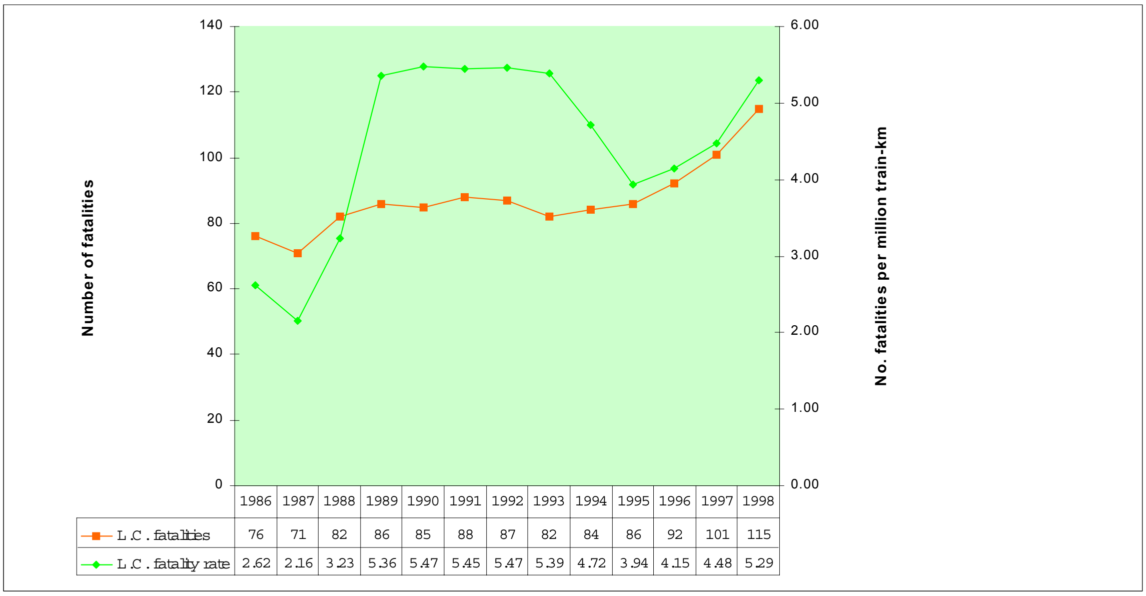
No trend information in respect of level crossing accidents was made available, but for the period 1988-1998 the number of level crossing accidents was recorded as 2,595 (representing 66.3 per cent of all railway accidents during this period). It is likely that there has been a rising trend both in the number of level crossing accidents and in their share of total railway accidents. Expressed as a rate per million train-km, accidents over the period 1988-1998 averaged 12.34 per million train-km. This was greater than the accident rate in India by a factor of more than 100 and greater than the accident rate in Canada by a factor of 4. By these measures, Viet Nam has a disturbingly high incidence of level crossing accidents.

It has been estimated that 60 per cent of all level crossing accidents occur at unofficial crossings, with 30 per cent occurring at unprotected official crossings and 10 per cent at protected crossings.

(b) Fatalities

The trend in the number of fatalities and in the fatality rate per million train kilometres is shown in Figure 2.7. This indicates that the number of fatalities in level crossing accidents increased by an average of 3.5 per cent per year between 1986 and 1998, but that between 1996 and 1998 the rate of increase had risen to 11.8 per cent per year. During the latter period, the average speeds of express passenger trains were estimated to have increased from 48 km per hour to 54 km per hour (12.5 per cent), which is likely to have had some influence on increases both in the numbers of level crossing fatalities and the associated number of fatalities.

Figure 2.7: Numbers and rates of level crossing fatalities in Viet Nam



	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
L.C. fatalities	76	71	82	86	85	88	87	82	84	86	92	101	115
L.C. fatality rate	2.62	2.16	3.23	5.36	5.47	5.45	5.47	5.39	4.72	3.94	4.15	4.48	5.29

Source: Country Report for Viet Nam.

Figure 2.7 also indicates a dramatic increase in the rate of level crossing fatalities per million train kilometres between 1988 and 1989 and again between 1997 and 1998. This is explained by the fact that the number of fatalities continued to rise while *rail traffic*, measured in terms of train kilometres, declined. No information in respect of trends in the volume and composition of road traffic over these two periods was available. Nevertheless, it is likely that over these periods road traffic volumes increased significantly, especially in the Hanoi and Ho Chi Minh City urban areas which have by far the greatest concentration of level crossings within Viet Nam's railway network.

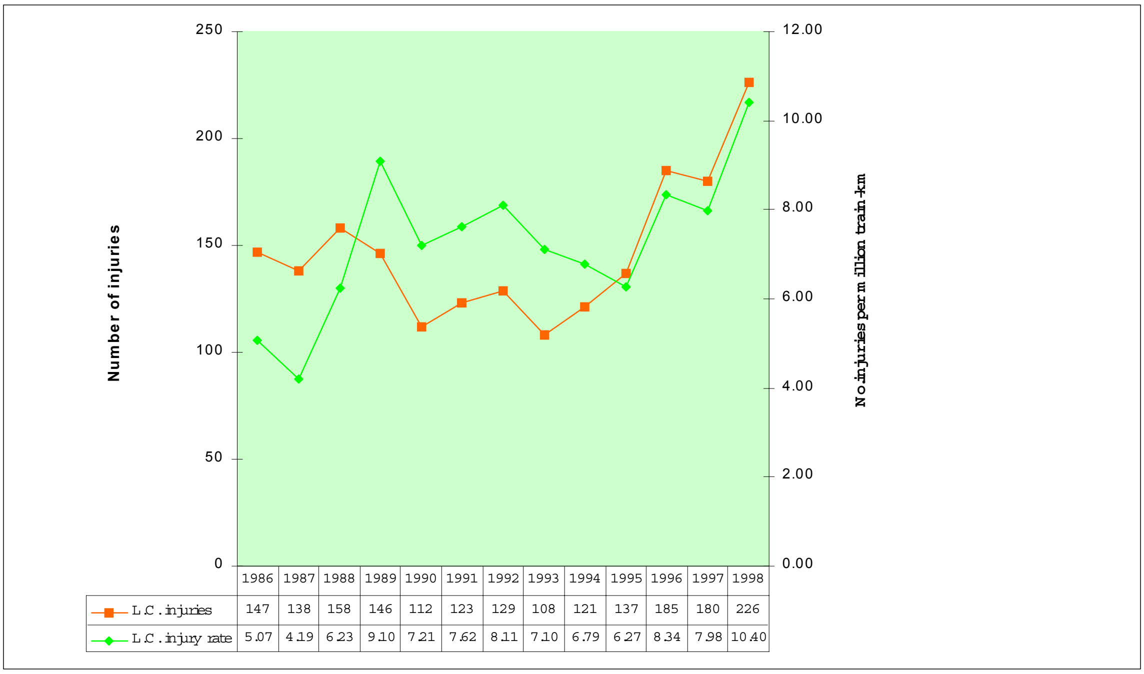
Over the past decade, the level crossing fatality rate averaged about 4.9 per million train-km, which was greater than the corresponding rate in India by a factor of 25 and greater than the corresponding rate in Canada by a factor of 11.

While no information on the corresponding trend in fatalities in all types of railway accidents was made available, over the past decade level crossing accidents accounted for 988 (or 75.2 per cent) out of a total of 1,313 persons killed in all railway accidents in Viet Nam. Clearly, *level crossing accidents claim by far the greatest loss of life in railway operations in Viet Nam.*

(c) Injuries

The trend in the number of injuries and in the injury rate per million train kilometres is shown in Figure 2.8.

Figure 2.8: Numbers and rates of level crossing injuries in Viet Nam



	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
L.C. injuries	147	138	158	146	112	123	129	108	121	137	185	180	226
L.C. injury rate	5.07	4.19	6.23	9.10	7.21	7.62	8.11	7.10	6.79	6.27	8.34	7.98	10.40

Source: Country Report for Viet Nam.

Over the period 1986-1998, the number of injuries sustained in level crossing accidents rose by an average of 3.6 per cent per year, but during the three year period 1995-1998 the average annual increase was 18.2 per cent. In common with level crossing fatalities, it is considered that increasing train speeds contributed to the recent dramatic growth in level crossing injuries. Expressed as a rate per million train kilometres, the number of level crossing injuries averaged 7.7 over the past decade. This was 24 times greater than the rate recorded in India and about 20 times greater than the rate recorded in Canada over the same period.

2.5.3 Level crossing characteristics and effectiveness

(a) General characteristics/overall density

Grade separated intersections between road and rail exist at only 11 locations throughout Viet Nam. Six of these are located within the Greater Hanoi area, of which five date back to the early part of 20th century when the French colonial administration constructed a railway viaduct to link up with the Long Bien Bridge across the Red River. Level crossings are therefore the predominant form of road/rail intersection in Viet Nam and are likely to remain so for some time into the future.

Details of the density and number of level crossings by type, as supplied by Vietnam Railways are given in Table 2.20*.*

Table 2.20: Number and density of level crossings in Viet Nam

Number of route-km	Total no. of level crossings	Level crossing density (no. per route-km)	No. of official level crossings		No. of unofficial level crossings
			Protected	Unprotected	
2,712	4,842	1.8	367	833	3,642

Source: Country Report for Viet Nam.

Official level crossings are those which have been authorized (and most often) designed and constructed by Vietnam Railways. As may be seen in Table 2.20, they comprise only one quarter of all level crossings in Viet Nam. They are of two types, protected and unprotected.

Protected crossings are those which have some form of barrier protection facing road vehicles in order to prevent their intrusion onto crossings when trains are passing. The types of barriers most commonly used are simple full width lifting barriers and trolley gates.

Both are manually operated, requiring 24 hour per day manning of all protected crossings.[2] While all official crossings have warning boards facing road traffic, only some have manually operated red light warning signals against road traffic. In most cases these are steady light signals, although a set of flashing red light signals was observed at one major crossing in Hanoi. Audible warning mechanisms (mostly in the form of warning bells) are installed at a minority of protected level crossings. These, also, are operated by railway crossing staff. As reported by Vietnam Railways, warning signals against trains are installed at only 7 locations on the system, although at least 3 locations at which these signals are installed were visited during the ESCAP mission to Hanoi. When activated by level crossing staff, these signals display a steady white light against train drivers to indicate the presence of an obstruction on the crossing. Warning of the departure of a train from the nearest station and of its impending arrival at a protected level crossing is mostly given to the crossing keeper by telephone, although it is possible that at some protected crossing locations on the system this warning would be received by block telegraph. In general, the railway system of Viet Nam is not equipped with relay interlocked signals, although Alstholm, through French government assistance, are currently engaged in a project to install interlockings at 32 stations between Hanoi and Vinh. As part of this project, a level crossing near Dong Giao (130 km south of Hanoi) is being interlocked with the block system on a trial basis.

By definition, the 3,642 unofficial crossings (representing 75 per cent of the total number of level crossings on the system) are unprotected. These are crossings which have been established illegally by local communities. They range from fairly sophisticated constructions made from paving blocks placed either side of the track to rudimentary paths built across the tracks from rubble or earth fill. In Viet Nam, their number is fairly fluid – they can be constructed one day and removed the next. While train drivers may be aware of their existence, their safe use is totally dependent upon the judgement and safety awareness of local road users.

(b) Level crossing types and density by area

The railway system of Viet Nam is divided into three administrative divisions, known as “Unions”. Union I, incorporating that part of the system between the border with China and Dong Hoi (south of Vinh on the Hanoi-Ho Chi Minh City trunk line), contains 54 per cent of the system’s route kilometres, but some 75 per cent of its unofficial level crossings. Union II (Dong Hoi-Dieu Tri) has 22 per cent of the system’s route kilometres but only 6 per cent of its unofficial crossings, while Union III (Dieu Tri-Ho Chi Minh City) with 24 per cent of the system’s route kilometres contains 19 per cent of its unofficial crossings. If 60 per cent of level crossing accidents are thought to occur at unofficial crossings, then clearly the area covered by Union I has a major level crossing safety problem.

As might be expected, level crossing density is greatest in the urban areas of Hanoi and Ho Chi Minh City. Hanoi with a rail route kilometrage of 34 has no fewer than 305 level crossings, or an average of one crossing every 110 metres. Of these, 32 are manned, 55 are equipped only with road warning boards and 218 are

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[2] One exception is the crossing at the major Dai Co Viet/Le Dzuan road intersection about 3 km south of central Hanoi. Here, a total of 11 electrically powered trolley gates is provided for road/rail traffic separation. When this crossing was visited during the course of the ESCAP mission, however, the electric motors used to power the trolley gates were unserviceable and the trolley barriers were manually deployed by some of the 9 railway staff per shift assigned to this location.

unofficial. No information was provided on the number of official level crossings in Ho Chi Minh City, but the number of unofficial crossings is estimated at 52.

Unfortunately, accident and associated casualty details were not available by area, so that it was not possible to identify the relative extent of the safety problem in urban versus non-urban areas of Viet Nam, nor indeed to identify “hot-spots” with high accident frequencies and casualty rates. This is indicative of the lack of any systematic approach to railway safety data collection and analysis within Vietnam Railways, an issue which is discussed in greater depth in Section 2.5.7. As a consequence, it is only possible to *infer* a relationship between the dense concentration of level crossings (and especially of unprotected level crossings) and the frequency of road/rail collisions at level crossings in urban areas.

(c) Relative efficiency of different types of crossing protection

Level crossing efficiency may be measured in two ways: in terms of the effectiveness of different types of protection systems in preventing accidents and in terms of the capability of each type of protection system to minimize the delay to road traffic waiting for the passage of trains (and sometimes to minimize the delay to trains, where there is a requirement for low speed operation of trains through level crossings).

For the reasons of data non-availability, as indicated earlier, it was not possible to conclude whether the barrier protection systems in use in Viet Nam had been effective in preventing accidents – although it may be reasonable to make such an inference.

In terms of their efficiency in minimizing delay to road users, observations made during the course of the ESCAP mission to Hanoi revealed that barriers were closed on average for *not longer than two minutes*. Such a delay is likely to be acceptable even with the heavy road traffic experienced at some intersections in Hanoi, since average rail traffic in the section observed (between Hanoi and Gia Bat), at about 8 pairs of trains per day, is comparatively light. Nevertheless, it appears that the management of Vietnam Railways has adopted a future target of a one minute delay for all protected level crossings. This it hopes to achieve by installing train-actuated barrier protection at crossings which do not carry sufficient traffic to justify grade separation.

2.5.4 Administration of safety regulations in relation to level crossings

In Viet Nam, there is no supra-railway organization which is responsible for administration of safety regulations. Vietnam Railways is itself responsible for ensuring that government regulations relating to railway safety are enforced.

The current government decree which governs safety at road/rail crossings is “Governmental Decree 39/CP ensuring safety and security for railway transport” of 5 July 1999.

Five articles of this decree are relevant to level crossing safety. These are as follows:

- *Article 31*, which requires all organizations and individuals having a need to open a level crossing to be responsible for the cost of installation, management, maintenance and repair of road signs and equipment necessary for security and safety at that place;

- *Article 32*, which requires that level crossing installation must be “commissioned” and carried out in conformity with established standards and specifications;

- *Article 44,* which contains a number of provisions relating to occupation of level crossings by trains and to action to be taken when accidents occur at level crossings. Specifically, it states that: the railway is forbidden to stop trains inside level crossings except in the case of a sudden accident; that the delay to road traffic arising from the shunting or stopping of trains inside a level crossing should not exceed three minutes for a Class 1 or 2 crossing and five minutes for a Class 3 crossing; and that in the case of an accident at a level crossing the Head of Train Staff, railway drivers and other rescue staff must determine action needed to restore through road and rail traffic as soon as possible;

- *Article 45,* which states that level crossing barriers must be closed at least one minute before the arrival of a train in the case of an electrical barrier and at least one and a half minutes before train arrival in the case of a manual barrier. Similarly this article limits the closure of level crossing barriers to not more than 3 minutes before train arrival in the case of Classes 1 and 2 crossings and to not more than 5 minutes before train arrival in the case of Class 3 crossings; and

- *Article 46*, which states that: (a) the railway mode has priority of passage; (b) pedestrians and other road users must comply with warnings be they instructions of level crossing keepers, signal indications by means of lamps, flags or signs, or deployment of protective barriers; (c) at barrier-equipped level crossings, pedestrians and other road users must immediately respond to stop signals by halting on the right-hand side of the road at least 3 metres in front of the stop sign; (d) at non-barrier equipped level crossings, pedestrians and other road users have a duty to keep a look-out for trains and if one is approaching to stop on the right hand side of the road at least 5 metres from the nearest rail; (e) in situation (d) pedestrians and other road users must accept responsibility for any accidents; and (f) that pedestrians and other road users are forbidden to open barriers themselves.

The Country Paper for Viet Nam contained no specific mention that unofficial crossings were prohibited by Decree 39/CP, but as such crossings were described as illegal in the Country Paper, then it might reasonably be assumed that the decree does contain such a prohibition.

2.5.5 Level crossing system evaluation techniques (technical and financial)

No systematic evaluation of level crossing safety performance or of the need/justification for upgraded crossing protection is carried out by Vietnam Railways. However, some technical evaluation is undertaken, as is indicated by the current programme to pilot test the Westinghouse system of train actuated warning signals and protective barriers on the Viet Nam railway network.

To a large extent, the absence of systematic evaluation of safety performance and enhancement is due to the lack of an effective information system, but the fragmentation of management responsibility for safety must also have an impact.

While the Union Railways and lower levels of the organization exercise day-to-day management responsibility for operation of level crossings and for adherence to government safety regulations, the headquarters unit of Vietnam Railways has responsibility for the planning and mobilization of capital expenditure, including the expenditure on upgraded level crossing protection systems. The safety statistics supporting the case for capital spending on safety enhancement are maintained manually (generally in disaggregated form) at the level of the Union Railways and are not as yet assembled into a computerized database at headquarters level.

Despite the absence of any systematic and regular evaluation by Vietnam Railways of level crossing safety, rules issued by the Ministry of Transport, Communication and Post contain criteria for setting level crossing upgrading priorities. These criteria, as shown below, essentially distinguish between three categories (or classes) of level crossing on the basis of their combined road and rail traffic density, the categories of roads involved, the location (i.e. urban/non-urban), and their visibility rating:

First class level crossings are those where

- railway lines intersect with roads of first, second or third class classification;
- railway lines intersect with urban roads carrying a dense mix of private and public transport; and
- the “Traffic Movement Indicator”, or TM (number of trains per day x number of road vehicles per day) is greater than 20,000.

Second class level crossings are those where

- railway lines intersect with roads of fourth or fifth class classification;
- railway lines intersect with urban roads carrying a relatively less dense mix of private and public transport; and
- the TM is between 5,000 and 20,000 if there is sufficient visibility or between 1,000 and 5,000 if there is insufficient visibility.

Third class level crossings are those which do not satisfy any of the above criteria.

The road classifications used as the basis for these level crossing criteria are given in Table 2.21.

Additional criteria specified in the level crossing rules are that: Class 1 and 2 level crossings having a rail traffic density of at least 16 trains per 24 hours require barrier protection; level crossings with at least 12 trains per 24 hours, but with restricted visibility require barrier protection; and branch lines having a traffic density of not greater than 4 trains and 150 road vehicles per 24 hours do not require barrier protection.

Table 2.21: Road classification system in Viet Nam

Factor ↓ Class →	I	II	III	IV	V	VI
PCU * per day	> 6000	3000 – 6000	1000 – 3000	300 – 1000	50 – 300	≤ 50
Speed (km/hour)						
– Flat or plateau areas	120	100	80	60	40	25
– Mountain/highland areas	-	-	60	40	25	-

Source: Vietnam Railways.

* PCU = passenger car unit. Other vehicles are converted into PCU's using the following factors: bicycle 0.2; motorcycle 0.3; buses and medium trucks 2.0; three axle trucks 2.5; prime movers and semi-trailers 3.0.

It is further stipulated in the level crossing rules that *Class I crossings should be grade separated.*

Two main difficulties are associated with the practical application of these criteria for the upgrading of level crossings.

The first is that the traffic density criteria are not realistic. For example, Class 1 crossings are identified as those with a TM of at least 20,000 and a train density of at least 16 per 24 hours, giving a road traffic density of only 1,250 vehicles per day (20,000/16). This figure is likely to be exceeded at most of the level crossings in Hanoi and very possibly at a large number of crossings outside urban areas. It must also be noted that a road traffic density of 1,250 vehicles per day is close to the extreme lower limit of the traffic density criterion for a class 3 road, when in fact Class 1 level crossings have been indicated as intersecting with road classes between 1 and 3, for which an upper traffic density limit in excess of 6,000 per day has been indicated. It is hardly likely that traffic amounting to 16 trains and 1,250 road vehicles per day would produce sufficient benefits in terms of accident prevention and reduced delay to road users to completely offset the costs of constructing road overpasses in place of Class 1 crossings.

The second difficulty is that Vietnam Railways do not take counts of the road vehicles using level crossings. Neither are such counts taken on a regular basis by the responsible road management authorities. Therefore, there is no objective basis upon which the TM value for any crossing can be determined and upon which level crossing upgrading priorities may be set.

2.5.6 Level crossing safety initiatives

The management of Vietnam Railways properly attaches greatest priority to converting unofficial level crossings to official crossings with at least some form of warning signage facing road users and with an adequately surfaced roadway across the tracks.

Construction of road overpasses in place of the most densely trafficked crossings has so far been beyond the capacity of the railway to finance, although this is considered the most desirable option in the long term[3].

In late 1999, Vietnam Railways submitted to the Ministry of Transport, Communication and Post a request for funds and an expenditure programme, with the following principal objectives.

- progressive conversion to official status and upgrading of the estimated 3,642 unofficial level crossings on the railway system;
- progressive installation of barrier protection and flashing road warning signals at 833 official, but currently unprotected, crossings; and
- installation of manual or train-actuated road warning signals at all 367 protected crossings on the railway system.

Initial priority in the programme, which would have a total cost estimated at VND 831,690 million (US$ 64 million), would be given to the officialization of, and installation of barrier protection and flashing road warning signals at 431 unofficial crossings with a particularly poor safety record. It was expected that the programme would be undertaken in 3 phases, the elapsed time of each phase depending upon the level of funding assistance to be provided by the government. Funding was expected to be sourced mainly from local government authorities as well as from local community level crossing users (although the form of funding by the latter, be it from tax revenues or direct charges, was not specified). To date, the central government has not indicated its approval of the programme.

Details of the elements and costs of the programme are given in Table 2.22.

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[3] Recent construction of a road overpass bridge on the Hanoi-Ho Chi Minh City mainline with a total length of 33.84 metres was estimated to cost VND 95,117 million (US$ 7.3167 million). This cost is equivalent to VND 2,811 million (US$ 216,215) per metre.

Table 2.22: Proposed Level Crossing Upgrading Programme, Viet Nam

Programme objective	Type of installation	Number	Unit Cost VND Mill. (US$ Mill.)	Total cost VND Mill. (US$ Mill.)
Officialization/upgrading of unofficial level crossings	Manual lifting barrier (with flashing road warning signals)	31	410 (0.0315)	12,710 (0.9777)
	Automatic lifting barrier	217	300 (0.0231)	65,100 (5.0077)
	Automatic road warning signals (steady light)	3,394	127 (0.0098)	431,038 (33.1568)
	Sub-total	*3,642*		*508,848 (38.1422)*
Upgrading of official unprotected crossings	Trolley gates (manual) with flashing road warning signals	29	550 (0.0423)	15,950 (1.2269)
	Manual lifting barrier (with flashing road warning signals)	138	410 (0.0315)	56,580 (4.3523)
	Automatic lifting barrier	666	210 (0.0162)	139,860 (10.7585)
	Sub-total	*833*		*212,390 (16.3377)*
Upgrading of official protected crossings	Road crossing resurfacing	367	30 (0.0023)	11,010 (0.8459)
	Flashing road warning signals (for manual lifting barriers)	367	210 (0.0162)	77,070 (5.9285)
	Service roads along railway lines	44,744 (m)	0.5	22,272 (1.7209)
	Sub-total	*367*		*110,452 (8.4963)*
TOTAL PROGRAMME				*831,690 (63.9762)*

Source: Vietnam Railways.

Upgrading of the initial tranche of 431 unofficial crossings would be undertaken during phases I and II, for a total cost estimated at VND 101,051 million (US$ 7.77 million). Vietnam Railways has also proposed an alternative programme under which all elements in the above table would be undertaken except installation of automatic road warning signals at unofficial crossings other than the priority group of 431. The overall cost of the alternative programme has been estimated at VND 423,893 million (US$ 32 million), or about half that of the preferred alternative.

In addition to the above, Vietnam Railways recently took a series of technical and administrative measures to improve level crossings safety. Thus, 579 level crossings have recently been paved with concrete panels, 172 have been bitumen-surfaced and another 374 have been gravelled. Furthermore, in an effort to increase the vigilance of gatekeepers, their working rules have been amended. While they previously worked a 12-hour shift and went off duty for 24 hours, they now work an 8 hour shift before going off duty for 16 hours.

Other initiatives taken by the Vietnam Railways to improve level crossing safety have been focused on community awareness broadcasts on national television and provision of assistance to education authorities in the preparation of materials for dissemination in schools. However, the railway administration lacks an effective budget for activities of this type.

2.5.7 Level crossing safety impediments

In common with other Asian countries, Viet Nam suffers from a general lack of a safety ethos, or of an awareness in the wider community of the crucial importance of safe living and working practices. This is perhaps the biggest impediment faced by the railway in seeking to reduce the incidence and consequences of accidents at its level crossings, since this factor is likely to frustrate the efforts of the railway to reach the community through public safety education programmes. The indiscipline of some road users in Viet Nam was exemplified by visits to several level crossing locations where road vehicles continued to proceed through crossings even as the barriers were being closed (see Photograph 1 showing the large trolley-gate protected crossing at the Dai Co Viet/Le Dzuan intersection).

Photograph 1

To some extent poor general education levels may also constrain the effectiveness of public safety education programmes, but there is no evidence of a necessary link between the overall level of education and safety awareness. While a strong case exists for augmenting Vietnam Railways’ budget for and role in public safety education, it has to be accepted that the benefits of this measure are unlikely to be achieved in the short term.

The second major impediment is the apparent failure of the railway to prevent the illegal construction of level crossings by local communities. Viet Nam has one of the greatest proliferations of unofficial level crossings in Asia and Vietnam Railways has indicated that unofficial crossings account for about 60 per cent of all level crossing accidents. The fact that most of the railway right of way in Viet Nam is not fenced and (for reasons of cost) is impractical to fence, exacerbates this problem. There is no certainty that the railway's plan to install automatic road warning signals at all current unofficial crossings will be approved and even if it is there are doubts about the effectiveness of this measure (unaccompanied by some form of barrier protection) in reducing the frequency of level crossing accidents. For this reason, there appears to be no realistic alternative to strengthening the powers (and the resolve) of railway staff to enforce the government's safety directives and rules in order to eliminate further proliferation of unofficial level crossings.

A third impediment relates to the poor physical layout of many level crossings (even official crossings) in Viet Nam. An inspection of level crossings south of central Hanoi, during the ESCAP mission, indicated:

- severely restricted track visibility at the approaches to most of the crossings visited. In some cases, it was not possible for motorists to have a clear view of the track in both directions until they had nearly entered the crossing (see Photographs 2 and 3, page 43); and

- placement of road warning signboards too close to the track to be able to provide motorists with adequate advance warning of a crossing. In the case of some of the crossings visited only one warning sideboard was provided either side of the track and it was situated not more than 1.5-2.0 metres from the nearest rail (see Photographs 3, 4 and 5, page 43-44).

The combination of these two factors at unprotected level crossings could produce a potentially life-threatening situation. Indeed, at the unprotected crossing featured in the photographs, the study team were informed that there had recently been accidents involving fatalities at that location and that the railway had recently been requested to install barrier protection there.

The restricted visibility of the track at some locations was clearly caused by the dense concentration of shophouses too close to the track (see particularly Photograph 2). If existing building regulations do not provide for adequate spatial separation of buildings from the boundary of the railway right-of-way, the railway would be well advised to urge the relevant authorities (through the Ministry of Transport and Communications) to have these regulations amended accordingly.

The placement of road warning signs is a matter falling within the responsibility of road authorities who must provide signage, as well as the road approaches, located outside the railway right-of-way (the railway being responsible for all items located within the railway right-of-way, including barriers and warning signals as well as the road pavement across the tracks). Photograph 2 also provides a good example of how road warning signboards located too close to the tracks can be obscured by commercial signage located a further distance from the track.

Photograph 2

Photograph 3

Photograph 4

Photograph 5

2.6 Level crossing safety in Bangladesh, Philippines and Thailand

2.6.1 Level crossing safety record

(a) Accidents

Table 2.23 shows data on level crossing accidents for the railway organizations of Bangladesh, the Philippines and Thailand.

Table 2.23: Level crossing accidents, 1988-1998

Year	Bangladesh	Philippines	Thailand
1988	15		
1989	7		
1990	10		
1991	7		
1992	9		
1993	10		
1994	14		
1995	15		
1996	9		
1997	23		
1998	17		
Total	136	466	4,688

Source: Questionnaire responses, Bangladesh, Philippines and Thailand.

Level crossing accidents represent a substantially high proportion of all railway accidents in Thailand (94.6 per cent between 1988 and 1998), but a minor proportion of all railway accidents in the Philippines (29.6 per cent between 1988 and 1998), and an even more modest proportion of all railway accidents in Bangladesh (3.8 per cent between 1988 and 1998).

When compared with the volume of traffic, as represented by train-kilometres, the rate of level crossing accidents in Bangladesh is quite high (0.74 per million train-km for the seven year period 1988-1995), but is insignificant as compared with Thailand (12.9 per million train-km for the five year period 1991-1995). No comparable data were available for the Philippines.

(b) Fatalities

In Thailand, fatalities in level crossing accidents represent the vast majority (92 per cent) of all deaths in all types of railway accidents throughout the railway network. In Bangladesh, fatalities in level crossing accidents represent 46 per cent of deaths in all types of railway accidents – a much higher proportion than the proportion of level crossing accidents in total railway accidents, possibly because of the heavy incidence of bus accidents in the railway accident total. In the Philippines, however, level crossing accidents account for only 5 per cent of the total number of fatalities in railway accidents.

Table 2.24: Level crossing fatalities, 1988-1998

Year	Bangladesh	Philippines	Thailand
1988	4		
1989	8		
1990	5		
1991	4		
1992	12		
1993	4		
1994	16		
1995	25		
1996	16		
1997	10		
1998	18		
Total	122	4	414

Source: Questionnaire responses, Bangladesh, Philippines and Thailand.

Again, when related to traffic volumes, the level crossing fatality rate in Thailand is disturbingly high – 1.05 per million train kilometres – but even at this level, the Thai fatality rate is only about one fifth of the rate experienced by Viet Nam, which has the worst level crossing safety record of any country reviewed in this study. In Bangladesh, the fatality rate averaged 0.66 per million train kilometres, somewhat lower than the accident rate. No comparable data were available for the Philippines.

(c) Injuries

In Thailand, the number of persons injured in level crossing accidents represents the major proportion (76 per cent) of all persons injured in all railway accidents throughout the system, while in Bangladesh the percentage injured in level crossing accidents is 44 per cent and in the Philippines 31 per cent.

Table 2.25: Level crossing injuries, 1988-1998

Year	Bangladesh	Philippines	Thailand
1988	19		
1989	16		
1990	37		
1991	36		
1992	39		
1993	19		
1994	60		
1995	63		
1996	30		
1997	37		
1998	58		
Total	414	462	1,088

Source: Questionnaire responses, Bangladesh, Philippines and Thailand.

The comparative analysis of level crossing safety performance in these three countries and also in Viet Nam has to be tempered by the fact that motorization levels in Thailand are many times greater than they are in Bangladesh and in Viet Nam and several times greater than they are in the Philippines.

2.6.2 Level crossing characteristics and effectiveness

(a) Number and density of level crossings

Data provided by the railway systems of Bangladesh, the Philippines and Thailand indicate the following level crossing populations, by type, on each network:

Table 2.26: Density of level crossings and number, by type

Route length/type of level crossing	**Bangladesh**	**Philippines**	**Thailand**
Route-km	2,734	484	4,041
Official – protected, no.	402	49	467
Official – unprotected, no.	926	161	1,145
Unofficial (unprotected), no.	821	98	625
Total	2,149	308	2,237
Level crossing density, no. per km	0.79	0.64	0.55
Level crossing spacing, one every _ km	1.3	1.6	1.8

Source: Questionnaire responses, Bangladesh, Philippines and Thailand.

Of the three countries reviewed, Bangladesh has the greatest density of level crossings (one every 1.3 km) and the highest percentage of unofficial crossings (38 per cent). Curiously and conversely to what might be expected, these characteristics are not reflected in higher accident, fatality and injury rates – which might suggest that the safety performance data are understated. For example, it has to be questioned whether railway safety statistics capture full details of the numbers of ***road users***, as distinct from railway passengers, killed or seriously injured in level crossing accidents.

None of the above three railway systems has what might be considered an acceptable percentage of protected level crossings. However, it is significant that Thailand with only 21 per cent of its level crossings protected had unacceptably high accident and casualty rates.

(b) Technical characteristics of level crossings

Table 2.27 provides details of the level crossings of Bangladesh, Philippines and Thailand classified according to their equipment and manning status. ***Nearly all protected crossings in these countries are manned.*** Only Thailand has a significant number of open crossings equipped only with flashing lights and audible warning devices.

No details of the accident/casualty histories of these various types of level crossings were provided, so that it was not possible to make any definitive comment on their safety effectiveness.

During 1999, Thailand brought into service the first 14 of a new type of level crossing equipped with barriers, flashing lights and audible warning devices and closed circuit television (CCTV) allowing control from a remote location. It is understood that this system is similar to the British MCB/CCTV (Manually controlled barriers with CCTV) style of crossing. The apparent advantage of this system is that it would permit ***manual control*** of one or more crossings from a single location, resulting in staff savings and reduced operating cost. Its disadvantage might arise from the fact that level crossing staff would not be on hand to respond in an emergency.

Table 2.27: Level crossing population, by technical classification

Country/Railway System	Crossing type – description	Number on system (as at June 1999)
Bangladesh*	Mechanical full width lifting barrier (manned)	123
	Mechanical half width lifting barrier (manned)	22
	Electrical and mechanical half width lifting barrier (manned)	6
	Mechanical full width swinging gate (manned)	251
	Total, protected	*402*
Philippines	Mechanical barrier with flashing lights, bells and fixed road signs (manned)	4
	Mechanical barrier with bells and fixed road signs (manned)	8
	Mechanical barrier with flashing lights and fixed road signs (manned)	1
	Mechanical barrier with fixed road signs (manned)	14
	No barrier, bells and fixed road signs only (manned)	3
	Fixed road warning signs only (manned)	18
	Total, protected	*48*
	Fixed road warning signs only (unmanned)	135
	Automatic lifting barrier and fixed road warning signs (unmanned)	4
	No barrier, automatic flashing lights and bells with fixed road signs (unmanned)	1
	Automatic barrier and bells only (unmanned)	1
	No equipment or signage (unmanned)	119
	Total, unprotected	*260*
	Grand Total	***308***
Thailand	Electrical full or half width lifting barrier with remote control and CCTV (manual)	14
	Electrical full or half width lifting barrier (manual)	104
	Mechanical full or half width lifting barrier (manual)	34
	Mechanical full or half width hoisting barrier (manual)	230
	Sliding trolley gate (manual)	16
	Automatic half width lifting barrier (unmanned)	64
	Total, protected	462
	Open crossing with automatic flashing warning light only (unmanned)	31
	Fixed road warning signs only (unmanned)	1,113
	Total, unprotected	1,144
	Grand Total, official crossings	***1,606***

Source: Questionnaire responses, Bangladesh, Philippines and Thailand.

* *In the absence of details of unprotected level crossings in Bangladesh, it was assumed that they are all unmanned without any form of equipment or signage.*

2.6.3 Level crossing system evaluation techniques

In Bangladesh, level crossing installation and upgrading priorities are established on the basis of the ***assumed*** road and rail traffic volume likely to use crossings in future. The Bangladesh Railway does not take counts of road traffic and consequently road traffic density at individual crossings is known only from local experience.

Similarly, in the Philippines railway staff do not take road traffic counts – neither is this information forthcoming from the highway authorities. Consequently, priorities for the installation of new level crossings or the upgrading of existing crossings are not established on the basis of expected road and rail traffic density. Rather, the Philippine National Railways applies criteria based on the location of a crossing. For example, if the crossing is located inside Metro Manila it must be staffed and at minimum equipped with lifting barriers flashing lights and fixed road warning signs. On the other hand, if the crossing is located in a rural area it is provided with fixed road warning signs only. Altogether, the PNR classifies its level crossings into eight groups having homogeneous locational characteristics.

In Thailand, an index of road and rail traffic, called a Traffic Moment (TM) indicator is used to establish priorities for level crossing installation or upgrading. State Railway of Thailand staff presently take road traffic counts on an as required basis, but for the future plan to take counts at least once a year for the busier road/rail intersections. The decision criteria used by the SRT and based on TM indicators for individual crossings are as follows:

TM Range	**Indicated type of crossing**
$TM \leq 10{,}000$	Fixed road warning signs only
$10{,}000 < TM \leq 100{,}000$	Manual barriers
$100{,}000 < TM$	Road overpass or underpass

It appears however that these decision criteria have not been rigorously applied due mainly to funding shortages. The decision taken nearly three years ago to cancel a massive track elevation project for Bangkok (the Hopewell project) has compounded the problem of resolving road and rail conflicts inside one of Southeast Asia’s most congested cities.

CHAPTER 3: RAILWAY LEVEL CROSSING SAFETY EXPERIENCE AND ENHANCEMENT IN DEVELOPED COUNTRIES

3.1 General

As was observed in Chapter 2, accidents at railway level crossings clearly dominate the railway accident picture in Asia. Not only are they dominant in terms of frequency, but they can be more severe in their consequences than other types of railway accidents, simply because they can involve injuries and fatalities to railway passengers as well as to road vehicle occupants and other users of railway level crossings. Depending upon the size and weight of road vehicles involved in level crossing accidents, as well as the force of impact, trains are often at risk of derailment (or at the very least, of compressive destruction) upon impact with road vehicles, with the possibility that the lives of the passengers on the train, as well as those of road vehicles, are endangered.

Nevertheless, the assessment of safety enhancement measures for level crossings is, and should be, in no way separate from the assessment techniques used across the broad spectrum of accident types both for railways and other transport modes. In particular, the concept of *risk management* is as applicable to level crossing safety as it is to other railway safety issues.

Much can be learned from the experience of the railways of the United States, continental Europe, the United Kingdom, and Japan in developing a suitable methodology for assessing level crossing safety and safety enhancement measures. There are few countries which have achieved more in this context than the United Kingdom where, over the years, an increasing premium has been placed on the need for ensuring greater safety at the interface of rail and road transport.

3.2 Some definitions

Since measures for railway safety enhancement increasingly depend upon a prior assessment of risk and of the potential for risk reduction, a few definitions relating to risk management are in order.

First, *risk* is the probability that a safety hazard will result in an accident involving casualties (loss of life, injury or property damage).

A *safety hazard* is an activity, combination of activities, or set of circumstances which could produce an accident. The Engineering Safety Management guidelines of Railtrack (the privatised railway infrastructure provider in the United Kingdom) define a hazard as a “state or event with the capability of causing harm”. In the case of level crossing accidents a combination of environmental factors (the physical setting) and activities can provide the circumstances which may trigger accidents. For example, a level crossing protected only by flashing lights and involving a road crossing of the railway track(s) at an oblique angle will provide the circumstances for an accident, but only if motor vehicle drivers approach the crossing at speed without the intention to stop at the lights *and* if their arrival at the crossing happens to coincide with that of a train.

Safety hazards have associated with them notions of the *frequency* and *consequences* of accidents. *Frequency* may be expressed in terms of the number of accidents of a given type per unit of time or per unit of rail traffic, e.g. per train kilometre. A high probability or risk of accidents will be reflected in a high accident frequency. Accident *consequences* are the results of accidents in terms of the number of persons killed or injured, or of property damage, deaths and injury of animals, etc.

Risk may be subdivided into three categories:

- *Individual risk,* which is the annual probability of death for a specific person, e.g. a regular commuter, a train driver, a motor vehicle driver;
- *Societal risk,* which is the risk for the exposed population as a whole, including the potential for given hazards to cause multiple fatalities; and
- *Collective risk*, which is the risk associated with the total number of fatalities per annum attributable all to identified hazards.

The concept of "Equivalent Fatalities" is often used in estimating the above risks. This concept combines fatalities, major and minor injuries into a single overall casualty estimate by assuming (typically) that 10 major injuries or 200 minor injuries are equivalent to a single fatality.

Risk can be managed by reducing either the accident frequencies or consequences (or both) associated with given hazards. However, it has to be noted that the risks associated with most hazards are finite – i.e. they can never be completely eliminated. Further, there is a point in the management of risk beyond which further measures become impractical in the sense that the costs of their implementation will exceed the monetary value of the benefits they can provide.[4] This is a fact which has been accepted in the United Kingdom but not on the European continent as will be discussed in a later section.

3.3 Experience of the United Kingdom in safety management

In the United Kingdom, administration of safety policy and standards in the public domain is the responsibility of the 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 latterly, Railtrack Plc – with the HSE ensuring that safety policy guidelines and standards are observed.[5] The statutory instrument which gives the HSE its mandate is the Health and Safety at Work Act of 1974. This Act imposes a "duty of care" on employers and requires them to manage their activities in such a way that the safety risks imposed by these activities are *"as low as is reasonably practical".*

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[4] Andrew J Smith*, Managing Safety Through Identifying, assessing, Mitigating and Monitoring Risk,* paper presented at Safety on European Railways Conference, London, 4 December 1997.

[5] On 10 October 1999, five days after two trains collided on the main western line at Ladbroke Grove near Paddington Station, the British Government announced that Railtrack's authority for safety management would be withdrawn and given to an as yet un-named organization.

More will be said about the meaning and practical application of these words, but it is first useful to note that a fundamental change in the philosophy of safety management in railways occurred in the United Kingdom in the late 1980's. Prior to this time, the guiding philosophy was one of "safety first, at any price", in which safety enhancement was accorded top priority in the railway capital expenditure programme. Unlike other capital investment proposals, those related to safety improvement were not required to undergo full cost benefit analysis. The consequences of the safety at any price philosophy were that the costs of investments in safety improvement could be several times greater than the financial value of the benefits they were capable of producing.

3.3.1 A change in the philosophy of railway safety management

It took a catastrophic collision between two morning commuter trains at Clapham junction in South London in December 1988 to bring about a fundamental change in the way railway safety is managed in the United Kingdom. This accident which claimed the lives of 35 passengers was attributed to a signal failure. It was considered that the substantial loss of life and injuries resulting from this accident could have been avoided had an Automatic Train Protection (ATP) system been in place on the lines into Clapham Junction. Essentially, an ATP system warns a driver to slow down or to stop and when that warning is not heeded, the system provides further audible and visual warnings, before automatically applying the brakes.

The inquiry into the Clapham Junction accident, chaired by Sir Anthony Hidden QC, recommended that British Rail should accelerate the programme on which it had embarked one month before the accident to develop an ATP system for installation throughout its network.[6] The original programme had been aimed at implementation of ATP within five years, but this timeframe was considered by Hidden to be excessive.

An unintended consequence of the Hidden Report was that those responsible for safety management on the British Rail network began seriously to question whether Hidden had been correct to recommend ATP in the first place. Their challenge to the hitherto accepted wisdom of implementing safety improvement measures without financial justification (as implied in the recommendations of the Hidden report) was based on concerns about the daunting scale of the investment required for full installation of ATP. A review of the proposed ATP installation programme (post the Clapham Junction accident) resulted in an estimated installation timeframe of 10 years, not 5 years as recommended by Hidden, with the following costs:

Table 3.1: Costs of ATP (£ million)

Installation (10 year timeframe)	545
Operating and maintenance (20 year timeframe)	280
Total	***825***

Source:Modern Railways, September 1994.

By extrapolating historical data, it was also calculated that ATP would avoid 52 equivalent fatalities (actual fatalities and serious injuries considered to be

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[6] *"ATP unaffordable-official"* in Modern Railways, Vol.51, No.552, September 1994.

equivalent to fatalities) over a twenty-year period. After allowance for the avoided cost of railway asset and property damage, as well as of traffic disruption, (estimated in total at £ 66 million over 20 years), this would give a *cost per life saved* of £ 14.6 million. Against this cost had to be set the *value of a fatality prevented (VFP)*. Here, British Rail could draw upon the lengthy experience of the UK Department of Transport in assigning a value to a *statistical life* in calculating the benefits of a road construction project. At the time of British Rail's review of the ATP programme in the wake of the Hidden findings, the Department of Transport valued a road fatality at £ 715,000 in 1992 prices, but for railway accidents which carry a high risk of multiple fatalities, the appropriate figure was considered to lie in the range of £ 1-2 million. (The statistical life valuation methods used by the Department of Transport are further discussed in Section 3.3.4 below). Even at the higher end of the VFP range, the cost of installing and maintaining ATP would have been seven times the value of a fatality prevented.

The doubts that this analysis raised about the failure of ATP to provide adequate safety improvement benefits brought into question the whole approach to assessment of the costs and benefits of investments in railway safety. Thus it provided the cue for establishing a new risk minimizing approach to railway safety management which would ensure greater effectiveness of investments in safety enhancement. [Whether the Ladbroke Grove accident (see footnote 5, point 3.3), which involved a greater number of fatalities and serious injuries than the Clapham Junction accident and which arguably was "ATP – preventable", will cause a further reassessment to be made of the direction of railway safety management in the UK remains to be seen].

3.3.2 Development of a Risk Management Approach in British Railways

Demonstration by those responsible for generating safety hazards that they have in place suitable procedures for managing the risk posed by these hazards is seen as a key factor of UK safety regulations. Such a demonstration is required by the governing legislation in the form of the Health and Safety at Work Act 1974 and of the specific railway industry provisions such as the Railway (Safety Case) Regulations 1994.

The governing legislation and regulations require that the Health and Safety Executive (HSE*) must accept and approve a Railway Safety Case before a railway may begin to operate.* Full compliance with these regulations is a prerequisite for issuance of an operator's license by the Rail Regulator. The Safety Case must show how a responsible operator will *manage, monitor and (over time) review* safety risks. The objective of these activities will not simply be to reduce risks, but rather to strike a balance between the benefits of risk reduction, the costs (including operational costs) associated with that reduction and the commercial returns from railway operation.

While the HSE has overall responsibility for the application of safety policy and regulations in the UK railway industry, the management of safety risk has until recently resided with the privatised railway infrastructure provider, Railtrack.[7]

The risk management system developed for application within British Rail in the late 1980's was adopted by Railtrack. It was eventually manifested in the

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[7] Railtrack is the railway infrastructure company floated in 1996 to take over ownership and maintenance of the former BR network.

Railtrack manual “Engineering Safety Management”, known colloquially as the “Yellow Book”, two versions of which, YB 1 and YB 2, have so far been produced. YB2, issued in September 1997, defines the total approach of Railtrack to Engineering Safety Management and is generally considered to represent the “state of the art” in railway risk assessment in the United Kingdom.

The announcement on 10 October 1999 that Railtrack’s authority for railway safety management would be reallocated to another, as yet un-named, body calls into question the future of YB2. However, since YB2 has been the system in use up until the present, the approach it embodies is discussed here.

(i) The ALARP Principle

At the core of the Railtrack approach to railway risk assessment is the application of the so-called ALARP Principle (illustrated in Figure 3.1). Application of this principle is intended to ensure that the risk, or probability, of railway accidents with serious consequences in terms of loss of life and injury, is kept to a level which is “as low as is reasonably practicable”. ALARP defines three levels of risk:

- *intolerable risk,* which cannot be justified or accepted, except in extraordinary circumstances;
- *tolerable risk*, which can be accepted only if risk reduction is impractical or if the cost of risk reduction greatly exceeds the benefit gained; and
- *negligible risk* which is broadly acceptable and does not require risk mitigating measures.

The implications of ALARP are that if risk is determined to be at the intolerable level, measures must be taken immediately to reduce it to a tolerable level. Similarly, if risk is found to be at a tolerable level, risk mitigating measures should still be applied, *provided that they are capable of practical application and that the benefits to be gained exceed the costs of their application.*

It should be noted that the ALARP principle, by accepting risks for which there are no cost effective mitigating measures, stands in marked contrast to the European approach to public safety and safety in the workplace as set out in the Framework Directive of the European Union (89/391/EEC). This states that safety “is an objective which should not be subordinated to purely economic considerations.”[8]

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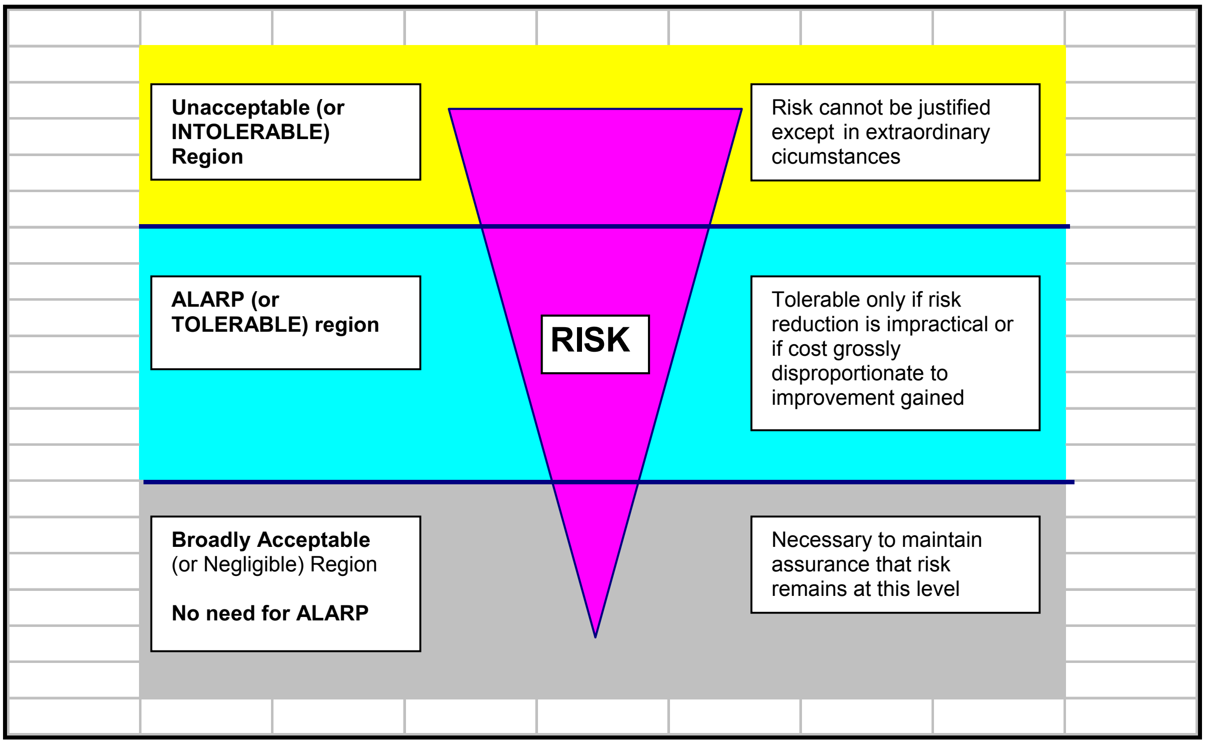
[8] W.S.Atkins, Review of Railway Safety Management for European Commission, 1995.

Figure 3.1: The ALARP Principle



Source: P.R. Cheesewright, *Recent Developments in Risk Assessment in Rail,* paper presented atSafety on European RailwaysConference, London, 4 December 1997.

(ii) Risk Management Process in the United Kingdom

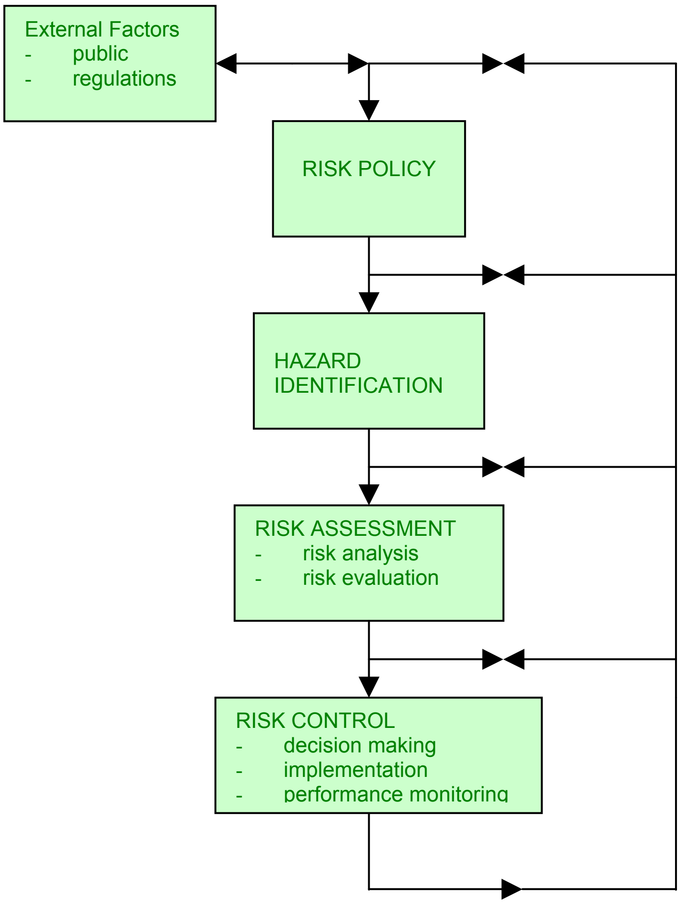
The ALARP Principle is applied as part of a Risk Management Process, the essential features of which are shown in Figure 3.2. Railtrack until very recently has had primary responsibility for the application of this process, under the broad supervision of Rail Inspectorate of the HSE.

Risk management involves three main activities: hazard identification, risk assessment, and risk control. These three activities, as shown in Figure 3.2, are guided by public attitudes to safety, regulation and by government policy on risk management.

- <u>Hazard identification</u>

  This activity is intended to identify all reasonably foreseeable events/situations having the potential of causing harm to passengers, railway staff or to the general public, or of causing property damage. A number of techniques are available to assist the identification process, including Hazard and Operability (HAZOP) studies, Preliminary Hazard Analysis (PHA) and Failure Modes, Effects and Criticality Analysis (FMECA). These techniques generally involve "brainstorming" meetings, at which guidewords are used to identify hazards.

Figure 3.2: Railtrack Risk Management System



Source: W.S.Atkins, Review of Railway Safety Management for European Commission, 1995.

- <u>Risk Assessment</u>

This is comprised of frequency assessment, scenario modelling, consequence assessment, risk summation and cost benefit analysis.

An *assessment of accident frequency* for identified hazards is required in order to calculate their probability of occurrence. Frequency is estimated on the basis of historical data, but where available data provide an insufficient statistical sample or where a complex combination of events is required to trigger an accident, Fault Tree Analysis (FTA) is often used. FTA investigates the logical relationship between the circumstances, equipment failures and human errors which must exist in order for the top event of interest (e.g. derailment, train collision, train/motor vehicle collision) to occur. [The application of FTA is discussed at some length in Chapter 4]. Its accuracy depends upon the adequacy of the data needed to quantify individual component failures, or “basic events”. In some cases, this data is readily available (e.g. numbers of tracks and track circuits, train timings, etc), but in other cases sound engineering judgement and experience has to be relied upon.

Detailed scenario modelling will generally be required only where the circumstances and location of an event greatly influence its outcome, or consequences. Thus, the location and physical environment of a level crossing accident can often have a significant influence on the extent of human and property damage sustained. Event Tree Analysis (ETA) is the technique which is most often used for scenario modelling. It analyses and describes how an initiating event will lead to different outcomes, depending upon the interaction of the physical location of the event, human performance (e.g. of train and motor vehicle drivers) and the performance of safety protection devices. It involves constructing an Event Tree by laying out in chronological order each identified factor and then joining up all combinations of factors to provide a number of possible end events, or outcomes. The probability of each outcome can then be established by assigning probabilities to each branch of the event tree, on the basis that the frequency of occurrence of each hazardous outcome is the product of the frequency of occurrence of the initiating event and the probability that the event will develop to that particular outcome. [The application of ETA is also discussed in length in Chapter 4 of this report].

Consequence assessment is carried out in order to predict the severity of hazardous outcomes (in terms of casualties). Assessments are based on historical data relating to local factors (e.g. passenger loadings, topography, nature/condition of rolling stock, physical environment of level crossings) which are likely to have an impact on the potential number of casualties. Casualty estimates are usually expressed separately in terms of the number of fatalities, and of major and minor injuries, which are then combined into a total number of equivalent fatalities.

Risk summation is carried out by combining the results of the FTA, ETA and Consequence Analysis, in order to produce individual, societal and collective risk estimates. These estimates are then classified in accordance with the ALARP Principle, in order to prioritise expenditure on safety enhancement (or risk reduction) projects. Hazards, which are considered to pose an intolerable level of risk in terms of accident frequency and severity, automatically qualify for project expenditure without having to be subjected to cost/benefit analysis. Projects designed to reduce risks, which are identified as “tolerable”, are subjected to cost/benefit analysis in order to determine whether the benefits to be gained from safety enhancement projects would exceed the cost of project implementation. If cost/benefit analysis answers this question in the affirmative, the project is implemented, but if in the negative the project is rejected or returned for re-assessment of its capital and operating costs. Finally, for hazards with a negligible level of associated risk, no further action is required, other than to ensure from time to time that risk remained at this level.

Cost-Benefit Analysis is undertaken for any hazard scenarios shown to lie within the ALARP region, in order to determine whether there is any justification for further risk reduction. Such justification will depend upon there being a surplus of benefit over the cost of additional risk reduction. In this case, the “benefit” is the saving of human life and a financial value must be attached to this benefit, however distasteful this approach might be. In the United Kingdom, this benefit is referred to as the Value for the Prevention of a Fatality (VPF) and, for transportation safety projects, its value has been assessed to lie within the range of £ 0.8 – 2.5 million per fatality avoided. (For further discussion on safety benefit valuation in transport project appraisal see Section 3.3.4). As an example of the application of Cost-Benefit Analysis to a risk reduction project if it is assumed that the risk reduction measure being appraised will save three equivalent fatalities over its design life of 10 years, that it has capital and maintenance costs with a net present value of £ 500,000 and that the relevant VPF is £ 2.0 million, then the benefit-cost ratio of the proposed measure is 12 (i.e. 3 x 2/0.5). In this case the recommendation would be to implement the risk mitigation measure.

- Risk Control

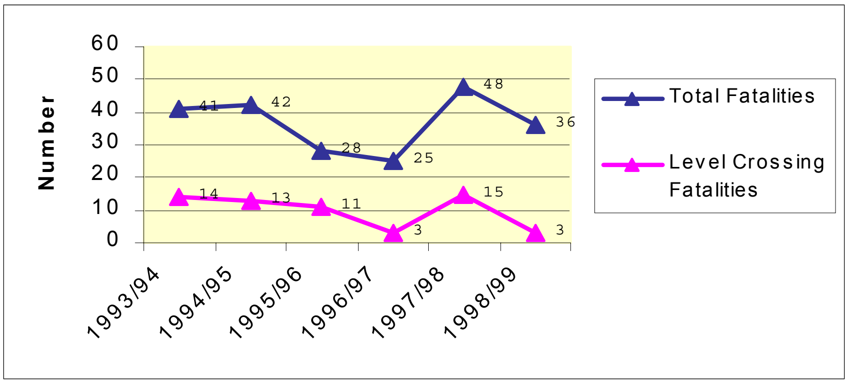
  This is the process by which risks are continuously monitored in accordance with the ALARP Principle and their conformity with an acceptable level of risk. Associated with this monitoring activity is subsequent action to implement risk mitigation or reduction measures as necessary. In the United Kingdom, the railway safety case is often described as a “living document”, requiring frequent review and revision whenever appropriate (such as when a procedure described in the safety case is to be changed). UK Railway Safety Case Regulations in any event require railway operators to review thoroughly their safety cases at least once every three years. This implies that they will also review the risk management strategies outlined in safety cases.

3.3.3 Risk management as applied to level crossing accidents in the United Kingdom

(i) Trend in and relative significance of level crossing fatalities

A safety survey published in Railway Gazette International of May 1992 indicated that the number of persons killed or seriously injured in level crossing accidents in the United Kingdom between 1980 and 1991 was 485 out of a total of all persons killed or seriously injured of 8,912, i.e. only 5 per cent of the total. At the same time, this survey indicated that there were no unprotected level crossings in the United Kingdom. More recent data on *fatalities* published by the Health and Safety Executive for the period 1993/94-1998/99 show that level crossing fatalities represent a higher proportion of all fatalities in railway accidents in the United Kingdom (standing at about 30-35 per cent over the five year period). However, with the exception of a sharp increase in 1997/98, there has been a marked downward trend in level crossing fatalities over the same five year period, as is shown in Figure 3.3. It is also notable that of the 15 persons killed on level crossings in 1997/98, 13 were pedestrians of whom 6 were using footpath crossings. It may be concluded that a substantial improvement in level crossing safety has been achieved in the United Kingdom in recent years.

Figure 3.3: Level crossing fatalities relative to total railway fatalities, United Kingdom



Source: HSE Railway Safety Statistics Bulletin 1998/99.

(ii) Accident record of various types of level crossings

Data on accidents, fatalities and injuries for the various types of protected level crossings in the United Kingdom between 1 April 1991 and 31 March 1992 were published in “Modern Railways” of June 1994 and are repeated in Table 3.2 below.

Table 3.2: Accidents at protected level crossings, 1 April 1991 - 31 March 1992

	Manual			Automatic				
	Gates	Controlled barriers	MCB/ CCTV	AHB	ABCL	AOCR	AOCL	TOTAL
BR crossings 31/03/92	362	314	283	422	10	5	199	1,595
Accidents	8		2	13			9	32
System failures*	1	7	7	9			1	
Rail pass. killed								
Rail pass. injured				43			1	44
Rail staff killed								
Rail staff injured			1	4			1	6
Road veh. occ. killed				2			2	4
Road veh. occ. injured		1		7			10	18
Pedestrians killed			1	2				3
Pedestrians injured		1	3					4

Source: Modern Railways June 1994.
Notes: MCB/CCTV = Manually controlled barriers with CCTV; AHB = Automatic Half Barriers; ABCL= Automatic Barriers Locally Controlled; AOCR = Automatic Open Crossing, Remotely Controlled; AOCL= Automatic Open Crossing Locally Controlled.

As might reasonably be expected, those level crossings which had a disproportionate share of accidents, fatalities and injuries were those without any or only a limited form of control, notably the Automatic Half Barrier type (no local or remote control and only half width barriers) and the Automatic Open Crossing Locally Controlled (with local control but without boom barrier protection). The AHB type which in 1992 represented just over a quarter of all protected crossings on the British Rail system, accounted for 41 per cent of all level crossing accidents, 57 per cent of all level crossing fatalities, and 76 per cent of all level crossing injuries. The AOCL type representing only 12.5 per cent of all protected level crossings in 1992, accounted for 28 per cent of all level crossing accidents, 29 per cent of fatalities and 17 per cent of injuries.

(iii) The Lockington accident and its significance

On 26 July 1986, a Ford Escort panel van with two occupants entered an open protected crossing at Lockington on the Bridlington to Hull line and collided with the 0933 Bridlington-Hull passenger train comprising two DMU (diesel multiple unit) sets each of two cars. The van was split into five parts, the front coach of the train turned through 180^0 and overturned, the second coach splayed across the opposite line, and the rear set derailed. The death toll of this accident was nine, and 59 people suffered injuries,10 of them serious injuries.

The subsequent enquiry found that the crossing equipment had been working correctly at the time of the accident and that the van driver had driven onto the crossing in error. The Lockington accident raised serious questions about the risks associated with AOCR (Automatic Open Crossing Remotely monitored) type level crossings. This type of level crossing protection system, which involves only flashing light protection for motorists, had replaced manually operated gates just six months before the accident. This was done as part of an economy drive to save the Bridlington-Hull line from closure.

The Lockington accident gave rise to doubts about the reliability of the automatic warning systems associated with the AOCR type of level crossing, since evidence had been given to the Inquiry into the accident that the crossing lights had frequently malfunctioned even during the short period during which the new AOCR crossings had been in service.[9] Common problems ranged from the lights working for a shorter time than the required 27 seconds to complete failure when a train was passing.

The Inquiry into the accident raised such a level of public concern that the Secretary of State for Transport commissioned a separate review of automatic open level crossing safety. The study, undertaken by Professor Stott was based on statistical analysis and engineering considerations. Stott's conclusions were that:

- the public expected higher safety standards at road/rail intersections than at ordinary road junctions; and
- collisions at AOC's were 20 times more likely than at AHB's *for the same traffic loading*

Stott's approach was to assume an arbitrary maximum acceptable fatality rate of one in 100 years and to calculate accident probabilities based on train speeds and "effective" traffic moments (where traffic moments are the product of rail and road movements through a level crossing). AOCR's were designed for train speeds of up to 75 miles per hour, in order to provide commercially acceptable transit times. Since train speed was the greatest single factor influencing the extent of fatalities, it was not surprising that nearly 80 per cent of crossings of the AOCR type failed to meet Stott's one in 100 year test. In fact, the actual number of collisions occurring on automatic open crossings was found to be 15 per decade and the number of fatalities

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[9] As reported in Modern Railways of June 1994.

on crossings of this type 30 per decade – a long way short of the assumed maximum acceptable rates.

What emerged from Stott's study was a compromise solution. Whereas the normal solution might have been to recommend installation of AHB's instead of the AOCR equipment, this would have involved a speed penalty of about 20 miles per hour. It was therefore decided to recommend a hybrid system combining the maximum train speed of the AOCR with the barrier equipment of the AHB's. The resulting system was known as an Automatic Barrier Crossing Locally Monitored (ABCL).

3.3.4 Safety Valuation in Transport Project Appraisal

(i) The need for monetary valuation of accident casualties

During the past decade, the UK Department of Transport has made considerable progress in terms of assigning *monetary values* for the prevention of death and injuries in transport accidents. Much of this work relates to road traffic accidents, but the principles enunciated therein are highly relevant to the valuation of death and injury prevention in railway accidents.

Why then is it important that the potential benefits of accident prevention be measured in monetary terms? The answer to this question lies in the convention that the benefits of transport projects are typically expressed in monetary terms to allow a comparison with the costs of their implementation. Thus, if the cost/benefit relationships of safety projects are to be weighed against those of other transport projects, they also must be reduced to monetary terms, but the valuation of safety benefits poses considerable difficulty.

(ii) "Gross Output" vs. "Willingness–to-Pay"

Many different approaches to the valuation of safety have been proposed, but only two have been adopted – namely the *"gross output"* approach and the *'willingness-to-pay"* approach. Both approaches have been used by the UK Department of Transport at various times in attempting to establish an effective methodology for the cost-benefit analysis of transport safety improvement schemes.

The gross output approach primarily assesses the cost of an accident as the discounted present value of a victim's future output, or income, "extinguished as a result of his or her premature demise." [10] To this estimate of income foregone is added an allowance for various other economic effects, such as vehicle damage, police and medical costs. In some countries, an additional (arbitrary) allowance is made for the pain, grief and suffering of the victim or the victim's dependents, relatives and friends.

The major objection raised by experts in this field to the gross output approach is that it does not reflect a person's true preference for safety, as distinct from the desire to preserve current and future levels of income.

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[10] M.W.Jones-Lee: *Valuing Safety in Transport Project Appraisal,* Paper for Railtrack/British Rail Conference on Value for Money in Transport Safety Measures, London, 26 July, 1994.

The willingness-to-pay (WTP) approach, on the other hand, values the cost of accidents as the maximum amount a person (or persons) would be prepared to pay for improvements in his/her own and others' safety. Thus, the WTP valuation is a natural measure of personal preference for safety. Its basis is a combination of mailed and personal interview surveys, as well as *revealed preference* studies in which an assessment is made of actual situations where people trade off income or wealth for physical risk (typically in hazardous occupations which command wage premiums). It is calculated for individuals and then aggregated for groups of individuals using distributional weights, in order to arrive at an overall value for the safety improvement concerned.

To permit comparisons between these alternative methods of safety valuation, it is necessary to standardize the estimates by relating them to the concept of avoidance of a *statistical death or injury.* As an illustration of this, if it is supposed that a group of 100,000 people enjoy a safety improvement that reduces the probability of death by 1 in 100,000 for *each and every* member of the group, the expected number of deaths within the group during a given future period will be precisely one. The safety improvement may thus be described as the avoidance of one *statistical death.* The statistical death saved may then be valued in accordance with either of the two alternative valuation methods in order to estimate the benefit of a safety improvement. [The value of a statistical death saved is referred to in UK railway safety documentation as the "Value of a Fatality Prevented" or VPF].

It has to be noted that the gross output and WTP methods of safety benefit valuation produce widely different results, as is shown by the values used by the United Kingdom Department in assessing the costs of road traffic fatalities (see Table 3.3).

Table 3.3: Gross output and WTP statistical life valuations used by United Kingdom Department of Transport for road accidents

	Gross output	*Willingness-to-pay*
1985* prices	£ 180,330	
1987 prices		£ 500,000
1992 prices		£ 715,330
1998 prices		£ 950,000

Sources: (1) M. W. Jones-Lee, *Valuing Safety in Transport Project Appraisal,* Railtrack/British Rail. Conference on Value for Money in Transport Safety Measures, London, July 1994 .

(2) *Judgement versus the cold numbers* in Modern Railways, July 1998.

* Last year for which a gross output based estimate was made.

(iii) Problems associated with WTP approach

The "willingness-to-pay" estimates in Table 3.3 are the median values from the survey data. As such, they are significantly lower than the mean values from the same survey data – for example, had the mean rather than the median been used for the 1992 estimate, a value closer to £ 2,000,000 (nearly three times the median figure of £ 715,330) might have resulted. One of the problems implicit in selecting the WTP approach is that of determining which central tendency measure – mean or median – best reflects the safety valuations of a majority of people. Most experts suggest that there is no substitute for critical, informed judgement in selecting a particular value from a given range. When in 1988, the United Kingdom Department of Transport decided to make quite a radical change in its method of valuing road fatalities (from a gross output to a WTP approach), it erred on the side of caution and selected a value at the lower end of the range of estimates then available. Subsequently, the WTP approach has gained greater acceptance and is now the approach to the valuation of safety recommended in the Treasury "Green Book".[11] It is possible that this may influence the Department of Transport in future to set its value for prevention of a road fatality closer to those implied by the mean estimates for the United Kingdom.

(iv) Valuation of Non-fatal Road Injuries

The major difficulty associated with obtaining WTP values for preventing non-fatal injuries is that these cover a wide spectrum, from minor cuts and bruises requiring no hospitalisation to injuries resulting in severe permanent disability. Nevertheless, such estimates have been attempted in both the USA and the United Kingdom.

In the United Sates, expert medical opinion was consulted to obtain estimates of "lost years of functioning" for various categories of injury. To these were applied a "value per life year" of US$ 120,000 (1986 prices) in order to obtain an estimate of the cost of various types of injury. The value per life year was itself estimated by discounting an assumed value of a statistical life of US$ 1.95 million at 6 per cent per annum.

In the United Kingdom, estimates were based on personal interview responses from a nationally representative sample of 891 persons in England, Scotland and Wales. Essentially the survey method involved asking respondents to rate the risk of sustaining various types of serious injury in relation to loss of life. The sample means for each types of injury were then applied to the value of statistical life (£ 715,330 in 1992 prices) to arrive at a value for preventing each type of serious injury. The values so derived were used by the Department of Transport to increase its valuation of serious injury from £ 20,000 (based on the gross output approach) to £ 75,000 (based on the WTP approach and at 1992 prices). The valuation of serious injuries as a proportion of statistical life ranged from 2.5 per cent for outpatient treatment and full recovery in 3-4 months to 100 per cent for paraplegia/quadriplegia and severe head injuries. Using the average value of £ 75,000 per injury, the value of a statistical life may therefore be calculated as the equivalent of 9.5 serious injuries.

(v) Willingness-to-Pay valuations of railway casualties

While the WTP approach has also been adopted for the valuation of casualties in UK railway accidents, the assessed magnitude of values is considerably greater than that applied in the case of road accident casualties.

There is no intuitive reason why there should be any difference between these values. However, the difference arises in the perception of a majority of respondents to accident valuation surveys that a rail single accident involving multiple casualties carries with it a greater risk than several small road accidents with one or two casualties. This perception is reinforced by the fact that, typically, accidents involving ten or more fatalities account for a very small proportion of all

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[11] HM Treasury (1991) : *Economic Appraisal in Central Government. A Technical Guide for Government Departments*.

road fatalities, whereas over an extended period such multiple fatality accidents are likely to account for a much larger proportion of all rail fatalities.

The further perception by survey respondents that the risks of railway accidents are largely outside of passengers' control also operates to increase the total cost of a rail fatality relative to that of a road fatality. The evidence is that people will be willing to pay a smaller amount for risk reduction if they perceive the risk to be under their own control, assumed voluntarily, largely their own responsibility, and above ground. The majority perception is that all four conditions are met in the case of road accident risk, but that in the case of railway accident risk only the last of the conditions is met (i.e. most railway accidents occur above ground), and in the case of underground metro risk none of the conditions is met.

Publicity given to railway accidents also tends to influence public attitudes. The Chairman of the UK Health and Safety Executive was recently quoted as saying that "the British public has no tolerance of accidents on the railway […] ten or so deaths a year are all over TV and there are ten deaths a day on the roads".[12]

The current valuation of preventing a fatality in a train accident in the United Kingdom is currently about £ 2.65 million, which is nearly three times the valuation of preventing fatalities in other types of rail accident or in road accidents.

From this it can be seen that fatality valuation in level crossing accidents involving deaths both of railway passengers and of motor vehicle occupants (such as might result from a train derailment after collision with a motor vehicle at a level crossing, viz. the Lockington accident) might present some difficulty where different values would be applied to rail and road vehicle occupants killed in the same accident.

3.4 Level crossing experience of the United States of America

(i) Administration of railway safety policy and regulations

In the United States, the railway industry is dominated by large private conglomerates. Regulation of the industry in all aspects of its operation, including safety, is the responsibility of the Federal Railroad Administration (FRA). The National Safety Transportation Board is responsible for the investigation of all serious railway (and other transportation mode) accidents. However, it has power only to make recommendations – the ultimate power of enforcement resides with the FRA.

(ii) Level crossing characteristics

In early 1999, there were 158,719 public level crossings and 100,716 private level crossings in the United States. (A private level crossing is located on a privately owned road and is intended for use by the owner's licensees or invitees. It is not intended for public use and is not maintained by a public highway authority).

An insignificant proportion of level crossings is manned. Outside of the major towns and cities, level crossings are largely unprotected by barriers or gates. Flashing lights and audible warning mechanisms are often provided at rail intersections with major highways as a means of alerting motor vehicle drivers, but

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[12] *Judgement versus the cold numbers* in Modern Railways, July 1998.

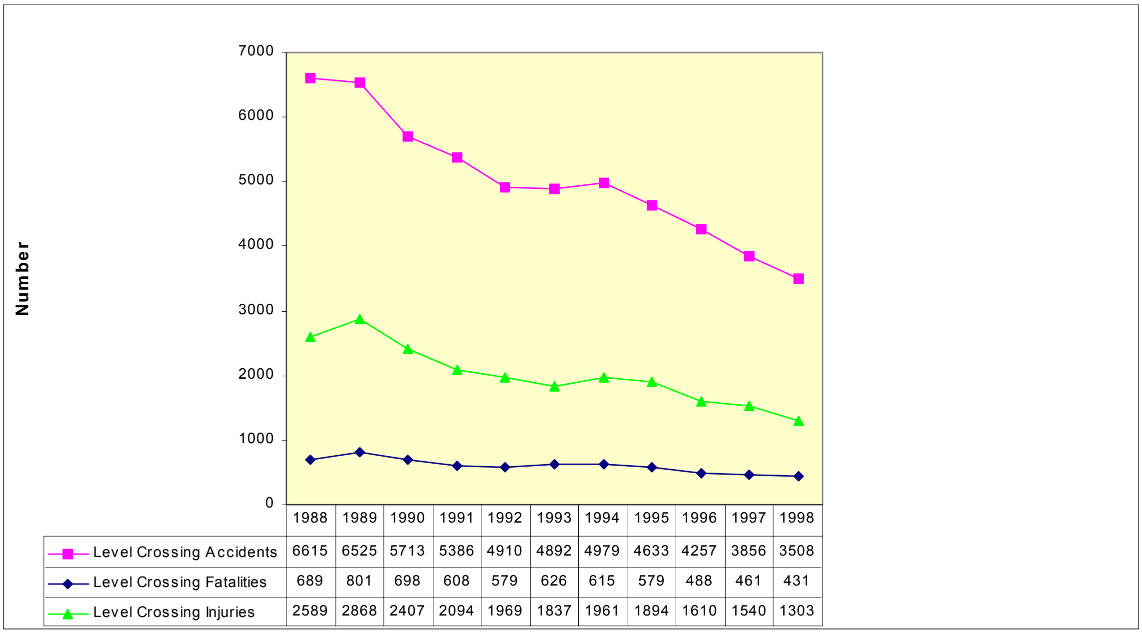
the great majority of level crossings in the United States are equipped only with fixed road signs.

(iii) Level crossing safety record

Statistics provided by the FRA for the ten year period 1988-1998 show that, since 1988, the number of collisions at road-rail grade crossings in the United States dropped by nearly half despite an 18 per cent increase in rail traffic, and the addition to the road network of 20 million new licensed drivers, over the same period.

Over this period also, the number of fatalities in level crossing accidents declined by 37 per cent and the number of serious injuries by 50 per cent, as may be observed in Figure 3.4.

Figure 3.4: Trend in level crossing accidents, fatalities and injuries, United States, 1988-1998



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Level Crossing Accidents	6615	6525	5713	5386	4910	4892	4979	4633	4257	3856	3508
Level Crossing Fatalities	689	801	698	608	579	626	615	579	488	461	431
Level Crossing Injuries	2589	2868	2407	2094	1969	1837	1961	1894	1610	1540	1303

Source: FRA Statistics, as reported on the Operation Lifesaver website, October 1999.

The data in Figure 3.4 cover both public and private level crossings.

Operation Lifesaver Inc, a non-profit, road-rail safety education organization has drawn some incisive observations from the latest available FRA statistics. They are:

- Whereas 431 persons were killed in level crossing collisions in the United States in 1998, 536 persons were killed while trespassing on railway rights-of-way and property;

- In 1998, nearly 96 per cent of all railway-related deaths resulted from motor vehicle collisions with trains and from pedestrian/trespasser train strikes;

- In the United States, a train collides with a person or vehicle on average every 115 minutes;

- A motorist is ***40 times*** more likely to die in a collision with a train than in a collision with another vehicle;

- More people die in road-rail crashes than in commercial airline crashes in an average year;

- More than ***50 per cent*** of crashes at public crossings occur where active warning devices (gates, lights, bells) exist;

- After full brake application, the average 100 car freight train with a line speed of 55 miles per hour (88.5 km per hour) will require more than one mile (1.61 km) to stop and an average 8 car passenger train with a line speed of 79 miles per hour (127 km per hour) will require about one mile to stop;

- The implications of the above observation are that a freight train sighted at a distance of 150 metres from a crossing would take only 6 seconds to reach that crossing, while a passenger train would take only 4.3 seconds to cover the same distance;

- The majority of road-rail crashes in the United States occur when the train is travelling at ***less than 30 miles per hour*** (48.3 km per hour)[13], and

- Some 73 per cent of all collisions between motor vehicles and trains occur in 14 states, namely: Alabama, Arkansas, California, Georgia, Illinois, Indiana, Louisiana, Michigan, Minnesota, Mississippi, North Carolina, Oklahoma, Texas and Wisconsin. While this list includes some of the most populous of the American states, by no means does population density alone explain the concentration of accidents in these states.

It is noteworthy that more people die in level crossing accidents each year in the United States than die in level crossing accidents in India. This is a curious result given the far greater population density of India, but may be explained by the fact that with 260,000 level crossings of all types, the United States has more than *six times* India's total number of level crossings and hundreds of times its motorization levels. Additionally, while a relatively small proportion of level crossing fatalities in India occurs in accidents at protected level crossings, such accidents account for about half of all level crossing fatalities in the United States.

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[13] *Highway-Rail Facts* from Operation Lifesaver Inc website October 1999.

(iv) Reasons for level crossing safety improvement in the United States

The public safety education programme being implemented by Operation Lifesaver Inc is likely to have made a substantial contribution to the sharp decline in level crossing accidents, fatalities and injuries in the United States over the past decade.

Operation Lifesaver is a non-profit, nationwide public education programme having the objective of eliminating collisions, deaths and injuries at road-rail intersections and on railway rights-of-way. It is sponsored by a wide range of government agencies (including federal, state and local government transport authorities) as well as by the highway safety and maintenance organizations and the nation's railroads.

The Operation Lifesaver programme aims to increase public awareness about danger at places where roads cross train tracks and on railway rights-of-way. It seeks to improve driver and pedestrian behaviour at road-rail intersections by encouraging compliance with traffic laws relating to crossing signs and signals. In addition to its educational function, the programme emphasizes the enforcement of existing traffic and trespassing laws, consolidation and closure of redundant level crossings, and engineering improvements including installation and upgrading of crossing warning devices and signs.[14]

Operation Lifesaver was founded in Idaho in 1972, after the Union Pacific Railroad and Community leaders joined together in a campaign to reduce the growing number of road-rail level crossing collisions. The public education programme they created was largely responsible for a 43 per cent drop in level crossing fatalities during the first year of its operation.

In 1998, throughout the United States, trained Operation Lifesaver presenters delivered 30,000 safety presentations to nearly 2 million individuals, of whom about half were schoolchildren. Another group targeted in the Operation Lifesaver campaign is truck drivers, since this group features prominently in level crossing accident statistics. In 1998, about 1,100 presentations were given to 40,000 professional truck drivers.

Extensive use is made of television and multimedia (video and the Internet) to broadcast level crossing safety messages. Examples of the television and video campaigns run recently are:

- "The Responsibility is Ours", a video film produced in cooperation with the Federal Highways Agency (FHWA) after a fatal collision between a school bus and a train and targeted at school bus drivers;
- "Die Hard if You're Dumb", an MTV-style video created by teenagers for teenagers with funding assistance from the FHWA;
- "They Shouldn't Die This Way", a video film produced with funding from the Department of Transportation and assistance from national law enforcement and fire-fighting groups with a focus on emergency responders to level crossing accidents; and

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[14] *What is Operation Lifesaver* from Operation Lifesaver website October 1999.

- "Highways or Dieways: the Choice is Yours" – spot television advertisements and possibly the most powerful public safety awareness campaign ever conducted, with seed funding of US$ 2.5 million from the Association of American Railroads and donated broadcast time to the value of US$ 5.0 million since the campaign began in Texas in 1996. These advertisements are estimated to have so far reached 100 million American viewers.

Another major emphasis in the work of Operation Lifesaver is the lobbying of federal and state governments to strengthen their highway codes and railway trespass laws. Significantly, while there has been a dramatic drop in the number of collisions between motor vehicles and trains, railway accidents involving pedestrians have been on the increase, to the extent of 14 per cent per year based on the latest available statistics. OLI has supported the adoption by state governments of the US Department of Transportation's *Model State Railroad Trespass and Vandalism Bills* (published in 1997). State penalties for trespass on railroad property now range from $5 to $2,500, and most of the fines imposed are in the inconsequential range. In some situations, also, local police must have written permission from a railroad before they can issue a fine or arrest persons they find trespassing on railroad land.

Finally, OLI has been lobbying the federal government to require state authorities and railroads to report to the FRA on a timely basis comprehensive and accurate information on level-crossing and trespasser accidents/incidents, including the vital demographic information on the persons involved in these events.

3.5 Level crossing experience of Canada

(i) Administration of rail safety policy and regulations in Canada

The ultimate authority for enforcement of railway safety regulations in Canada is vested in Transport Canada (the Canadian Department of Transport). The legislative instrument under which its powers are exercised is the Railway Safety Act (as amended 1998).

An independent Transportation Safety Board is responsible for all major rail (and other transport mode) accident investigations. Its recommendations are submitted to Transport Canada which must decide upon implementation (or otherwise). As an example of the way in which this system operates, following a serious derailment of a VIA Rail train near Biggar, Saskatchewan, on 3 September 1997, the Transportation Safety Board recommended, and Transport Canada accepted for implementation within 30 days, measures intended to reduce the risk of death or serious injury to passengers in the event of an accident. These measures included the provision of adequate safety equipment (such as emergency window exit hammers, appropriately equipped trauma kits, readily accessible flashlights, etc).

In late 1998, amendments to the Railway Safety Act were passed by the House of Commons. These included:

- a new policy statement;
- authority to require railways to report safety-critical information for the purpose of reviewing railway system safety performance;

- authority to require railways to implement Safety management Systems; and
- increased authority for rail safety inspectors[15]

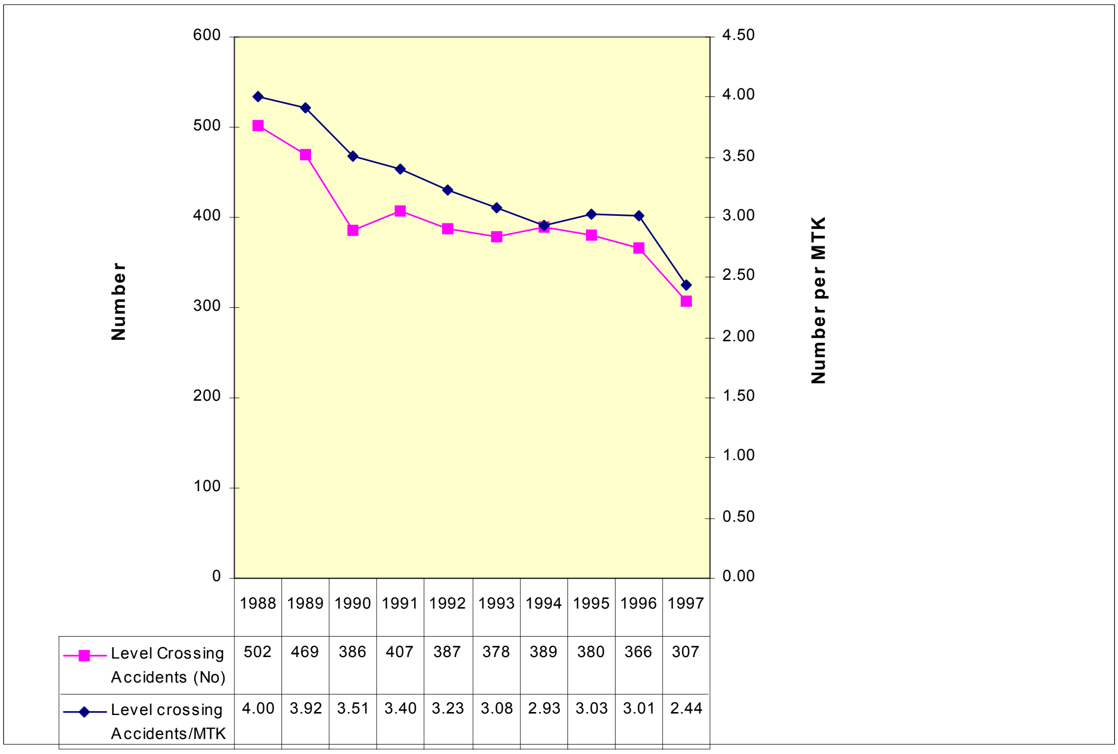
(ii) Level crossing characteristics

While no precise information is available on level crossing numbers and types, it appears likely that in common with the United States, Canada has a predominance of unmanned, unprotected level crossings.

(iii) Trend in of level crossing accidents, fatalities and injuries

Over the nine year period from 1988 to 1997, accidents at level crossings in Canada dropped sharply - from 502 to 307. This decline was also reflected in a declining *accident rate,* from 4.00 level crossing accidents per million train kilometres in 1988 to only 2.44 per million train kilometres in 1997 (see Figure 3.5).

Figure 3.5: Level Crossing Accidents in Canada



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
■ Level Crossing Accidents (No)	502	469	386	407	387	378	389	380	366	307
◆ Level crossing Accidents/MTK	4.00	3.92	3.51	3.40	3.23	3.08	2.93	3.03	3.01	2.44

Source: Transport Safety Board, Canada, Statistical Bulletin 1997.
Note: MTK = Million Train-Kilometres.

In the case of level crossing *fatalities*, the improvement has been even more dramatic, with the number of deaths falling almost by half in the nine year period, from 58 in 1988 to 30 in 1997 (see Figure 3.6). At the same time, the *fatality rates* fell from 0.46 to 0.24 per million train kilometres.

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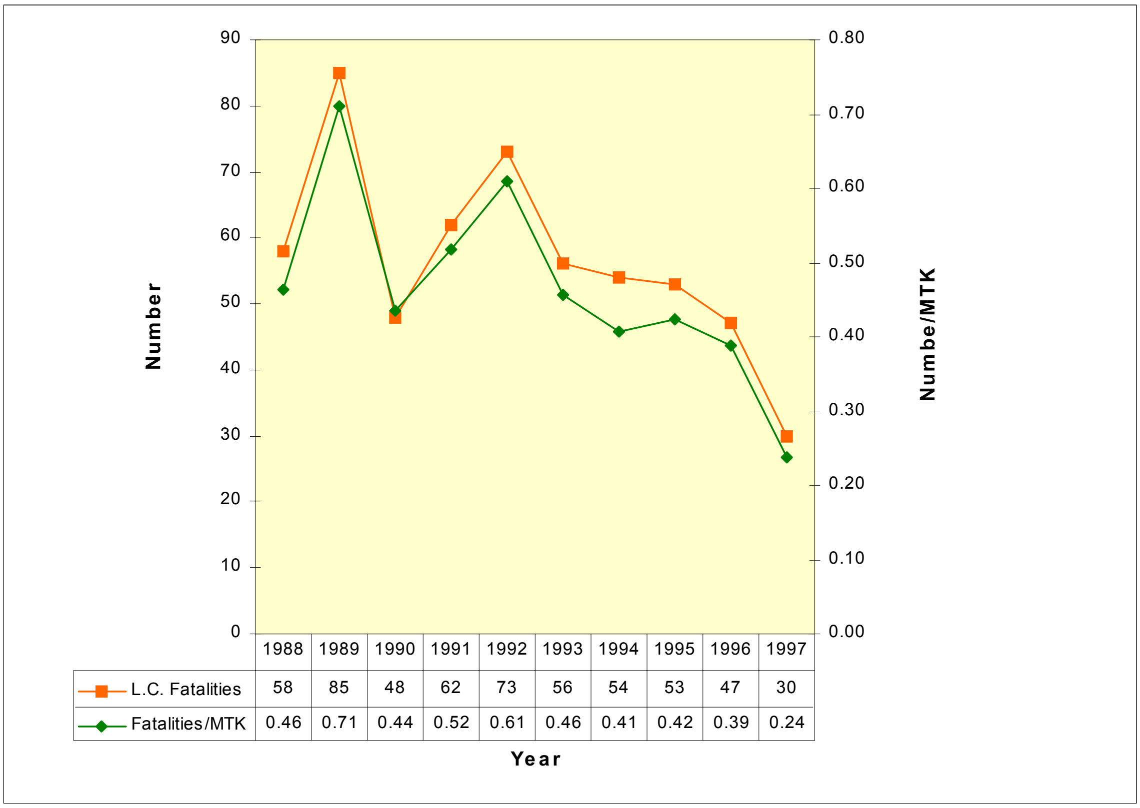
[15] Transport Canada Rail Safety Initiatives, 5 November 1998.

Level crossing fatalities as a proportion of Total Railway Fatalities in Canada have been falling consistently. However, at 42 per cent in 1996, they still represented a large proportion of all deaths in railway accidents.

It is noteworthy that, despite the marked decline in overall level crossing fatalities between 1988 and 1997, the proportion of persons killed at level crossings equipped with ***automatic warning devices*** increased over the same period, from an average of 49 per cent between 1991 and 1995 to 63 per cent in 1996.

The number of injuries at level crossings shows a similar declining pattern, falling from 56 in 1993 to 30 in 1997, with a corresponding decline in the injury rate from 0.46 to 0.24 per million train kilometres. (The trend in injuries is not available for the same time frame as for accidents and fatalities as the data series was changed in 1993 to include only serious injuries).

Figure 3.6: Level Crossing Fatalities in Canada



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
L.C. Fatalities	58	85	48	62	73	56	54	53	47	30
Fatalities/MTK	0.46	0.71	0.44	0.52	0.61	0.46	0.41	0.42	0.39	0.24

Source: Transport Safety Board, Canada, Statistical Bulletin 1997.
Note: MTK = Million Train-Kilometres.

(iv) Transport Canada Level Crossing Safety Initiatives

In the context of level crossing safety enhancement, Transport Canada has taken initiatives to formalize a number of standards for level crossing protection. In 1998, it started work on the development of a model to provide consistent measurements of the safety benefits of funding level crossing improvements. It has also been active in promoting public education campaigns, as well as providing financial support for fencing and crossing closures, in a bid to reduce crossing user and trespasser casualties.

In common with experience in the United States, level crossing safety improvements in Canada appear to have been very much the result of focused education programmes. For education programmes to be successful, however, a minimum level of safety awareness should exist within the culture of the targeted community. While safety awareness is a common characteristic of Western societies, it is not a characteristic found in the majority of Asian societies.

3.6 Level crossing experience of continental Europe

Trends in the number and safety performance of level crossings for four Western European railway systems (DB, SNCB, SNCF, NS)[16] were assessed, as were methods of risk assessment as applied to level crossing safety enhancement in the Netherlands.

(i) Trend in level crossing numbers, by type

The trend in the total number of level crossings installed on each of the four railway systems surveyed is shown in Figure 3.7. Over the ten-year period 1988-1998, the total number of level crossings can be seen to be *reducing* at a rate of about 1.6 – 2.0 per cent per annum in Belgium, France and the Netherlands, but *increasing* at a rate averaging about 2.5 per cent per annum in Germany. The trend for Germany, however was influenced by the absorption of the railways of the former German Democratic Republic into DB in 1994. It is likely that the declining trend in three out of the four countries surveyed is due to a steadily expanding programme of grade separation, rather than to the closure of level crossings per se.

Although no recent data are available for Germany, it appears that unprotected crossings comprise as much as 47 per cent of DB's total level crossings, with automatic crossings accounting for 48 per cent and manned crossings 5 per cent.

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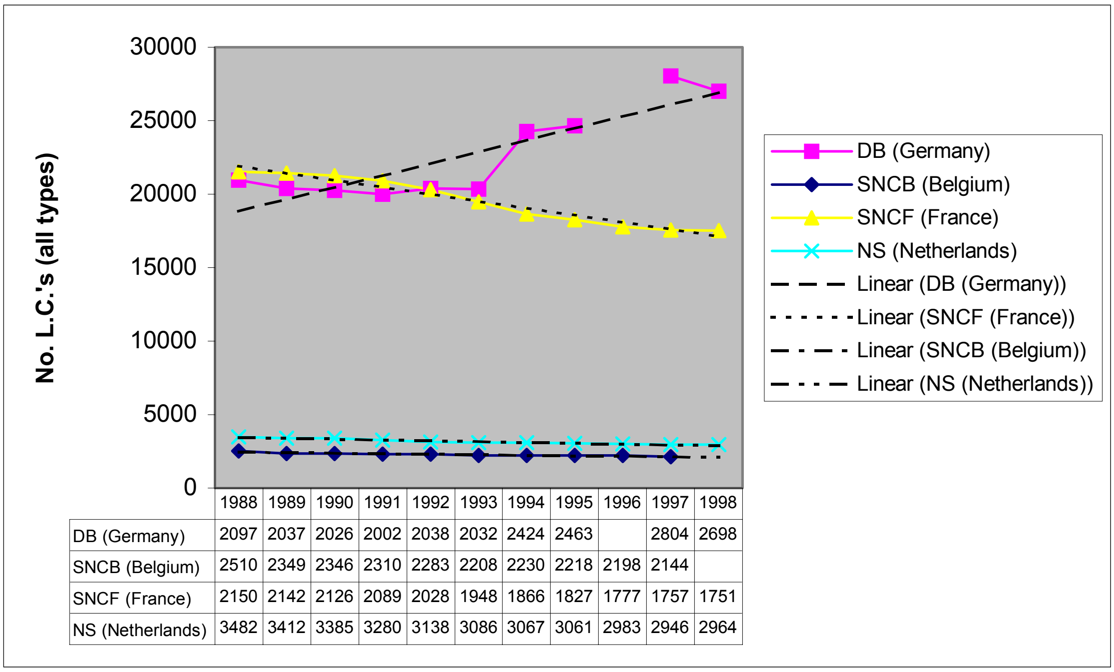
[16] These abbreviations signify the railway systems of the following countries;

DB – Germany
SNCB – Belgium
SNCF – France
NS - Netherlands

Figure 3.7: Number of level crossings in Western Europe



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
DB (Germany)	2097	2037	2026	2002	2038	2032	2424	2463		2804	2698
SNCB (Belgium)	2510	2349	2346	2310	2283	2208	2230	2218	2198	2144	
SNCF (France)	2150	2142	2126	2089	2028	1948	1866	1827	1777	1757	1751
NS (Netherlands)	3482	3412	3385	3280	3138	3086	3067	3061	2983	2946	2964

Source: International Union of Railways (UIC).

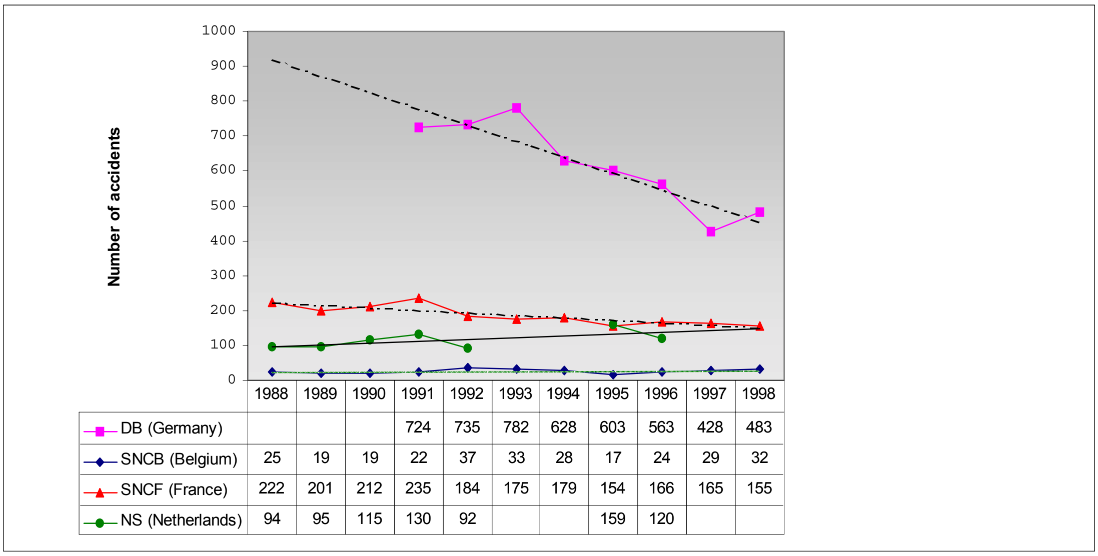
Of the four countries surveyed, France has the lowest percentage of unprotected crossings with just under 25 per cent of its crossings having no form of barrier protection. Belgium has a slightly higher proportion of unprotected crossings in its level crossing population at just on 25 per cent, while in the Netherlands unprotected crossings still account for 31 per cent of the total. Manned crossings have now been completely eliminated in the Netherlands, and in Belgium and France now account for only about 11 per cent of all level crossings. Automatic crossings now dominate the level crossing populations of Belgium, France and the Netherlands with 74 per cent, 64 per cent and 68 per cent of the total, respectively.

(ii) Trend in level crossing accidents, fatalities and injuries

(a) Accidents

Over the seven-year period 1991-1998, the number of level crossing accidents in Germany declined substantially from 724 in 1991 to 483 in 1998 (an effective rate of decrease of 5.6 per cent per annum). Trends for the other three countries were assessed over the full decade 1988-1998, although the series for the Netherlands was discontinuous over this period. In France, the number of level crossing accidents also followed a declining path, albeit at a more restrained rate than in Germany, while in Belgium they remained almost constant and in the Netherlands they increased steadily. These trends are illustrated in Figure 3.8.

Figure 3.8: Level crossing accidents in Western Europe



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
DB (Germany)				724	735	782	628	603	563	428	483
SNCB (Belgium)	25	19	19	22	37	33	28	17	24	29	32
SNCF (France)	222	201	212	235	184	175	179	154	166	165	155
NS (Netherlands)	94	95	115	130	92			159	120		

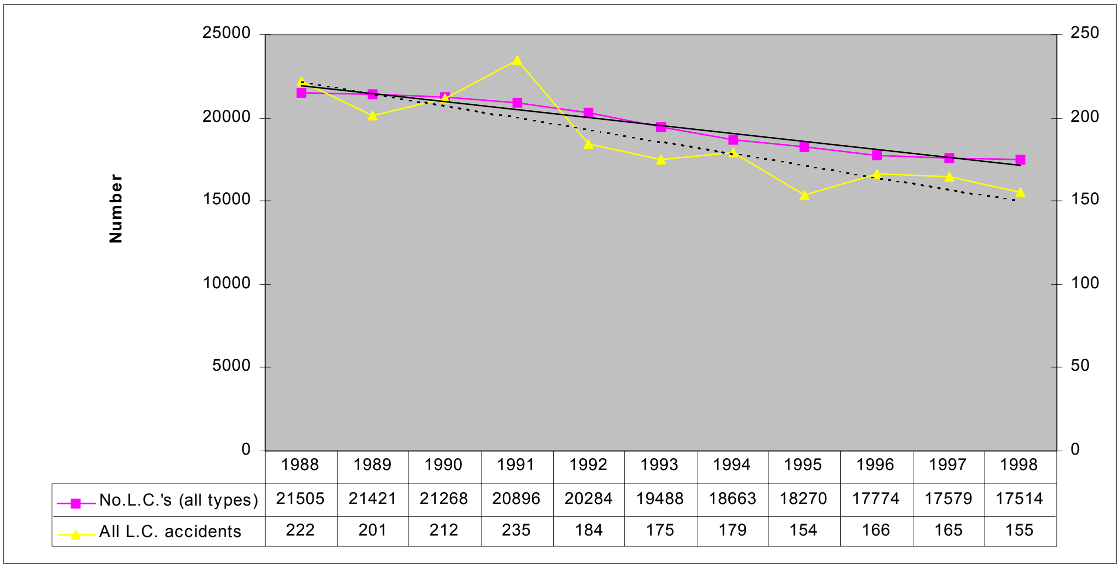
Source: (1) UIC.
(2) "Protection and elimination of level crossings" in Rail International, June 1999.

The rising accident trend in the Netherlands may have been concentrated at unprotected level crossings (which comprise 31 per cent of all level crossings), although a recent study undertaken by Railned (the government owned railway infrastructure company) suggests a heavy incidence of accidents at automatically protected crossings, as indeed is also the case in France (see below).

Figure 3.9 illustrates the trend in level crossing accidents in France against the trend in the number of level crossings of all types. These trends suggest that the reducing occurrence of accidents is positively correlated with the reducing numbers of level crossings. This is in marked contrast with the situation in the Netherlands where the number of level crossings has been *declining* over the past 10 years at about 1.6 per cent per year, but level crossing accidents have been *increasing* at a rate of about 3 per cent per year.

Additional information available for SNCF provides a breakdown of level crossing accidents by type of crossing. This information has been graphed in Figure 3.10. It shows that automatic level crossings are accounting for an increasing proportion of all level crossing accidents in France (75 per cent during 1998, as compared with 67 per cent ten years earlier). While the absolute numbers of accidents at automatic level crossings reduced at the rate of 2.3 per cent per annum over this period, those at unprotected crossings reduced at more than double, and those at manned crossings at more than seven times this rate. While it is not possible to explain the relativity of these trends without more information relating to the location (e.g. urban vs. non-urban) and combined road/rail traffic densities of the crossings involved, *it would seem that automatic level crossings pose a considerable safety threat to the French railway system.*

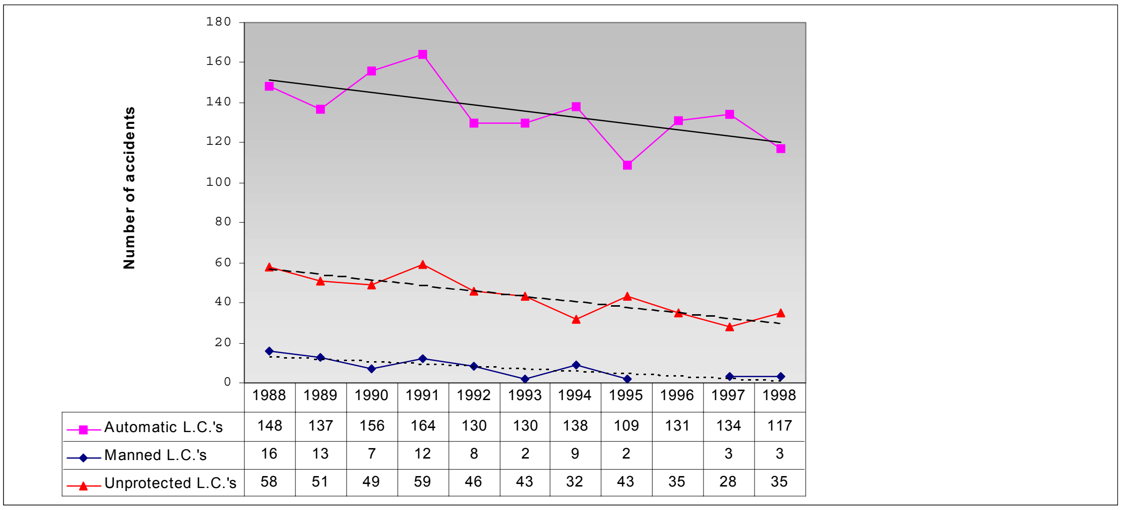
Figure 3.9: Relative trends in numbers of level crossings and accidents - France



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
No.L.C.'s (all types)	21505	21421	21268	20896	20284	19488	18663	18270	17774	17579	17514
All L.C. accidents	222	201	212	235	184	175	179	154	166	165	155

Source: UIC.

Figure 3.10 : Level crossing accidents, by type of crossing – France

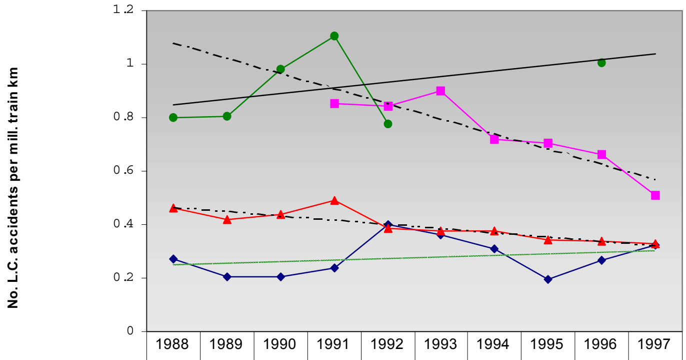


	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Automatic L.C.'s	148	137	156	164	130	130	138	109	131	134	117
Manned L.C.'s	16	13	7	12	8	2	9	2		3	3
Unprotected L.C.'s	58	51	49	59	46	43	32	43	35	28	35

Source: UIC.

When expressed as a rate per unit of rail traffic, in this case million train-kilometres, the accident occurrence was worst in the Netherlands which in 1996 had *more than one level crossing accident for every million train kilometres* over the NS rail network. Notwithstanding data discontinuities, a rising trend in the level crossing accident rate is apparent for the Netherlands over the past decade – see Figure 3.11. By contrast, accident rates in Germany and France were falling, while in Belgium the accident rate remained almost static over the decade.

Figure 3.11: Level crossing accident rates in Western Europe



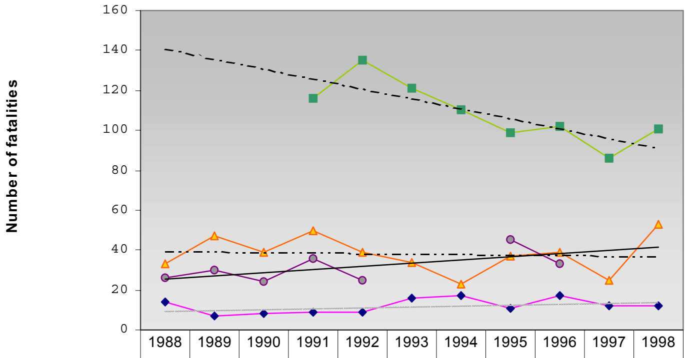
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
■ DB (Germany)				0.85	0.84	0.90	0.72	0.70	0.66	0.51
◆ SNCB (Belgium)	0.27	0.21	0.21	0.24	0.40	0.36	0.31	0.19	0.27	0.32
▲ SNCF (France)	0.46	0.42	0.44	0.49	0.38	0.37	0.38	0.34	0.34	0.33
● NS (Netherlands)	0.80	0.80	0.98	1.10	0.78				1.01	

Source: UIC.

(b) Fatalities

As is shown in Figure 3.12, only Germany among the four systems surveyed registered a significant and sustained reduction in the numbers of persons killed in level crossing accidents over the decade between 1988 and 1998. In France and Belgium the long term trend in fatalities was almost flat, although in the case of France, there was a sudden upturn in level crossing deaths in 1998 (53 as against only 25 in the previous year). While the declining trend in fatalities in Germany is encouraging, the data for 1998 indicate that more than 100 persons died in level crossing accidents in Germany in that year. The data series for the Netherlands is discontinuous, but indicates level crossing fatalities of about the same magnitude as those of France which has almost six times the number of level crossings.

Figure 3.12: Level crossing fatalities in Western Europe

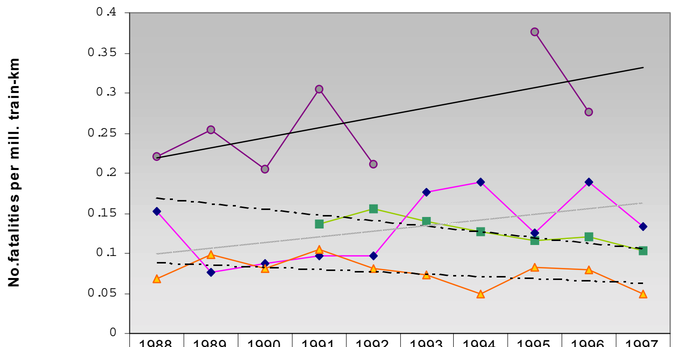


	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
■ DB (Germany)				116	135	121	110	99	102	86	101
◆ SNCB (Belgium)	14	7	8	9	9	16	17	11	17	12	12
▲ SNCF (France)	33	47	39	50	39	34	23	37	39	25	53
● NS (Netherlands)	26	30	24	36	25			45	33		

Source: (1) UIC.
(2) "Protection and elimination of level crossings" in Rail International, June 1999.

Considerably more information on the location and circumstances of accidents involving fatalities is needed before conclusions can be drawn as to the major factors contributing to these trends. Nevertheless, they are reinforced by trends in the level crossing fatality *rates,* as may be seen in Figure 3.13. These also indicate a marked improvement and a steady improvement respectively in the cases of Germany and France, a steadily rising trend in Belgium and a substantially rising trend in the Netherlands. At 0.28 persons killed per million train-kilometres, the fatality rate in the Netherlands in 1996 was more than double that of Germany and more than treble that of France for the same year. It is interesting to note that France with only 0.05 fatalities per million train-km in 1997 has one of the lowest level crossing death rates in the world, despite having just under one quarter of its level crossings unprotected and a predominance of unmanned automatic crossings.

Figure 3.13: Level crossing fatality rates in Western Europe



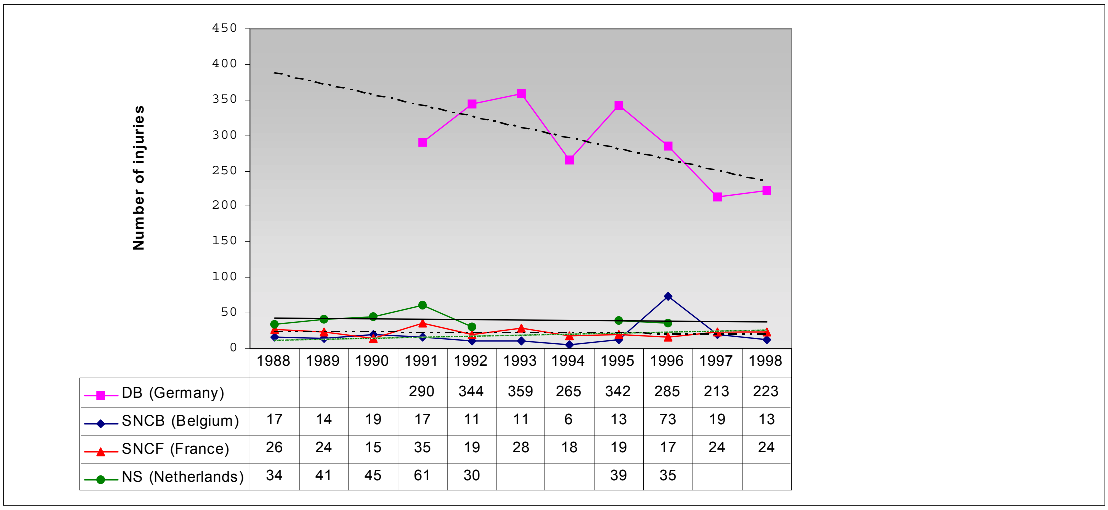
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
■ DB (Germany)				0.14	0.16	0.14	0.13	0.12	0.12	0.10
◆ SNCB (Belgium)	0.15	0.08	0.09	0.10	0.10	0.18	0.19	0.13	0.19	0.13
▲ SNCF (France)	0.07	0.10	0.08	0.10	0.08	0.07	0.05	0.08	0.08	0.05
● NS (Netherlands)	0.22	0.25	0.20	0.31	0.21			0.38	0.28	

Source: (1) UIC.
(2) "Protection and elimination of level crossings" in Rail International, June 1999.

(c) Injuries

During the ten year period 1988-1998, only Germany managed to achieve a significant reduction in the number of persons injured in level crossing accidents. In the other three countries, the number of persons injured at level crossings was almost static over the decade. The relevant trends may be seen in Figure 3.14.

Figure 3.14: Level crossing injuries in Western Europe

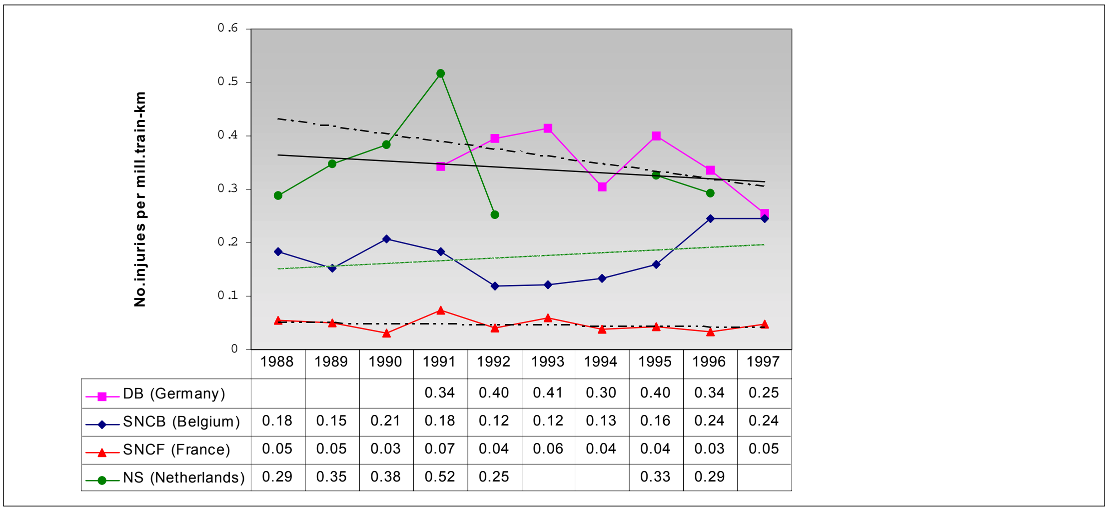


	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
DB (Germany)				290	344	359	265	342	285	213	223
SNCB (Belgium)	17	14	19	17	11	11	6	13	73	19	13
SNCF (France)	26	24	15	35	19	28	18	19	17	24	24
NS (Netherlands)	34	41	45	61	30			39	35		

Source: (1) UIC.
(2) "Protection and elimination of level crossings" in Rail International, June 1999.

In terms of the rate of level crossing injuries per million train-km, Germany again demonstrated the most significant improvement of the four countries surveyed, with an injury rate declining from 0.34 per million train-km in 1991 to 0.25 per million train-km in 1997. France's level crossing injury rate while remaining static over the decade was again among the world's lowest, with only 0.05 persons injured in level crossing accidents per million train-km in 1997. By contrast with its performance in terms of level crossing accidents and fatalities, the Netherlands demonstrated a declining trend in its injury rate over the decade – while in Belgium the number of persons injured per million train-km followed a rising trend, influenced mainly by an unexplained sharp increase in level crossing injuries in 1996.

Figure 3.15: Level crossing injury rates in Western Europe



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
DB (Germany)				0.34	0.40	0.41	0.30	0.40	0.34	0.25
SNCB (Belgium)	0.18	0.15	0.21	0.18	0.12	0.12	0.13	0.16	0.24	0.24
SNCF (France)	0.05	0.05	0.03	0.07	0.04	0.06	0.04	0.04	0.03	0.05
NS (Netherlands)	0.29	0.35	0.38	0.52	0.25			0.33	0.29	

Source: (1) UIC.
(2) "Protection and elimination of level crossings" in Rail International, June 1999.

(iii) Analysis of level crossing safety performance in the Netherlands

It is significant that the deteriorating safety performance of road/rail crossings in the Netherlands over the past decade has coincided with the de-manning of the last manned level crossings in that country and their replacement with automatic warning and barrier protection systems. While the overall number of level crossings in the Netherlands contracted by 15 per cent in the last decade (from 3,482 in 1998 to 2,964 in 1998), the number of "automatic" crossings (assumed to include crossings equipped with automatic barrier protection and those equipped only with automatic warning lights[17]) has grown slightly over the same period. Automatic crossings now comprise nearly 70 per cent of the total number of level crossings on the NS system, the balance (30 per cent) being unprotected crossings presumably equipped only with road warning boards at the crossing approaches.

The relatively poor safety record of level crossings in the Netherlands was documented in the preceding sections. It is probable that official concerns about this poor safety record recently prompted Railned, the organization responsible for managing the Netherlands Railway's infrastructure, to commission a major study of level crossing safety.[18] The study focused on the underlying causes of accidents at level crossings of the automatic half barrier half open (AHOB) type and the measures needed to reduce the chances (i.e. risk) of accidents at such crossings. Accident causes evaluated include those relating to the psychology of road users, as well as those influenced by equipment design and performance and by the physical environment of the level crossings themselves. Among other issues addressed by the study is an appropriate methodology for Cost/Benefit Analysis of level crossing safety enhancement measures.

The study was based on an analysis of 6,152 incidents at about 1,000 locations during the 12-year period from 1985 to 1997. A random sample of 100 collisions at AHOB crossings was taken from this data in order to construct a Fault Tree Analysis (FTA). The FTA helps to assess the frequency, probability and consequences of collisions at AHOB crossings.

The more significant results of this analysis suggest that:

- 93 per cent of all collisions are caused by the mistakes of road users;
- 7 per cent of all collisions occur because barriers are opened erroneously and trains permitted to pass either by human override action (6 per cent) or as a consequence of mechanical or electrical failure (1 per cent);
- 39 per cent of all collisions result from road users making "deliberate mistakes", i.e. by taking actions in full awareness of the risks involved. Included in these are accidents involving slalom or zigzag driving/walking around closed barriers (17 per cent), as well as accidents involving deliberately trying to cross after one train when it is known that a second train is approaching (16 per cent);

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[17] The barrier protected crossings falling within the "automatic" classification may be further dissected into those of the full barrier and half barrier type.

[18] *Improving Safety at Railway Crossings, Final Report on AHOB Crossings*, Railway Safety Department, Railned, 1999.

- 53 per cent of all accidents are caused by “non-deliberate” mistakes, e.g. through visual misjudgement or miscalculation (20 per cent), through wrong or late reaction (10 per cent) or through road users finding themselves and their vehicles on the track against their will, when trapped by other traffic or as a result of vehicle failure (23 per cent). Of those accidents resulting from visual misjudgement, most (14 per cent) were attributed to distraction or blinding, causing vehicle drivers not to notice crossings and signal indications; and

- 90 per cent of all drivers involved in collisions at level crossings use those crossings regularly. The “familiarity breeds contempt” phenomenon operates here.

It was found that on average level crossing accidents which result in train derailments occur about once a year. While this is certainly more frequent than it should be, during the period 1981-1997 derailments following level crossing collisions resulted in only one death (a railway passenger), one serious injury (a train driver) and minor injuries to 38 passengers.

The Railned study recommended a number of specific measures to improve the safety of level crossings of the AOHB type. These measures were classified under four headings:

(i) Eliminate risk by addressing the root cause of accidents;

(ii) Prevent accidents by implementing technical improvements (install devices for detection of vehicles obstructing level crossings);

(iii) Limit the *number of accidents* through better enforcement of rules and regulations and implementation of a public awareness campaign, backed up by technical and corrective measures (e.g. installation of red light cameras); and

(iv) Limit as much as possible the *damage resulting from accidents* through regulations, a public awareness campaign and technical measures aimed at improving emergency response and damage control.

The study report urges the prioritization of measures in accordance with those which: *eliminate* causes, *prevent* accident occurrences, and *mitigate* the consequences of accidents. It also classifies measures in terms of those related to the level crossing itself and those related to physical environment of the crossing.

From a list of all possible types of measures, the study identified a list of specific measures which it recommended for implementation in order to combat the deteriorating safety performance of the AOHB type crossings. This list of specific measures was as follows:

(i) Install barriers over open footpaths and cycling tracks;
(ii) Install gates under barriers over all footpaths and cycling tracks;
(iii) Place a STOP-sign on top of lowered barriers;
(iv) Equip crossing illumination lights with bigger lenses for higher light yield;
(v) Decrease or eliminate the “phantom effect” in level crossing illumination;

(vi) Increase the light yield of flashing warning lights;
(vii) Use bigger background signs;
(viii) Increase the intensity of beam lights on locomotives;
(ix) Provide warnings of traffic congestion for crossing users;
(x) Improve road surfaces over crossings;
(xi) Replace all fixed warning lights with flashing lights;
(xii) Install or improve speed humps at level crossing approaches;
(xiii) Provide warning signs advising motorist of presence of speed humps;
(xiv) Provide barrier segregation of road lanes either side of crossings in order to prevent slaloming (or “S” moves around lowered barriers);
(xv) Provide means of separating motorized and slow traffic on level crossings and extend footpaths and cycling tracks onto crossings;
(xvi) Paint road surfaces of all crossings with luminescent markings; and
(xvii) Paint uninterrupted lines along the road borders for a distance of nine metres either side of crossings.

Additional measures recommended were the closure of some level crossings and conversion of AKI crossings (level crossings with automatic warning lights but no barriers) to AHOB (Automatic Half Open Barrier) crossings.

The economic benefits likely to be produced by these measures were assessed by identifying from a Fault Tree Analysis those accident causes on which each measure was likely to have an impact and then establishing the likely number of injuries which would be avoided as a result of applying the measure (and eliminating the cause). These injuries were then given an equivalent value in relation to loss of life, as follows:

- Fatal injuries = 1.0
- Serious injuries = 0.5
- Minor injuries = 0.1

The number of equivalent fatalities thus calculated was then valued at the rate allowable for road traffic accident victims, and the resulting benefits of these measures compared with the costs of implementation.

All of the recommended measures were found to have a Benefit/Cost Ratio greater than one.

3.7 Level crossing experience of Japan

3.7.1 Level crossing evolution

There were railway level crossings in Japan since the introduction of the railway in 1873. The first level crossing warning devices were introduced in Japan in 1924 and modern level crossing barriers began to appear in 1949.

Level crossing accidents suddenly increased after 1950. There were many bus accidents at unprotected level crossings resulting in large numbers of deaths and injuries. After 1960, with the rapid growth in truck populations, collisions between trains and trucks increased in frequency. These accidents were caused by the negligence of truck drivers who ignored flashing light and audible warning indications at level crossings and the ensuing collisions often resulted in the derailment of trains causing large numbers of deaths and injuries among railway staff and passengers.

In 1961, an “Act to Promote Level Crossing Improvement” was passed by the Japanese Parliament with the objective of preventing level crossing accidents and of improving the flow of traffic at the interfaces between road and rail transport. This Act specified that priority must be given to the replacement of level crossings with grade separated crossings (i.e. road overpasses or underpasses). As well as to the improvement of level crossing infrastructure and the adoption of new level crossing safety devices. Still more, the Act introduced the payment of specific level crossing subsidies to small railway companies in order to encourage them to take measures to improve the safety of their level crossings.

The Act had an enforcement life of five years, but this was renewed several times, so that the legislation is still in operation.

In October 1970, a dump truck driver, in ignorance of flashing light and audible warnings, entered a level crossing between Saginoniya and Hanasaki stations on the Isezaki line of the Tohbu Railway Company and collided with an electric passenger train. This collision resulted in the derailment of the train leaving 5 persons dead and 234 injured. The level crossing was equipped with flashing lights and an audible warning mechanism, but was without protective barriers.

Soon after this accident, the Prime Minister’s department convened a Committee of Traffic Safety. The committee decided on many countermeasures to eliminate level crossing accidents. One of these was to define actions to be taken against dump truck drivers who operate their vehicles negligently in order to minimize delays and so fulfil their work quotas. Other countermeasures adopted by the committee were the amalgamation of small dump truck enterprises and the gradual installation of protective barriers at all crossings with a road width greater than 6.5 metres.

In addition to these countermeasures, the Committee of Traffic Safety in February 1971 formulated an “overall countermeasure plan for prevention of level crossing accidents”. This plan was to be implemented with the force of a regulation. It covered the integration and abolition of level crossings and their replacement with grade separated crossings, the strengthening of road traffic regulations as they apply to level crossings, and the improvement of level crossing infrastructure and warning devices. The plan initially had an enforcement life of five years, but was renewed every subsequent five year period and is still in operation up until the present time.

These two instruments, the “ Act to promote level crossing improvement” and the “overall countermeasure plan for prevention of level crossing accidents”, were highly significant initiatives and arguably resulted in a substantially reduced number of level crossing accidents in Japan.

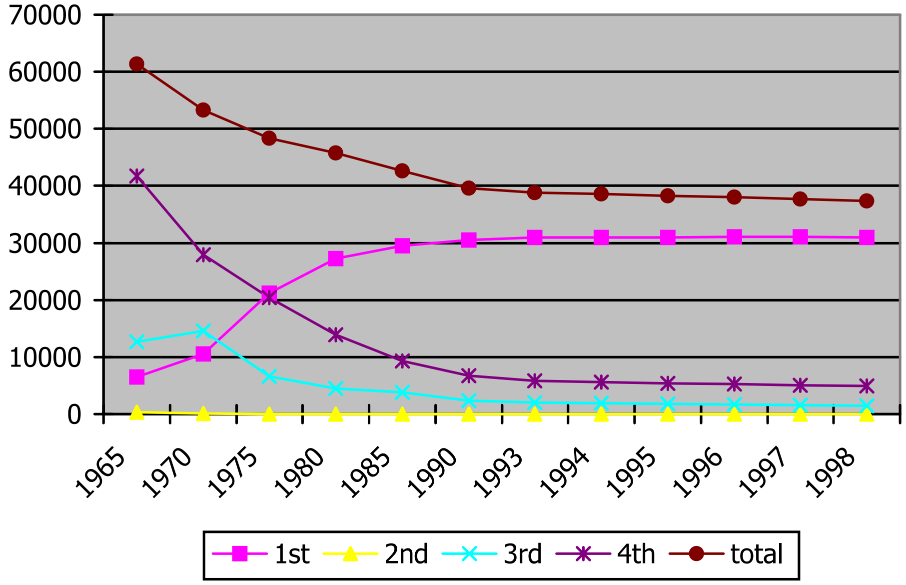
3.7.2 Current level crossing inventory

Level crossings in Japan are subdivided into four classes, depending upon the types of safety devices they incorporate. The first class is a protected level crossing with barriers and flashing road warning lights. The second class is a temporarily manned and protected level crossing, but these crossings are non-existent at the present time. The third class is a level crossing equipped with flashing lights, an audible warning device, and a fixed road sign indicating a level crossing, but without barriers. The fourth class is a level crossing equipped only with a road sign indicating a level crossing (i.e. without barriers, flashing lights and audible warning devices). The number of crossings in each class is shown in Table 3.4.

Table 3.4: Level crossings in Japan, by class

Class	1965	1970	1975	1980	1985	1990	1993	1994	1995	1996	1997	1998
1st	6543	10552	21199	27250	29547	30562	30969	30941	30994	31023	31080	30923
2nd	320	72	37	20	0	0	0	0	0	0	0	0
3rd	12681	14545	6621	4534	3788	2410	2042	1941	1812	1724	1599	1498
4th	41764	27961	20451	13949	9268	6683	5819	5640	5404	5233	5032	4905
Total	61308	53230	48308	45753	42603	39655	38870	38552	38210	37980	37711	37326

Source: Transportation Ministry, Japan.



In Japan, there are currently about 37,000 level crossings of all types, of which barrier protected (class 1) crossings comprise 83 per cent. Almost all of these are now unmanned. Second class level crossings have been eliminated, while third class crossings, equipped with flashing lights and audible warning devices, comprise only 4 per cent of the total. Finally, fourth-class level crossings, which are equipped only with fixed road warning signs, represent 13 per cent of total level crossings in Japan.

As may be observed in Table 3.4 and the associated figure, the total number of level crossings in Japan has been declining steadily over the 33-year period of analysis. This trend is explained largely by the operation of government policy to abolish or integrate level crossings. At the same time, it may be seen that the numbers of first class crossings were increasing, particularly during the decade between 1970 and 1980. This was a consequence of implementation of a policy to convert fourth-class crossings into first class crossing without going through the intermediate stage of conversion to third class crossings. The reason for this policy was that level crossings equipped only with flashing lights and audible warning devices were found to be ineffective at preventing level crossing accidents as compared with barrier protected crossings. This is apparent from the trends in accidents and casualties presented in Table 3.5.

Table 3.5: Level crossing accidents and casualties, by class of crossing

Year	Class	Accidents	Acc/100L.C.	Fatalities	Fatal./100L.C.	Injuries	Inj./100L.C.
1996	1st	381	1.23	91	0.29	130	0.42
	3rd	44	2.55	19	1.10	33	1.91
	4th	101	1.93	32	0.61	56	1.07
	Total	526	1.38	142	0.37	219	0.58
1997	1st	354	1.14	84	0.27	126	0.41
	3rd	43	2.69	13	0.81	20	1.25
	4th	102	2.03	27	0.54	36	0.72
	Total	499	1.32	124	0.33	182	0.48
1998	1st	368	1.19	106	0.34	107	0.35
	3rd	26	1.74	9	0.60	8	0.53
	4th	83	1.69	23	0.47	47	0.98
	Total	477	1.28	138	0.37	162	0.43

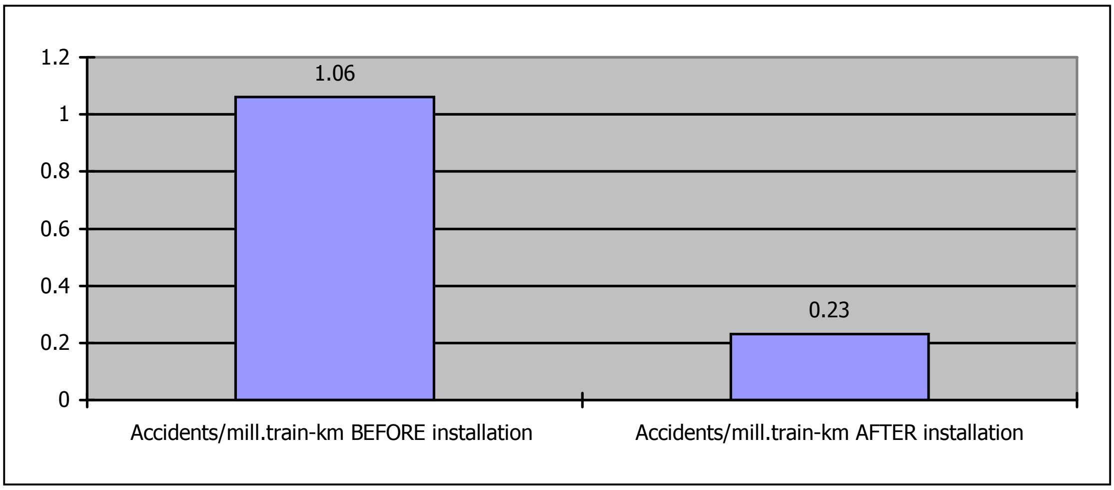
Source: Transportation Ministry, Japan.

From this table it might be concluded that 3rd class level crossings are the most dangerous in Japan, as measured by their accident ratio per hundred crossings.

However, may it also be concluded that 1st class level crossings in Japan are safe? The data in Table 3.5 suggest that 1st class crossings are only slightly safer than 4th class crossings with accident ratios (accidents per hundred crossings) only 30 per cent lower than that of the 4th class crossings.

There is the possibility of making level crossings safer through the installation of *obstruction detectors and warning devices*. Data for JR East Co. both before and after the installation of level crossing obstruction detectors show that this action resulted in a dramatic improvement in the level crossing accident ratio – see Figure 3.16.

Figure 3.16: Effect on first class crossing accident rates of obstruction detector installation



Source: JR East Co.

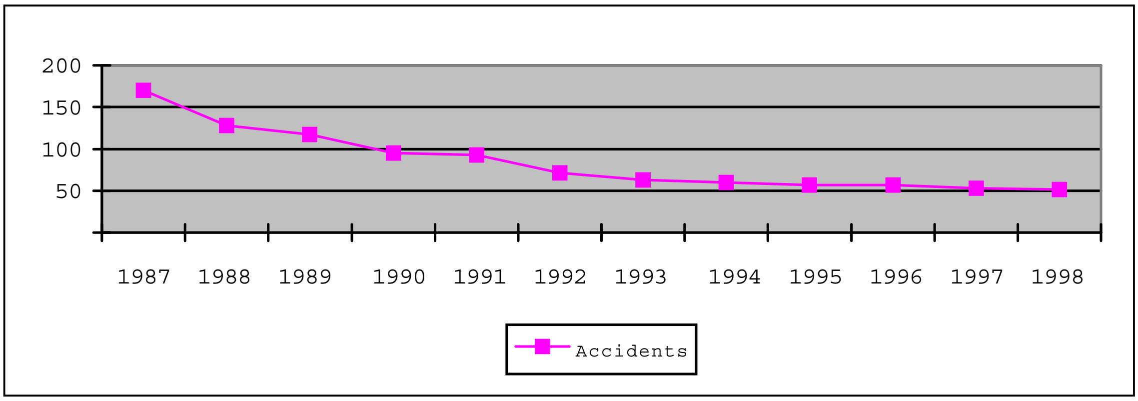
However, it must be noted that this improvement was achieved through the installation of c.o.d.'s (crossing obstruction detectors) at only the most densely trafficked first class crossings, representing less than one third of all first class crossings on the JR East system – see Table 3.6.

Table: 3.6 : Numbers of 1st class level crossings and crossing obstruction detectors (c.o.d.) on JR East system

	1987	1988	1989	1990	1991	1992	1993	1994	1994	1995	1996	1997	1998
No of 1st class L.C.	6,263	6,362	6424	6,583	6,660	6,725	6,746	6,745	6,729	6,724	6,681	6,585	6,567
No of c.o.d.	200	235	423	642	795	1,071	1,522	1,878	1,996	2,135	2,272	2,278	2,301

The steep reducing trend in accident occurrences resulting from c.o.d. installation at first class level crossings on the JR East system is apparent from Figure 3.17.

Figure 3.17: Trend in accidents at 1st class level crossings on the JR East Co.system



Source: JR East Co.

While the data displayed here are for the JR East system only, most of the other railway companies in Japan have also undertaken the installation of c.o.d's in recent years and as a result have achieved similar safety improvements.

3.7.3 Level crossing safety performance in Japan

(i) Accidents

The safety performance of the Japanese railway systems has improved dramatically over the 8 year period between 1990 and 1998, as is shown in Table 3.7 and Figure 3.18. During this period overall accidents reduced by nearly 30 per cent, but level crossing accidents *were down by nearly 40 per cent*. In 1998, level crossing accidents represented about half of all railway accidents in Japan, suggesting a need for a continuing focus on measures to eliminate level crossing accidents.

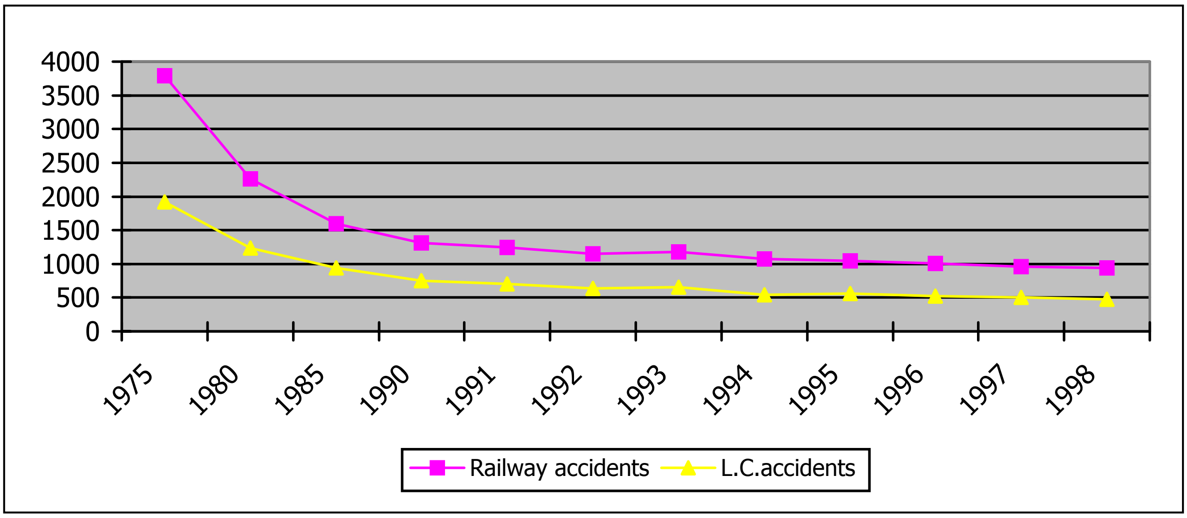
Table 3.7: Railway Accidents and Level Crossing Accidents in Japan

	1975	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
R.A	3794	2263	1594	1308	1241	1154	1180	1073	1046	1003	964	939
L.A	1917	1233	943	754	704	641	653	540	558	526	499	477

R.A : Railway Accidents (other than Level Crossing Accidents) L.A : Level Crossing Accidents

Source: Transportation Ministry, Japan.

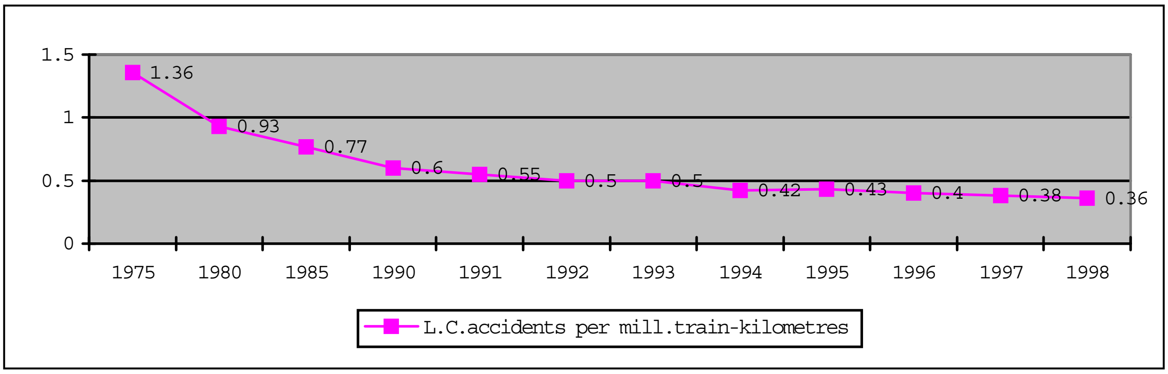
Figure 3.18: Significance of Level Crossing Accidents in the Overall Safety of Railways, Japan



Source: Transportation Ministry, Japan.

When related to rail traffic levels in million train-km, it can be seen that the safety performance of level crossings in Japan is comparable with the best of the safety performers in Europe. For example, in 1998 Japan achieved a safety rate of 0.36 level crossing accidents per million train kilometres as compared with the SNCF (France) which in that year achieved 0.33 level crossing accidents per million train kilometres. The results for Japan are shown in Figure 3.19.

Figure 3.19: Trend in level crossing accident rate (accidents per mill. train-km)



Source: Transportation Ministry, Japan.

An analysis of railway accidents by primary cause for 1998 indicates that level crossing accidents account for by far the greatest share of railway accidents in Japan (Table 3.8). Infringement on the railway is mostly by pedestrians, with 157 deaths in 1998.

Table 3.8: Railway accidents in Japan 1998, by primary cause

Cause	Accidents	Per cent
Level crossing accidents	475	50.7
Infringing on Railway	222	23.6
Obstacles on Railway	101	10.7
Railway Staff	24	2.6
Bad Maintenance of Rolling Stock &Track	15	1.6
Other	102	10.8
Total	941	100.0

Source: Transportation Ministry, Japan.

The primary cause of level crossing accidents in Japan, accounting for 62 per cent of all level crossing accidents, is motor vehicle drivers (for whatever reason) taking their vehicles over level crossings into the paths of oncoming trains. The great majority of these accidents occurred at First Class Level Crossings, as may be seen in Table 3.9.

Table 3.9: Level crossing accidents in Japan 1998, by primary cause

Cause	Classes of L.C.	Accidents	Per cent
Crossing at same time as train	First Class	103	42.6
	Third Class	18	3.8
	Fourth Class	74	15.5
	Total	295	61.8
Road vehicle stopped on level crossing		89	18.7
Road vehicle infringed level crossing clearance limit		63	13.2
Other		30	6.3
Total		477	100.0

Source: Transportation Ministry, Japan.

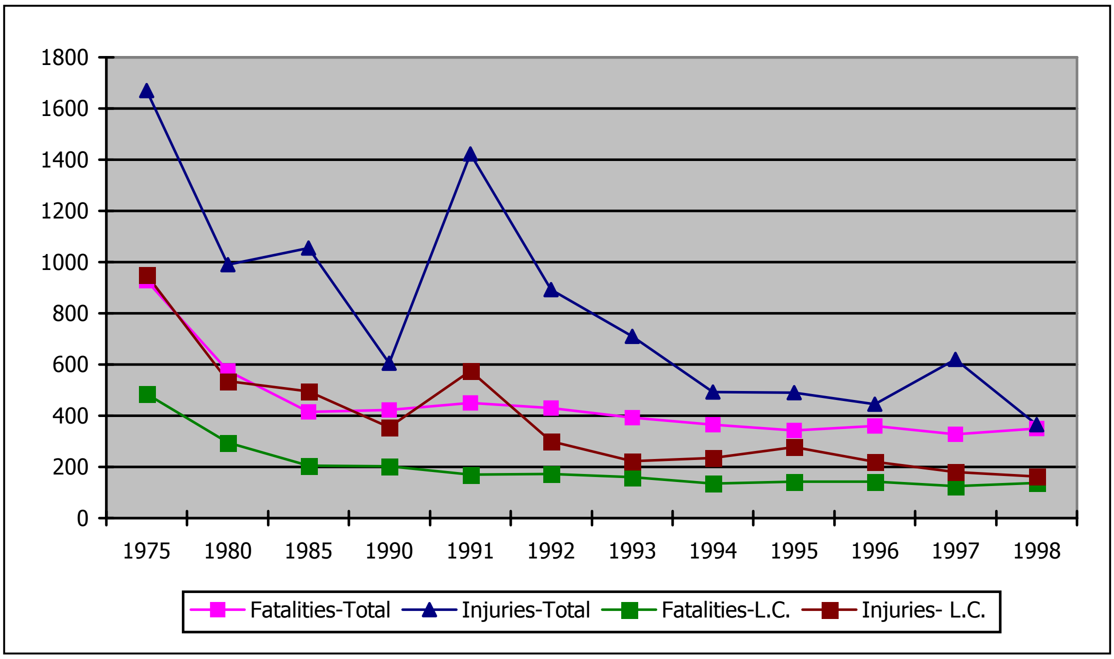
(ii) Fatalities and injuries

The trend in fatalities and injuries in level crossing accidents relative to those in all railway accidents in Japan is given in Table 3.10 and the accompanying diagram.

Table 3.10: Number of fatalities and injuries in level crossing accidents in Japan

Year	1975	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
All railway accidents:												
Fatalities	928	574	416	423	451	430	392	366	343	360	328	349
Injuries	1,669	989	1054	606	1423	893	709	492	489	444	619	365
L.C. accidents:												
Fatalities	486	294	206	202	170	173	159	136	143	142	124	138
Injuries	949	534	495	355	575	300	223	234	277	219	181	162

Source: Transportation Ministry, Japan.



Fatalities and injuries in level crossing accidents comprise a steadily reducing percentage of fatalities and injuries in all types of railway accidents in Japan. In 1998, the share of level crossing fatalities and injuries in the overall numbers for all railway accidents in Japan were 40 per cent and 44 per cent respectively.

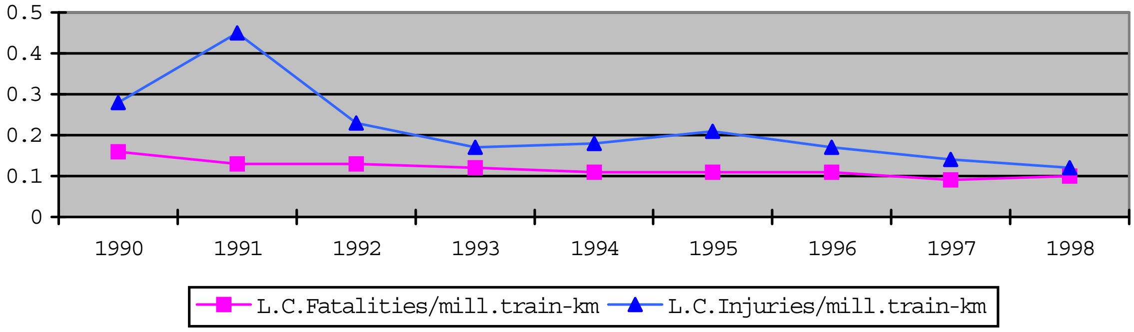
While the number of deaths in level crossing accidents has been declining steadily and consistently in all years except 1992 and 1998, the number of injuries has been falling at a significantly faster rate. The main exception to this trend occurred in June 1991 when a passenger train filled to capacity on the Fukutiyama line collided with a truck which was loading a power shovel car at a first class level crossing located on a curve. The truck could not move from the level crossing because a shovel arm of the power shovel car on the truck was caught in a large overhead line protector. A total of 333 persons sustained injuries in this single accident and, as a consequence, the total number of injuries for that year almost doubled.

The trends in fatalities and injuries in level crossing accidents expressed as rates per million train-kilometres are given in Table 3.11 and the accompanying diagram. These trends indicate a steadily reducing rate of casualty occurrence per million train-kilometres. The level crossing fatality record for Japan compares favourably with those for Western European countries, with a level crossing fatality rate in 1998 equivalent to that of Germany and lower than those of Belgium and the Netherlands. The level crossing injury rate of Japan in the same year was lower than those of all Western European countries, except for France.

Table 3.11: Trend in level crossing fatality and injury rates (per mill. train-km)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Fatalities	0.16	0.13	0.13	0.12	0.11	0.11	0.11	0.09	0.10
Injuries	0.28	0.45	0.23	0.17	0.18	0.21	0.17	0.14	0.12

Source: Transportation Ministry, Japan.



3.7.4 Level crossing evaluation methods in Japan

In Japan, combined road/rail traffic, or traffic moment, indicators are not used as the basis for deciding on the type of level crossing system which should be installed at various locations. Some level crossings in Japan quite satisfactorily carry more than 400 trains and 50,000 road vehicles per day (giving a TM indicator of more 20 million), so that decision rules based on low TM values have become somewhat irrelevant in Japan.

In recent years, most Japanese railways have used as a decision criterion for level crossing improvement, the Closed Road Traffic (CRT) indicator. This indicator is the result of multiplying average level crossing closure time per train by the TM factor. Thus the CRT indicator is the product of the road traffic units, the train traffic units and the level crossing closure time. As such it represents a very crude measure of the economic losses resulting from the blockage of road traffic flows at level crossings, bearing in mind that not all of the road vehicles passing through a crossing in 24 hours are actually detained at the crossing. However, it perhaps represents a better measure than the TM factor for comparing delay potential between countries, since if the TM factors for two countries are of a similar order of magnitude, but the crossing closure time for each is different, then the potential economic losses for each will also be different and a different message should be given to decision makers about upgrading priorities.

The rules applied by the Japanese authorities in theory require the grade separation of a level crossing when its CRT value exceeds 10,000. However, there are many level crossings with CRT values greater than 10,000 and indeed there are some with CRT values greater than 100,000. Consequently, some Japanese Railway Companies have now switched to new indicators.

One of these is JR West Co., which has developed what is known as a *Level Crossing Danger Index*. This composite index (***W***) is calculated by assigning scores to different danger elements, as follows:

W **=** ***Z1*** (accident history) **+** ***Z2*** (difference of width between level crossing and road, number of tracks, distance between fixed warning signs and the first rail) **+** ***Z3*** (train frequency per day) **+** ***Z4*** (road traffic volume in cars per day) + ***Z5*** (rail traffic volume, e.g. number of passengers per day).

A composite index with a high value will indicate a potentially dangerous crossing which would be given priority for grade separation. As an example of the method of scoring, if the crossing has on average three or more accidents per year, Z1 will be scored 11, but if the number of accidents per year is one or less than one, Z1 will be scored 3. Similarly, if there are 10 metres or less between the fixed warning sign and the track, Z2 will be scored 9, but if this distance is greater than 20 metres, Z2 will be scored 3, and so on. The highest scores (and therefore weightings) are assigned to accident history.

3.7.5 Motor vehicle driver education

All Japanese railway companies now emphasize motor vehicle driver education. Despite having equipped a majority of level crossings with many and various types of devices, such as automatic barrier systems, audible and visual warning indications, train approach indicators, obstruction warning devices, crossing obstructing detectors, and crossing failure indicators, still the majority of accidents (368 in 1998) occurred on automatically protected level crossings. Further, 92 per cent of those accidents were caused by car drivers. For this reason, railway companies began to give priority to campaigns designed to enlighten car drivers. These campaigns have the following elements:

(i) Public service advertisements in the mass media (TV, radio, newspapers, etc);

(ii) Poster displays in stations and on board trains, featuring photographs taken at accident scenes;

(iii) Broadcasting messages related to level crossing accident prevention over train Public Announcement systems;

(iv) Participation in Traffic Safety Weeks held all over Japan in spring and autumn (involving distribution of leaflets and other resource materials on accident prevention at level crossings);

(v) Strengthening the resolve of the police to discipline drivers who commit traffic offences in the vicinity of level crossings. (Japanese traffic safety regulations are unambiguous in that they require drivers to stop before proceeding across any level crossing, except when permitted to proceed by the relevant signal indications);

(vi) Participation in and assistance for school and community education programmes covering level crossing safety;

(vii) Presentation of lectures at short courses offered by driving schools and by driver licensing authorities for the renewal of drivers' licenses; and

(viii) Delivery of safety P.R. to the truck transportation industry and motorcar hire companies in each region.

3.7.6 Future level crossing safety policy

The wholesale technical improvement of level crossing protection systems in Japan in recent years has not resulted in a commensurate improvement in safety performance. The realization that such technical improvements were not realizing their goals in terms of improved safety led Japanese railway companies to introduce more radical countermeasures, including :

(i) Progressive abolition of level crossings through their integration with overpasses or underpasses between railway and road. During the past decade, JR East Co. abolished 348 level crossings and in a single year (1996) removed 68 level crossings by this means;

(ii) Installation of automatic level crossing barriers at unprotected level crossings;

(iii) Accelerated installation of crossing obstruction detectors at all level crossings not targeted for grade separation;

(iv) Improvement of level crossing structures and angles of intersection between the track and the road;

(v) Strengthening of regulations against unsafe driving practices and road transport operations, e.g. bans on heavy goods vehicles at small level crossings; and

(vi) Improvement of visibility at level crossings, e.g. through the adoption of large diameter barriers, double barriers, illuminated sign barriers, etc.

One of the major problems facing the Japanese railway companies is that until now level crossing barriers have not been interlocked with the signals facing trains. This was acceptable while road traffic volumes were relatively low and while the traffic priority of trains over road vehicles was recognized. However, now that road traffic has risen to vast proportions throughout the country, the railway companies need better self-defence and this may well require a change in future to a policy of interlocking all level crossings.

CHAPTER 4: RECOMMENDED TECHNIQUES FOR RAILWAY LEVEL CROSSING SAFETY ASSESSMENT IN THE ASIA-PACIFIC REGION

4.1 General

Information provided by the countries participating in this study tends to suggest that, within the region, railway safety, and particularly safety at intersections between roads and railway lines, is perhaps not accorded the priority it deserves. Much of this has to do with the lack of a strong safety ethos within the communities of the region. Personal safety, as such, is not highly valued and hence safety consciousness is not generally something which is stressed in education programmes, either in schools or in the wider community.

Nevertheless, the high rates of economic growth experienced in the region within recent years, coupled with the growth in personal disposable incomes and the related growth in motor vehicle populations have stressed the need for attitudinal change as far as personal safety is concerned. There is little doubt that road accidents and their associated casualties have increased almost in parallel with the explosive growth in the vehicle populations of several countries of the region.

The evidence is that accidents at the intersections between road and rail contribute only a very small proportion of total road accidents in most countries of the region. However, it is a growing proportion as increasing road construction and road vehicle populations create greater opportunity for level crossing accidents to happen. Additionally, level crossing accidents tend to have casualties which are disproportionate with their number and frequency within the overall road safety picture. For example, where accidents involving collisions between two or more motor vehicles will usually generate limited casualties, collisions between road vehicles and trains at level crossings can, and often do, generate multiple casualties of both rail and road users, particularly when such collisions result in train derailments. Therefore, too much is at stake to allow level crossing accidents to grow unchecked.

Of paramount importance in any programme to improve level crossing safety is the need to have access to continuously updated information – to detailed level crossing inventories, to details of accident circumstances, causes and casualties as well as to details of the growth in the road and rail traffic passing level crossings. Such a programme will depend upon regular hazard assessments being made of individual level crossing locations, in order to allow calculation of accident risks and probabilities and to be able to establish valid priorities for safety enhancement measures at level crossings. Essentially this will require the establishment of a comprehensive Safety Management System, of which a Safety Management Information System will be a vital component. Thus the characteristics of a Safety Management Information System are addressed in this chapter, as is the application of Quantified Risk Analysis (QRA) and Cost-Benefit Analysis (CBA) techniques to level crossing safety management.

Finally, technical descriptions of the wide range of level crossing protection systems and technologies available, as well as guidelines for making technical assessments and selections from among this range are also outlined in this chapter.

4.2 Requirements of a Safety Management Information System

Missions undertaken by ESCAP in connection with this study have demonstrated that there is a critical need for railway managements to have ready access to information on the circumstances, causes and consequences of accidents, so that they may take effective action to eliminate (or more realistically) to minimize these accidents in future. While several railway systems of the region appear to have no shortage of such information, it is generally not collected and assembled systematically and it is mostly dispersed among the operating sub-divisions of the railway organizations, i.e. it is not available in a useable format to the senior railway managers who are responsible for operational safety.

The requirements of a comprehensive Safety Management Information System are outlined in this section. Although Level Crossing Safety cannot be distinguished from other aspects of Railway Safety in terms of the need for an effective information system, the requirements of such a system are illustrated with particular reference to Level Crossing Safety.

There are three crucial elements in any effective safety information system:

- A comprehensive and up-to-date *inventory of potential hazards,* or railway assets likely to pose a safety risk (for level crossings this would include a listing of the characteristics of all level crossings);

- A *detailed report on all accidents*, listing their location, circumstances, primary causes, secondary causes (or contributory factors), casualties and other consequences, as well as the post-accident management action taken; and

- A *safety performance report* issued at regular intervals and measuring the numbers of accidents, fatalities and injuries relative to a valid measure of railway traffic, such as the number of train-kilometres run on the rail system.

(a) Inventory of potential hazards

A complete listing of the location, physical characteristics, environment, traffic level and accident history of every level crossing on the railway system is necessary to permit analyses at regular intervals of the safety risks posed by the presence of potential hazards. To the extent possible, *this listing should also cover unofficial level crossings in frequent use.*

Table 4.1 provides an example of the elements of a comprehensive inventory.

Table 4.1: Level Crossing Inventory for:
Rail System : (Name of System)
Date last updated:

Item No.	**Item**	**Description**
1.	Level Crossing Identification Number.	
2.	Location (geographical and km from system datum point).	
3.	Distance (m or km) from and name of nearest station.	
4.	Number of tracks crossing the road.	
5.	Number and width of road lanes crossing the tracks.	
6.	Category of road crossing the tracks (e.g. National/provincial highway Class I, II, III, local road, etc).	
7.	Type of surface of road crossing the tracks (e.g. Bitumen, asphaltic concrete, laterite, etc).	
8.	Condition of surface of road crossing the tracks – good, fair, poor.	
9.	Does the track approach the crossing on a curve? If so, indicate the radius of the curve.	
10.	Does the road approach the crossing on a curve? If so, indicate the radius of the curve.	
11.	Angle of intersection between tracks and road.	
12.	Nature of obstructions (if any) to road users' view of tracks in each direction and on both sides of the crossing.	

Table 4.1: Level Crossing Inventory (continued)

Item No.	Item	Description
13.	Nature of obstructions (if any) to road users' view of level crossing signage and signals on both sides of the crossing.	
14.	Is the crossing manned or unmanned?	
15.	Crossing protection – is the crossing protected or unprotected by barriers?	
16.	If protected, please state type of protection from list below. Against the relevant type please also indicate whether the barriers are manually operated by mechanical or electrical mechanisms, or are automatically operated by the passage of trains. (a) Single full width lifting barriers both sides of crossing; (b) Single half width lifting barriers both sides of crossing; (c) Dual half width lifting barriers both sides of crossing; (d) Single full width swinging gates both sides of crossing; (e) Dual half width swinging gates both sides of the crossing; (f) Trolley gates both sides of crossing; and (g) Other (please specify).	
17.	If item 14 (b) is indicated, are the road lanes approaching the crossing separated by median strips or other forms of physical barriers dividing contra-flow road traffic?	
18.	Warning indications to road users. Is the crossing equipped with: (a) Fixed warning boards or signs; (b) Fixed red light indicators; (c) Flashing red light indicators; and (d) Warning light indicators on barriers. (If yes to a, b, or c, please also indicate distance from signs or lights to nearest rail)	

Table 4.1: Level Crossing Inventory (continued)

Item No.	Item	Description
19.	Warning indications to train drivers. Please indicate from the list below the type of warning indication available to train drivers at this crossing. (For fixed signals, please also indicate distance (metres) from crossing and the type of warning indication given, e.g. steady white or red lights, etc): (a) Track circuited wayside signal; (b) Wayside signal operated by optic sensor (s); (c) Signal indication in driver's cab; (d) Wayside signal relay interlocked with other cautionary signals on line; (e) Manually operated wayside signal; (f) Other (please specify); and (g) None.	
20.	Maximum daily traffic (road and rail) using this crossing. (a) Rail - maximum number of passenger trains per day - maximum number of freight trains per day - typical number of passengers per passenger train (b) Road - maximum number of road vehicles per day (if possible broken down by major type (e.g. small truck, large truck, small bus, large bus, car, motorcycle, etc).	
21.	Accident history. Please provide details of date, circumstances, casualty and property damage details of accidents at this level crossing.	
22.	Details and dates of any modifications to the equipment of this crossing. Please indicate authority under which these modifications were made.	
23.	Hazard risk rating. Please assign score of between 1 and 10, with 1 indicating high (unacceptable) risk and 10 negligible risk. Wherever possible, these ratings should be backed up with Fault Tree or probability analysis of recent accidents.	

It is essential that level crossing inventory information should be updated at frequent intervals. While it is not practical to specify rigidly the length of these intervals, updating should occur as soon as there is a change in the status of each crossing. For example, if there is an accident at a crossing, if there is a significant change in the levels of traffic using a crossing, or if the physical conditions or equipment at a crossing have been modified in any significant way, the inventory record for that crossing should be amended without delay. In addition, there should be a complete review of all inventory data at least once a year.

Continuous updating and dissemination of level crossing inventory records is only possible if the records are centrally maintained on computer files. A stock standard PC oriented database software package, such as Microsoft Access, is quite adequate for this purpose. Use of a database software package for maintenance of level crossing inventory records will also permit summary reports to be produced at regular intervals, either at a system-wide or a sub-divisional level. For example, a frequency distribution, by type of equipment installed or by combined rail and road traffic volume, could be generated simply and easily by such a database package.

The format of inventory records could be as shown in Table 4.1, but this table was presented only as an example of the desirable elements of a level crossing inventory and can no doubt be improved upon to suit the specific requirements of individual railway systems.

(b) Detailed accident reports

Railway managements with responsibility for safety must have access to reports containing sufficient information on the circumstances, causes, contributory factors and consequences of level crossing accidents in order to be able to take effective action to minimize such accident occurrences in future. In some countries of the region, though certainly not in a majority of countries, it is established procedure for the police, or railway inspection staff, or both, to prepare a detailed accident report immediately after each significant accident occurrence. Such reports may or may not contain sufficient information to assist the development of effective countermeasures and policy in relation to level crossing safety. It is vital therefore that railway safety managers have routine access to accident reports which will contribute to the effectiveness of their management role and hence to a reduction in railway accidents and their associated casualties.

A key requirement of accident reports is that they should satisfy two needs – they must be capable of assisting prompt and effective management action and they must provide an adequate basis for practical analysis of accident occurrences and causation factors. Recently *Railned*, the railway infrastructure management authority of the Netherlands, commissioned a study of accident causation at Automatic Half Barrier Crossings in the Netherlands.[19] The availability of detailed accident reports covering 6,152 level crossing accidents at 1,000 locations over a period of 12 years (1985-1997) enabled the RailNed researchers to draw valid conclusions about the relationship between accident causation and road user characteristics and behaviour patterns.

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[19] *Improving Safety at Railway Crossings, Final Report on AHOB Crossings*, Railway Safety Department, Railned, 1999.

Table 4.2 provides an example of a possible format for a Detailed Level Crossing Accident Report. As is the case with Level Crossing Inventory data, these reports can be generated effectively by database software packages such as Microsoft Access, which will also facilitate the assembly of cross-sectional and time series data for all or a subset of level crossings within the railway system.

Table 4.2: Detailed level crossing accident report

Item No.	Accident details
1.	Date and time of occurrence.
2.	Location *(geographical and km from system datum point*).
3.	Physical conditions at time of accident (e.g. *daylight/after dark , clear skies or overcast, dry or wet, visibility conditions*).
4.	Circumstances. Describe event sequence, such as: Road vehicle (*specify type and licence number*) driven by *(name and address of driver*) and carrying one other occupant entered level crossing after warning lights and bells had activated and collided with train number xxx (provide full description of train, e.g. 3.45 pm *down passenger Station A to Station B*), comprising *(number and type of locomotives and number and type of passenger cars*). Train driver applied full braking on sighting the vehicle when about y metres from the crossing, then exited the cab. Upon impact, the locomotive and the first three carriages were derailed and the wreckage of the road vehicle was dragged along the track for y metres before coming to rest on the down side of the crossing.
5.	Speeds. Estimated train speed prior to impact: x km/hour; Regulation speed through crossing: x km/hour; Estimated speed of motor vehicle prior to impact: x km/hour. Any evidence that the road vehicle driver attempted to slow down or apply brakes before impact?
6.	Operation of barriers, audible and visual warning equipment. (if relevant) If this equipment is installed, was it functioning normally at time of accident?
7.	Train driver profile. Sex: ; Age: ; Number of years in present position: ; Record: e.g. details of training and attainment of required proficiency standards, previous rail accidents, details of cautions or fines; Evidence of impairment by alcohol or drugs at time of accident? General state of health? .
8.	Road vehicle driver profile. Sex: ; Age: ; Local or non-local resident?: ; Previous convictions for traffic offences? Evidence of impairment by alcohol or drugs at time of accident? General state of health? .
9.	Casualties. Fatalities at scene: 2 occupants of road vehicle (both male, aged x and y years); 3 train passengers. Subsequent* fatalities: 2 train passengers. Serious injuries (requiring hospitalisation for an extended period): 10 train passengers and one train driver. Minor injuries (requiring paramedic or outpatient treatment): 15 train passengers. Likely compensation payments to injured train passengers and to relatives of train passengers killed: (*amount specified in local currency).* Likely compensation payment to injured railway personnel: *(amount specified in local currency).* * Note a “fatality” may be recorded as such if a person who sustains serious injuries in the accident dies within one year of the accident occurrence.
10.	Railway Equipment and Property Damage. Cost of rectification works (lifting and repair of locomotive(s) and carriages; track repairs; and repairs to level crossing and signalling equipment): *amount specified in local currency.* Cost of any related damage to non-railway property: *amount specified in local currency.*
11.	Direct and consequential delays to operations. Indicate: (a) total elapsed time between suspension of service on the line and resumption of service following rectification works; (b) total compounding delay to all schedules resulting from service interruption due to this accident; and (c) estimation of related delay cost (*amount specified in local currency).*
12.	Established primary cause(s) of accident. Indicate only those factors established by a railway board of inquiry or other official investigating authority as *primary* causes of this accident. e.g. road vehicle driver ignored visual and audible warning indications and entered the crossing into the path of an oncoming train.
13.	Established secondary cause(s) of accident. Indicate only those factors established by a railway board of inquiry or other official investigating authority to have contributed to the accident occurrence. e.g. the roadway crossing the tracks was wet at the time of the accident, creating slippery driving conditions and in combination with the poor state of the road vehicle’s tyres causing wheel-slide after application of the vehicle’s brakes.
14.	Corrective action taken or to be taken following this accident. Provide details of any action taken or considered necessary in order to minimize the probability of accidents occurring at this crossing in future.

(b) Safety Performance Report

A measure of the effectiveness of level crossing safety enhancement actions in reducing the frequency and associated casualties of level crossing accidents may be provided by time series analysis of accident and casualty data. This may be done in two, or a combination of two, ways: either accident and casualty numbers are assessed over a number of years and a statistical trend established; or these numbers are related to some relevant measure of risk exposure (such as train-km) and a statistical trend of the dividend of the two series is established, or both. Examples of these two approaches are provided in *Chapters 2 and 3* of this report, wherein the trend in level crossing accidents and number of casualties is assessed for selected railway systems of this and other regions. Safety performance trends may be presented in *Safety Performance Reports* to be issued at regular and frequent intervals.

A safety performance report may be generated for an entire railway system, or for any sub-division of this system. By way of comparison, it is possible to generate reports focusing on the relative level crossing safety performance of any given number of railway systems. However, if comparative reports of the latter type are to be generated, care should be taken that: (a) there is consistency in the accident and casualty measures used (e.g. are only “serious”, not minor, injuries reported in each case, and what does the term “accident” comprehend for each of the railway systems being compared?); and (b) the comparative analysis clearly identifies both the similarities and differences of each railway system for which safety data are being compared.

Comparative analyses of level crossing safety performance across different railway systems or across different sub-divisions within the same system are likely to be somewhat meaningless if they are based only on the trend in the absolute numbers of accidents, fatalities and injuries. Even if they are related to system route length, or to the number of level crossings on a system, they will not provide a valid basis for comparison since different railway systems or subdivisions vary widely in terms of their traffic density and composition.

Railway traffic density in fact provides a useful measure of the exposure of the railway to the risk of collision with road vehicles at level crossings, because, for a given number of crossings on a system, this risk will increase in direct proportion both to the level of usage of these crossings by rail traffic and to the level of usage by road traffic. Since it is usually not possible to obtain a satisfactory measurement of the latter, the level of railway traffic, as represented by the number of *train-kilometres* provides an indicator of traffic growth which can affect the probability of accidents at level crossings.

It is common practice to compare level crossing accident occurrences and related fatality and injury numbers with train kilometres by expressing them in terms of a *rate per million train kilometres*. However, it must be remembered that train-kilometres is not a homogeneous measure of risk exposure, since passenger trains will generally expose many more persons to level crossing accident risk than freight trains. Nevertheless train-km is a basic operating statistic for most railways and is generally available separately for passenger and freight trains. A further refinement of safety performance analysis might therefore be to calculate accident and casualty rates on the basis of both measures.

4.3 Relevance and application of Quantified Risk Analysis to level crossing safety management

Capital shortages typically threaten the capacity of most railway systems of the region to provide more than just a very basic level of protection against road/rail collisions at level crossings. Given the stringency of budget restrictions, it becomes essential to establish priorities for level crossing improvement activity. Level crossings are certainly not homogeneous in terms of accident risk probabilities. Some have a much greater propensity for accidents than others.

Quantified Risk Analysis (QRA) provides a suitable basis for establishing level crossing improvement priorities. This it does by allowing a ranking of level crossings in terms of their accident risk probability. Those crossings with high accident probabilities would normally qualify for funding allocations (subject to satisfactory cost/benefit results), while those with low accident probabilities would be assigned a low priority for improvement funding. QRA results should be linked to the Level Crossing Inventory Recording System which provides for the reporting of hazard probabilities against each level crossing (see Table 4.1, item 23).

Factors influencing the probability of accident occurrence at level crossings include:

- Rail traffic density (measured in terms of the maximum number of trains passing the crossing within a 24 hour period);
- Road traffic density (measured in terms of the maximum number of motor vehicles of all types passing the crossing within a 24 hour period);
- Presence of physical obstructions restricting the visibility of the track, warning signs or signals to road users;
- An absence of full width barrier protection at level crossings;
- An absence of flashing lights and audible warning devices at level crossings;
- Poor road surface condition at level crossings (leading to the grounding of low slung road vehicles); and
- Poor alignment and elevation of the road crossing the track (the road may cross the track at an oblique angle or may approach the crossing on a steeply rising grade).

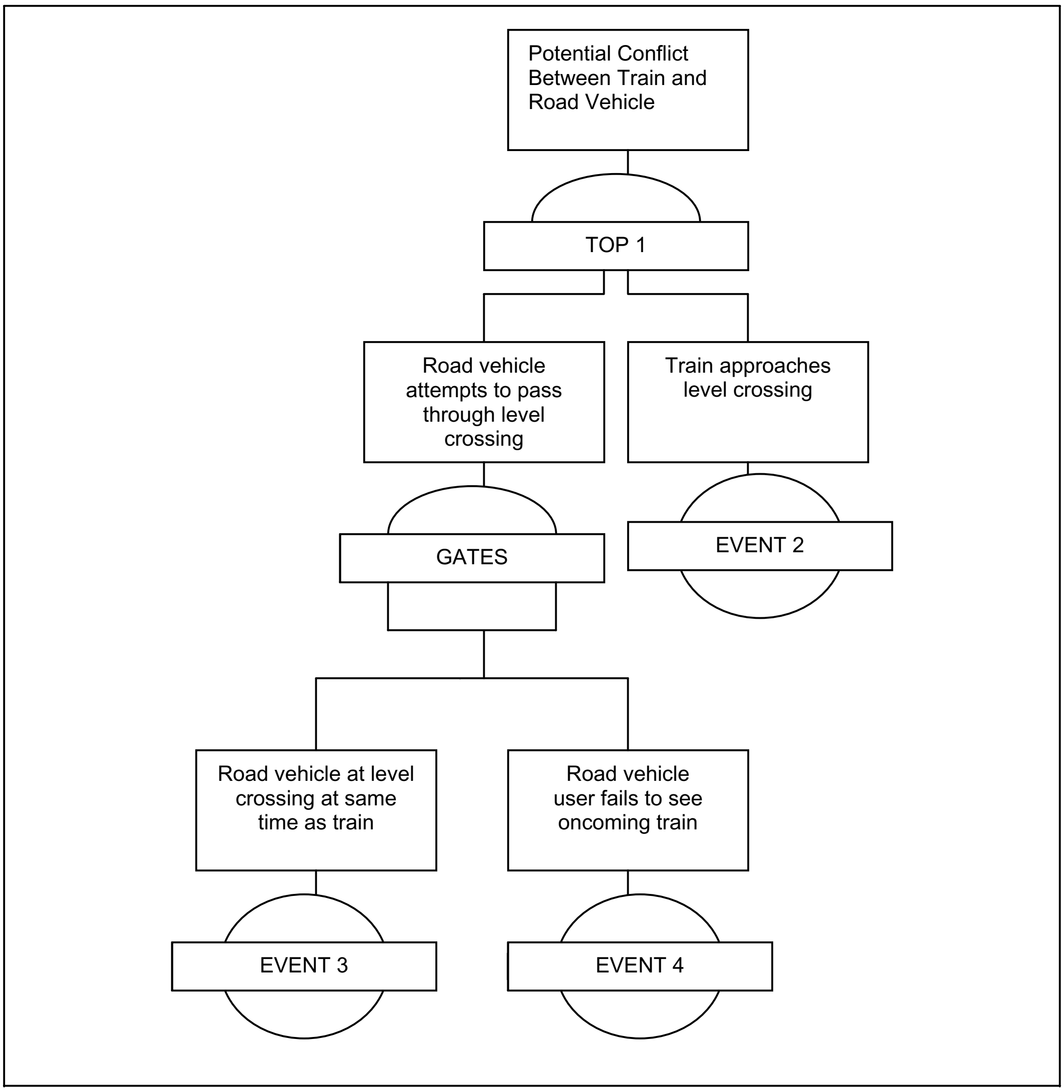
It is strongly recommended that accident probabilities should be calculated for all official level crossings on the railway system (and possibly for the more critical of the unofficial crossings) and that these calculations should be updated as soon as there are changes to any of the factors listed above.

In addition to accident probabilities, it would also be highly desirable to calculate the probability of multiple fatalities and injuries resulting from accidents at individual crossings. The probability of such outcomes is influenced by all of the above factors and also by the level of usage of crossings by crowded road and rail passenger vehicles. The latter may be difficult to calculate in the absence of adequate information, but may be substituted by Fault Tree Analysis (FTA) and Event Tree Analysis (ETA). The principles governing the use of these two concepts and the benefits they offer are discussed in the following sections.

(a) Fault Tree Analysis

Fault Tree Analysis examines the logical relationship between the circumstances, equipment failures and human errors which must exist for the main (or top) event to occur. In the example shown in Figure 4.1, the top event is a collision between a train and a road vehicle at a level crossing. The circumstances are the simultaneous arrival of the train and the road vehicle at the level crossing. The human error is the failure of the motorist to see the train and to continue onto the crossing. No equipment failure is indicated in this example, but if such were to occur it would constitute a fifth event. The purpose of FTA is to assist the calculation of frequency of an accident of a given level of severity when detailed data do not exist.

Figure 4.1: Application of Fault Tree Analysis Techniques



For example, if only the daily number of trains and the daily number of road vehicles passing through a crossing is known, the probable frequency of conflicts between the two *at that location* may be calculated. For a crossing which carries 6,000 road vehicles and 70 trains per day, the probable frequency of conflict between road and rail movements at that crossing is 6,000/420,000 (70 x 6000), or 1.4 in 100 – a very high frequency.

The presence of full width protective barriers and integrated warning signals at that crossing will, all other factors being equal, reduce the probable frequency of conflict to zero, but of course other factors are rarely, if ever, equal. Equipment failure or human error in particular will intervene in this case to increase the probable frequency of conflict to some point between zero and 1.4 in 100. In Figure 4.1, human error is represented by Event 4, "Road vehicle user fails to see on-coming train".

If data from accident reports can be used to indicate the frequency of such occurrences at a particular crossing the probability of occurrence can be calculated as the ratio between the number of such occurrences in a year and the annual traffic moment (daily number of trains x daily number of road vehicles x 365 days) for that particular crossing. For example, if from a sample of accident reports for a particular crossing carrying 70 trains and 6,000 motor vehicles per day, it is established that on average 10 collisions per year are caused by motorists failing to observe warning signals then the probability of such accidents occurring at the specified crossing (**Pr_c**) is given by the following equation:

$$Pr_c = 10/(420{,}000 \times 365) = 1 \text{ in } 15.3 \text{ million}$$

In this case the very low probability or risk of collision due to failure of motorists to observe signals results from the low frequency of such accidents in relation to the volume of road and rail traffic using the crossing. Similar calculations may be done in order to estimate the probability of collisions at the specified crossing being caused by other factors, such as the failure of signalling or barrier equipment, human error on the part of railway employees etc.

Subject to data availability, the probability of collisions involving particular types of road vehicles, such as buses, may also be calculated for particular crossings, as may the probability of fatalities and injuries resulting from such collisions. The difficulty is that most often the safety databases maintained by the railways of the region are incapable of providing this level of detail.

FTA helps to identify the chain of events leading up to the top event (i.e. a collision between a train and a road vehicle) and for which indicative data must be obtained in order to calculate the frequency or probability of accident occurrence. If the necessary data are not available then *estimates* of the frequency of the identified events will have to be substituted in order to produce the final probability calculation.

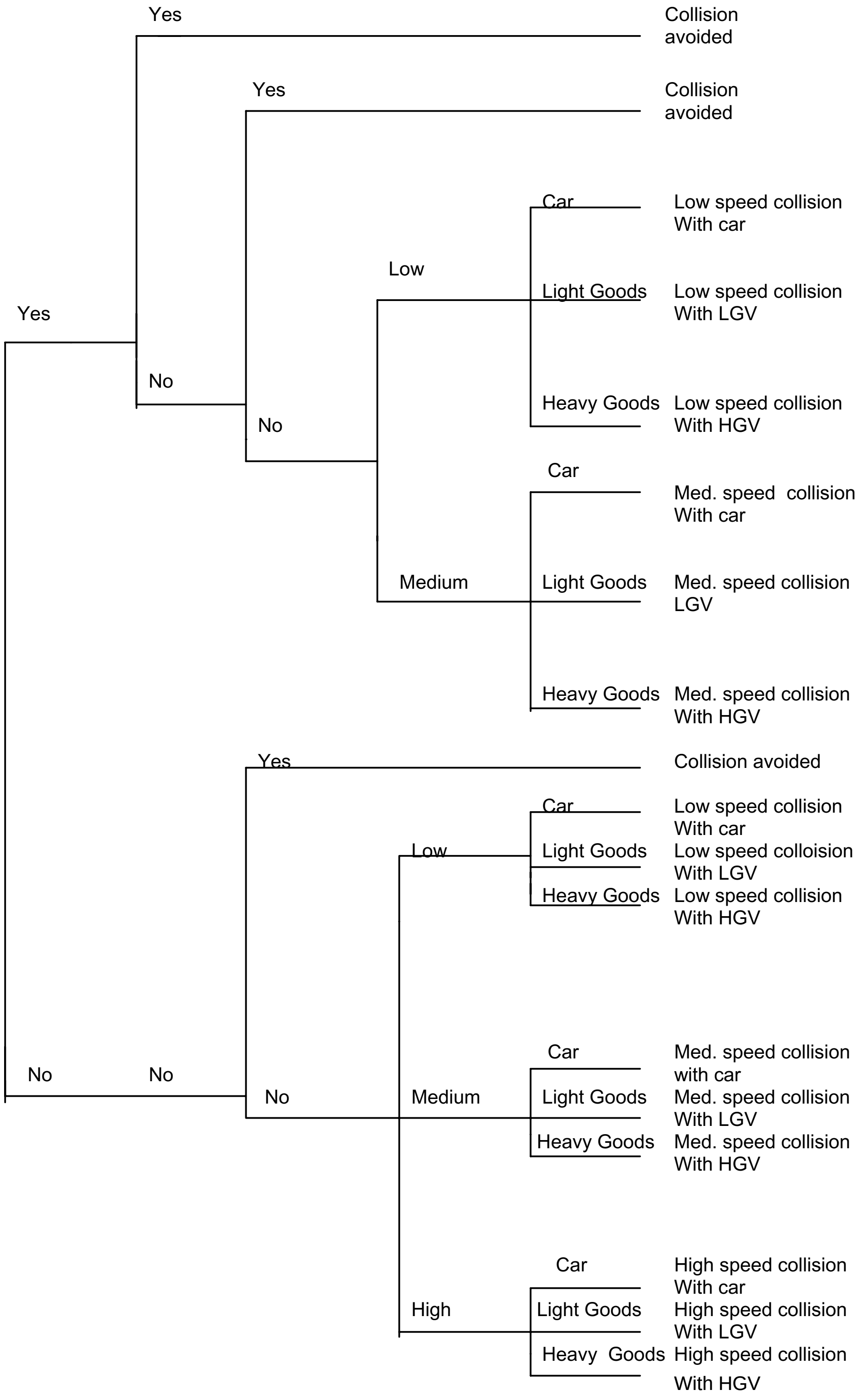
(b) Event Tree Analysis

Event Tree Analysis (ETA) is used where there is a more complex relationship between the consequences of an event and its circumstances and/or location. In particular it shows how an initiating event may lead to a number of different outcomes depending on such factors as the geographic location of the event, successful implementation of the various human emergency response activities, the types of road vehicles involved (in the case of level crossing accidents) and the performance of the relevant protective safety systems. Figure 4.2 illustrates

Figure 4.2 : Application of Event Tree Analysis Techniques

Conflict between train and road vehicle	Train driver applies emergency braking	Train driver stops train before crossing	Road vehicle clears crossing before collision	Train speed on impact with road Potential vehicle	Size of road vehicle (1)	Consequences	Frequency

(1) LGV, Light Goods Vehicle; HGV, Heavy Goods Vehicle



the construction of an event tree. This example was excerpted from *"Managing Safety Through Identifying, Assessing, Mitigating and Monitoring Risk"*, a paper presented by Andrew J Smith, Managing Director, International Risk Management Services at the "Safety on European Railways" Conference held in London on 4 December 1997.

As can be observed in Figure 4.2 an event tree is constructed by setting out each identified factor in chronological order and then joining up all possible combinations of factors to produce a number of possible end events. Probabilities may then be assigned to each branch of the event tree in order to calculate the final frequency of each outcome. The frequency of occurrence of each hazardous outcome is then the product of the frequency of occurrence of the initiating event and the probability that the event develops to that particular outcome. In the example provided in Figure 4.2 the final outcome is a collision between a train and a road vehicle at a level crossing and its severity is determined by: avoiding action taken by the train driver and/or by the motorist; the speed of the train on impact with the road vehicle; and the type and size of the road vehicle. The probability that each type of intermediate factor or event will apply may be calculated, but calculation of these probabilities and hence of the probability of the final outcome will depend on the availability of data from actual experience *at the particular level crossing being analysed*.

ETA provides guidance in more complex cases as to the type and scope of information which is necessary as a basis for calculating accident probabilities at specified level crossings. These probabilities will in turn indicate priorities for level crossing safety enhancement measures.

4.4 Cost-Benefit Evaluation of level crossing safety management measures

Shortages of capital funds for railway development in the region have made it essential that all capital expenditure proposals are prioritised using acceptable methods of evaluation. This requirement applies as much to safety enhancement as it does to other types of expenditure proposals. However, in the case of safety enhancement, the evaluation process has two main elements:

(i) First, quantified risk analysis (QRA) techniques are applied in order to indicate which of a railway system safety enhancement measures should be accorded high priority for implementation, purely on the basis *of their risk-minimizing potential*. This procedure was described in detail in the preceding section; and

(ii) Second, those projects which pass the QRA screening process are then subjected to Cost-Benefit Analysis (CBA) in order to establish whether they will produce an acceptable rate of return for the money invested in them.

Level crossing safety enhancement projects typically have two types of benefits. The first is clearly that of minimizing, if not eliminating, collisions between trains and motor vehicles at level crossings and in the process minimizing, if not eliminating, the deaths, injuries and human suffering associated with these collisions. The second is a secondary benefit – that of minimizing the delays to both rail and road traffic at level crossings as a result of imposed speed restrictions on rail operations and of excessive barrier closure times against motor traffic.

Conceivably, there are three situations in which cost-benefit appraisal of level crossing safety enhancement projects will be required. These are: cases in which a value must be assigned to the benefits of alternative level crossing protection systems in terms of saving human life and minimizing human injuries; cases in which the delay reduction benefits offered by alternative level crossing protection systems must be assessed; and cases in which a comparative cost assessment of alternative methods of safety enforcement at level crossings is to be carried out. Each of these is considered in the following sub-sections.

4.4.1 Valuing human life

The concept of having to assign a value to human life in order to justify expenditures on life-saving projects may be distasteful to some railway safety managers. Yet, this is precisely what is being demanded of them, as safety projects increasingly fall within the ambit of the capital expenditure justification processes of the region's railways.

The difficulty with the application of this approach in Asia is that the values notionally placed on human life have been low in relation to the costs of life-saving measures. Historically, the failure of some railway systems in the region to commit expenditures to the elimination of unofficial level crossings and to the adequate protection of official level crossings has provided implicit evidence of the generally low valuation of human life throughout the region.

As has been demonstrated in the preceding section, it is possible through the application of Quantified Risk Analysis to historical data to establish the probabilities of fatalities and serious injuries in level crossing accidents, with and without improvement of level crossing protection. These probabilities will provide an indication of the life-saving potential of various safety enhancement measures, such as the installation of full width protective barriers at crossings which formerly had no protection.

For example, if it is established that there is a probability that six fatalities per year will occur at a given crossing, currently without any form of protection, but that this probability will reduce to only one fatality per year after installation of full width protective barriers, then it might be concluded that this initiative has the potential to save 5 lives per year[20]. In the case of several railway systems of the region, the life-saving potential of protective barrier installation at level crossings is very high. Notable examples are provided by countries such as Viet Nam and Thailand, which experience a high frequency of level crossing fatalities, mostly at unofficial level crossings.

If it is possible through risk assessment to establish the life-saving potential of a barrier installation project, then it is reasonable to attach some value to this benefit against which may be offset the cost of undertaking the safety improvement. If the valued life-saving benefit exceeds the cost of the safety initiative, then the latter will normally be implemented.

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[20] The probability of train/road vehicle collisions, and hence of fatalities, at a given level crossing will be close to zero, but normally some allowance will be made for the probability of malfunction due to equipment failure or human error.

In Chapter 3 the approach adopted in the United Kingdom for fatality valuation was described at length. The two main approaches used are the "gross output" and "willingness-to-pay" approaches. Of these two approaches only the gross output approach would seem to be capable of practical application in Asia. This is because the wide spread of incomes in Asian countries would tend to make it difficult to obtain a representative sample indication of the community's valuation of human life, as would be required in the "willingness-to-pay" case.

Application of the gross output approach to valuing fatality prevention in Cost-Benefit Analysis involves the following process steps:

(i) Obtain the current gross domestic product per capita estimate for the country;

(ii) Estimate the remaining working life of a "typical" accident victim;

(iii) Calculate the present annual value of the foregone future income stream of a "typical" accident victim – this is the product of (i) and (ii), discounted back to the present;

(iv) Calculate the present annual value of the proposed investment in the project and its associated operating costs[21]; and

(v) Calculate the ratio between (iii) and (iv) – effectively the Benefit/Cost ratio for the project.

Data obtained for India illustrate the application of the value of fatality prevention approach to a Cost-Benefit Analysis of a Level Crossing Barrier Installation, as shown in Table 4.3.

Table 4.3: Example of Cost-Benefit Analysis of level crossing barrier installation based on value of fatality prevention

Item	Description	Rs. mill.	US$
	Cost of manual barrier installation		
(i)	Capital cost - lifting barrier with flashing light and block signal	1.6984	38,600
(ii)	Capital cost net of taxes and government charges		34,740
(iii)	Present Annual Value of (ii) [15 year life; 12% discount rate]		5,101
(iv)	Annual staffing cost	0.25	5,682
(v)	Annual staffing cost net of government taxes and charges		5,511
(vi)	Annual maintenance cost net of government taxes and charges		551
(vii)	*Total, annual economic cost (items (iii) + (v) + (vi)*		*11,163*
	Benefit of manual barrier installation		
(viii)	Potential fatalities avoided (number per year)		6
(ix)	Per capita GDP (US$)		476
(x)	Average remaining working life per victim (years)		24
(xi)	Foregone income: (ix) x (x) x (xi) in US$		68,544
(xii)	Present Annual Value of foregone income (xi) [24 years; 12% discount]		8,805
(xiii)	*Annual benefit*		*8,805*
(xiv)	***Benefit/Cost Ratio***		***0.79***

Sources: (1) Indian Railways - cost of barrier installation and maintenance.
(2) Economist Intelligence Unit, Country Report for India 1999-2000 – GDP per capita data for India.

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[21] The Present Annual Value (PAV) of an investment is computed as an annuity and includes both an allowance for depreciation and a return on the investment. Thus the PAV is the annual amount which must be received in order to cover both the replacement of the asset and a return on investment in the asset.

In this example, it is assumed that one prevented fatality can be valued in terms of the income which would have been foregone if that person had died in a level crossing accident at an unprotected level crossing. It is further assumed that installation of manual barriers at that crossing has the potential to save six lives per year.

It should be noted that in this case the Cost-Benefit Analysis represents an *economic*, rather than a financial, evaluation in that the cost of barrier installation is the resource cost borne by the community (i.e. it is net of government taxes and charges) and the benefit is the loss of income to the community which would be prevented as a consequence of the barrier installation project. The latter is most appropriately represented by the per capita Gross Domestic Product for the country in which the assessment is being made. A financial evaluation would be inappropriate in this case as the principal benefit, avoided loss of future income, would be a benefit realized not by the railway but rather by the community at large. Basically, the railway undertakes an investment in barrier protection at a level crossing in order to prevent loss of life and to safeguard the future income of the community.

In the example given in Table 4.3, the economic benefit generated by the barrier installation project covers only 80 per cent of its economic cost, indicating that at the given level of fatality prevention (6 deaths per year) the project is unlikely to be justified in economic terms. In fact, a breakeven point (at which the projects costs and benefits are equated) would be reached at 8 prevented deaths per year.

A similar process may be repeated in order to calculate the benefit resulting from avoided injuries, except that injuries should be valued by sampling data from any relevant source, including railway accident reports, insurance claims, or police reports.

4.4.2 Assessing the delay reduction benefits of alternative level crossing protection systems

While the safety of railway passengers and of road users must be a paramount issue in the appraisal and choice of a suitable and cost effective level crossing protection system, some consideration must also be given to the operational efficiency of the system. In this context, “operational efficiency” means the capability of keeping delays to both rail and road traffic to the minimum consistent with safe operation of level crossings.

Field inspections undertaken during the course of ESCAP missions to India and Viet Nam in connection with this study revealed that delays to motor vehicle traffic can be extensive at manned level crossings. If these delays could be cut to a minimum perhaps as a result of installing electrically actuated crossing barriers, it is likely that significant *economic* benefits in the form of travel timesavings would accrue to road users. Further, if warning signals facing train drivers could be installed at manned level crossings, the maximum permissible speeds of trains through these crossings might also increase with the result that the railway would realize *financial* savings in the form of reduced running times, a reduced requirement of motive power and rolling stock, and an associated reduction in operating costs, while there would be *economic* benefits to rail passengers in the form of reduced travel times.

Barriers which are operated manually tend to be closed for longer periods than barriers which may be remotely controlled by crossing staff using electrical actuation systems, simply because the physical act of closing barriers will require more time than if the barriers can be activated remotely by mechanical or electrical means.

Typically, if barriers remain closed for excessive periods on crossings carrying a high volume of road and rail traffic, the build-up of road traffic will exceed the capacity of the crossing to safely discharge this build-up before the next train arrival at the crossing. Road traffic build-up in this situation obeys the rules of Queuing Theory: the longer the barrier closure, the greater the build-up and the slower the passage of motor vehicles over the crossing once the barriers have been raised.

An inspection of level crossings in the vicinity of Agra during the ESCAP mission to India in October 1999 provided ample evidence of difficulties encountered with traffic build-up when crossing closures are excessive. At one crossing within the Agra city limits, a Class A level crossing protected with double half boom barriers on both sides of the crossing was closed for 8 minutes awaiting the passage of a fast electric passenger train on the double-tracked Mathura-Agra-Bhopal mainline. This train was followed by another in the opposite direction about 10 minutes later, but it took 2-3 minutes to clear the crossing of traffic which had built up while the barriers were closed awaiting passage of the first train. Clearly, excessive crossing closure times will severely limit the train carrying capacity of a railway line if the road traffic using the crossings on the line exceeds a certain critical level. The Indian Railways has specified a daily TM (traffic moment) level of 100,000 at which grade separation of crossings would be justified, but budget restrictions have prevented this work being done except for a limited number of railway crossings of the national highway system.

For the purposes of this analysis, IR costs have been used to assess the relative costs and benefits of grade separation. The same approach can be used for the assessment of more modest improvements to level crossing warning and protection systems. There are two types of benefits resulting from grade separation of level crossings: *financial benefits* accruing to the railway in the form of increased line capacity and reduced operating costs and *economic benefits* accruing to individuals, i.e. railway passengers and road users in the form of travel time savings.

Calculation of financial benefit of reduced delay at level crossings

The case described above has been used for the purpose of illustrating an approach to measuring the financial benefit to the railway of reduced train headways which would result from replacement of level crossings with road overpasses. The relevant calculations are given in Table 4.4.

In the case of the level crossing observed in the vicinity of Agra, barrier closure was found to be 5 minutes for each train on average. On the assumption that barriers would remain open to road traffic for a similar period, the minimum headway (interval between trains running in each direction) would have to be 10 minutes. Thus the capacity of the line would be about 100 trains per day in each direction (60 minutes/10 minutes headway x 24 hours per day x service occupancy factor of 0.7).

Removal of the level crossing through the construction of a road overpass might have the potential to reduce headways to 5 minutes, but in order for the additional line capacity benefits to be realized *all other* level crossings on the line would also have to be replaced by road overpasses.

If this could be achieved, the new capacity on the line would be 202 trains per day in each direction (assuming that all trains ran at the same speed and that the signalling system installed on the line was capable of delivering 5 minute headways). However, even if only half of this additional capacity could be effectively utilized, it is likely that some 50 additional trains per day could run in each direction between Mathura and Bhopal. If it is further assumed that all of these trains are freight trains, then IR has the possibility of realizing a significant additional financial contribution (revenue less long run marginal cost) from the operation of these trains. Against this additional financial contribution would have to be offset the cost of constructing and maintaining multiple road overpasses along the line. If the cost of an overpass is of the order of, say, US$ 2 million, or 88 million Rupees, and the overpass could have an economic life of, say, 50 years then the Present Annual Value of the cost of replacing about 300 level crossings with overpasses between Mathura and Bhopal, supplemented by the annual cost of maintaining those overpasses would be of the order of 3.5 billion rupees.

Table 4.4: Financial analysis of road overpass construction programme

Item	Description	Units (as spec.)
A.	***Cost of road overpass construction***	
(i)	Capital cost - Rs. Mill.	88.000
(ii)	Present annual value of (i) [50 year life; 12% discount rate] - Rs. Mill.	10.597
(iii)	Annual maintenance cost (10% of PAV) - Rs. Mill.	1.060
(iv)	*Total annual cost - per crossing, Rs. Mill.*	11.656
(v)	Assumed number of crossings between Mathura and Bhopal	300
(vi)	*Total annual cost – all crossings, Rs. Mill.*	3,497
B.	***Increase in line capacity due to crossing elimination***	
(vII)	Current headway, with level crossings - in minutes (estimated)	10
(viii)	Equivalent train capacity (number of trains/direction/day, assuming 70% service occupancy)	101
(ix)	Future headway, without level crossings - in minutes (estimated)	5
(x)	Equivalent train capacity (number of trains/direction/day, assuming 70% service occupancy)	202
(xi)	Additional capacity provided per direction per day	101
(xii)	Practical use of additional capacity per direction per day	50
(xiii)	Additional trains per year (both directions; 312 operating days per year)	31,450
(xiv)	Additional net-ton km per year, millions (av. 1500 t payload; 600 km haul)	28,305
C.	***Required net revenue/contribution to cover annual cost (as per vi), Rs. per ntk***	***0.1235***

Notes: *(1)* *Item B (vii). If the average barrier closing time is currently 5 minutes and the crossing is then opened for an equal period of time, the minimum headway on each track must be 10 minutes, to allow safe separation between trains running in the same direction.*

(2) *Items B (viii) and B (x). On multiple track lines, line capacity is calculated as the summation of the capacity of each track. This in turn is calculated as: number of minutes in a day (1440) x service occupancy factor (70%) / headway in minutes.*

(3) *Item B (xii). It is assumed that the railway can only make use of 50 per cent of the additional capacity provided by reduced headways made possible by grade separation and the existing signaling system on the line,* ***in order to schedule additional freight trains****. Some proportion of the available new train paths will be used for passenger trains which are not positive contributors of net revenue.*

The additional train operating capacity resulting from the reduced headways possible with grade separated road/rail crossings would be about 31,200 trains per year producing an additional 28.3 billion net-tonne kilometres per year. Thus the net revenue or financial contribution required to breakeven on this capacity expansion project would amount to about 0.12 rupees per net tonne-km.

Of course, the level of contribution available would depend upon the type of traffic, as well as the market conditions and tariffs prevailing at the time. However, on the basis of the results of a financial analysis conducted as part of the Trans-Asian Railway Southern Corridor Study in 1998[22], it was found that the contribution on container traffic amounted to about 1.21 rupees per net tonne-km, or about ***ten times*** the breakeven rate identified above. Even if the additional traffic generated by capacity expansion mainly comprises bulk freight traffic, it is quite likely that the net revenue generated by this traffic will also exceed the level of net revenue required to breakeven on the annual capital and maintenance costs of a road overpass. Thus it might be concluded that a capacity expansion programme, involving replacement of all level crossings on a line with road overpasses would offer an attractive rate of return to the railway.

A similar approach may be used for calculating the benefits of a level crossing replacement programme in terms of reduced running delays and reduced operating costs.

In calculating the economic benefits of reduced level crossing delays, the time per year expended by road users waiting for the passage of trains through level crossings is given by the following formula:

$$T_i = (365 \times K \times t_i \times n_i) / 60 \text{ minutes}$$

Where: T_i = Total time lost (in person-hours);
K = Number of barrier closures within 24 hours;
t_i = Average duration (in minutes) of every barrier closure; and
n_i = Average number of persons waiting at a level crossing during every barrier closure.

If it is desired to measure the economic benefits of equipping a manually operated crossing with automatic crossing equipment, this formula may be used for the purpose of calculating the total delay involved and then the delay may be valued at the level of Gross Domestic Product (GDP) per capita prevailing in the economy in which the measurement is being made.

By way of illustration a hypothetical example based on the experience of India might be used. This example has the following elements;

- a manually-operated level crossing on a double track section carries 90 trains (45 in each direction) and 10,000 motor vehicles per day;
- barriers for this crossing are closed for an average of 5 minutes per time;

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[22] United Nations, New York 1999, *Development of the Trans-Asian Railway: Trans-Asian Railway in the Southern Corridor of Asia-Europe Routes.*

- on average there are 35 motor vehicles each containing 3.5 persons waiting during periods of barrier closure (i.e. 122 persons in total); and
- conversion of the crossing for automatic operation will result in reduction of barrier closure to 2 minutes per time (with an average of 49 persons waiting with every barrier closure).

The resulting delay calculations and their valuation are given in Table 4.5.

Table 4.5: Economic benefits resulting from reduction of barrier closure time

Item	Description	Units (as spec.)
A.	***Estimation and valuation of delays to motorists using a manually-operated level crossing***	
(i)	Estimation of total delay (in person-hours) per year	333,975
(ii)	Per capita GDP per hour for India in US$	0.0543
(iii)	Valuation of total delay in US$ per year [A (i) x A (ii)]:	18,135
B.	***Estimation and valuation of delays to motorists using an automatic level crossing***	
(iv)	Estimation of total delay (in person-hours) per year	53,656
(v)	Per capita GDP per hour for India in US$	0.0543
(vi)	Valuation of total delay in US$ per year [B (i) x B (ii)]:	2,913
C.	***Net time saving benefit of B relative to A, valued in US$ per year***	***15,221***
D.	***Cost of automatic barrier installation***	
(vII)	Capital cost - automatic lifting barrier with flashing light and block signal	53,900
(viii)	- optical sensor obstruction detector	81,600
(ix)	- *Sub-total*	135,500
(x)	Present annual value of (ix) [15 year life; 12% discount rate]	19,895
(xi)	Annual operating and maintenance cost (assume 2 x maint. Cost of manual system)	1,136
(xii)	Total annual cost	21,031
(xiii)	***Annual cost net of government taxes and charges***	***18,928***
E.	***Benefit / Cost ratio (C / Dxiii)***	***0.80***

Notes: (1) *Item A (i) If a crossing carrying 10,000 motor vehicles per day is closed for 5 minutes with every train passage, the average number of vehicles detained at the crossing during the period of barrier closure will be: (10,000 vehicles/1440 minutes per day) x 5 minutes = 34.7. If this number is multiplied by an average of 3.5 occupants per vehicle, the total number of persons delayed by the barrier closure will be 34.7 x 3.5 = 121.4. Applying the formula given in 4.4.2 (b), above, will produce the following calculation of the annual time loss in person hours: 365 days x 90 barrier closures per day x 5 minutes per closure x 122 persons delayed = 334,000 (approximately).*

(2) *Item B (iv). The method used to calculate this item is identical to that described above, except that the average barrier closure time is 2 minutes, rather than 5 with the related reduction in the build-up of waiting vehicles.*

This example shows that even at the low valuation applying to road users' time, an improvement of level crossing warning and protection systems can result in a substantial time saving benefit to the community. However, these results are quite sensitive to changes in the volume of motor vehicle traffic using the crossing. For example, if the number of road vehicles using the crossing were reduced by one third, to 7000 per day, on average there would be only 85 persons waiting at the barriers (34 with 2 minute closures), the net time saving would reduce to US$ 10,621 per crossing per year and the Benefit/Cost Ratio to 0.56. In this case, breakeven on the cost of automatic barrier installation (i.e. when benefits and costs are equalized and the BCR is 1.0) would occur when 12,500 motor vehicles per day use the crossing, detaining an average of 152 persons per barrier closure (61 with 2 minute closures) and producing a net time saving of US$ 18,981 per crossing per year.

A similar approach may be applied to the valuation of the economic benefits of time savings realized by rail passengers as a result of level crossing signalling improvements. Again, these benefits have to be quantified over the full route distance, but are likely to be of a much lower order of magnitude than those for motorists, since a relatively small number of trains operating throughout the region are likely to be subjected to speed restrictions through level crossings.

4.4.3 Financial analysis of alternative methods of safety enhancement at level crossings

A recurring theme throughout this study has been the relative advantages and disadvantages of installing manually operated barrier protection systems, as compared with automatic systems, at level crossings. It is desirable, therefore, to propose a method for comparing the quantified costs and benefits of each. It should be noted that this is one case where a financial, rather than an economic, evaluation is appropriate, since it is the railway which must seek a minimum cost solution to the problem of safety enforcement at its level crossings.

An example of a financial comparison of the two alternative systems, based on Indian Railways data, is provided in Table 4.6. The two alternative systems are:

- A manually operated full width barrier system, with block signal and flashing road warning lights; and
- A train-activated full width barrier system, with a block signal, flashing road warning lights, and an obstruction detector connected to the block signal.

It is important that exactly the same level of protection should be provided by the systems being compared, so that the comparison is on a strict like-for-like basis. For this reason, it is necessary to equip the automatic system with an obstruction detector, activated by an optical sensor which will send a signal indication of the presence of any type of obstruction on the level crossing – to which the train driver may respond before the train reaches the level crossing. In the case of the manually operated barrier system, the crossing keeper has the function of an obstruction detector and is able to provide the signal warning to the train driver.

Table 4.6: Financial comparison of manual and automatic barrier systems

Item	Description	Rs. mill.	US$
A.	***Cost of manual barrier installation***		
(i)	Capital cost - lifting barrier with flashing light and block signal	1.6984	38600
(ii)	Present Annual Value of (i) [15 year life; 12% discount rate]		5667
(iii)	Annual staffing cost	0.25	5682
(iv)	Annual maintenance cost (assume 10% of staffing cost)		568
(v)	*Total, annual cost*		*11917*
B.	***Cost of automatic barrier installation***		
(vi)	Capital cost - automatic lifting barrier with flashing light and block signal	2.3716	53900
(vii)	- optical sensor obstruction detector	3.5904	81600
(viii)	*- Sub-total*		135500
(ix)	Present Annual Value of (viii) [15 year life; 12% discount rate]		19895
(x)	Annual operating and maintenance cost (assume 2 x maint.cost of manual syst.)		1136
(xi)	*Total, annual cost*		21031
C.	***Net cost advantage for manual installation***		***9114***

This example shows that a manual barrier system has a substantial cost advantage over an automatic barrier system, *provided that it can provide the same level of safe operation as the automatic system.* Clearly, the need to incorporate an obstruction detector in the automatic barrier installation reduces the cost effectiveness of this alternative by a substantial margin. However, the very low cost of labour in this example from India also contributes significantly to the cost-effectiveness of the manual barrier system, since labour rates would have to be expanded by a factor of nearly 2.6 to equate the overall costs of the two systems.

4.5 Technical assessment of level crossing protection devices

In this section, the range of level crossing protection systems currently available and likely to be available in future is considered and an approach to appraising the technical merits of the alternatives is suggested. As was observed in Chapter 2, only the protection of level crossings with barriers and suitable warning devices is likely to result in the desired level of safety in Asia.

4.5.1 Currently available level crossing protection systems

(a) Crossing warning signals

In general, these are of two types: automatic and manually operated signals.

Manually activated signals are operated by level crossing staff, on instructions transmitted by telephone or telegraph signal from the nearest station.

Automatic warning signals need short track circuits or markers which detect trains and activate warning indications at level crossings. These warning indications are usually flashing lights, or sounds emitted by bells or claxons (horns), or a combination of these two. If visibility at a crossing is a problem, then flashing lights may be increased in intensity and may be installed so as to suit the lay of the surrounding land and buildings. Similarly, audible-warning devices may be increased in frequency and amplitude, to compensate for the sound absorption qualities of the physical environments of level crossings.

From experience, the level of safety afforded by these devices on their own is insufficient. This is particularly true in the case of level crossings accommodating two or more tracks. If unmanned level crossings are to be contemplated in these situations, then some form of train approach indication is absolutely essential.

(b) Automatic crossing barriers

These have multiple functions, including provision of:

- a physical barrier to prevent or (perhaps more realistically) to dissuade motorists from entering a level crossing into the path of an oncoming train;
- a crossing warning signal, indicating the presence of a level crossing;
- a train approach indicator warning of oncoming trains; and
- a crossing failure indicator warning of mechanical or electrical failure of level crossing equipment.

If desired, train detectors and obstruction warning devices based on a phototube system may be connected to automatic crossing barrier mechanisms.

There are many types of automatic level crossing barriers, the most commonly used types being swinging or lifting booms. Automatic trolley gates exist and a small number in fact have been installed within the region (mainly in Viet Nam), but in general use of the trolley gate system is restricted to manned level crossings.

Automatic swinging boom barriers have a greater number of mechanical parts than automatic lifting boom barriers and thus are exposed to greater risk of spare part shortages.

Automatic half barrier level crossings are found in many countries of Europe. This system functions satisfactorily when the road carriageways may be physically segregated. In the case of many two lane rural roads in Europe, however, lane segregation has not been possible and accidents caused by motorists making slalom (or S pattern) moves through half barriers are frequent. Despite the relatively low cost of the half barrier system it has not been widely used in Asia. Indeed, Japan withdrew from use of this system several years ago.

To enhance the visibility of barriers to motorists, a number of different methods have been devised including painting in tiger stripes and use of large diameter booms, double booms and high positioned booms (for trucks).

(c) Mechanical crossing barriers

Mechanical crossing barriers are operated by level crossing staff using hand or electrically powered levers, winches or windlasses. In addition, mechanical barriers providing complete protection of level crossings are connected to manually operated warning signals. Combination systems of this type are widely used within the developing countries of Asia since they may be manufactured inexpensively within the region. By contrast, automatic electronic crossing devices are wholly manufactured within developed countries and must be imported at substantial cost for installation within the developing countries of the region.

There are three main types of mechanical barriers: lifting booms, swinging booms or gates, and trolley gates. Of these types, the trolley barrier provides the most effective form of protection against break-through by heavy goods vehicles. However, of necessity trolley barriers are of heavy construction and are best deployed by means of remotely controlled electric motors. This type of barrier is used at a major level crossing intersection in Hanoi, Viet Nam, but the Vietnam Railways has encountered problems with maintenance of a sufficient stock of spare parts in order to keep the motor systems functioning.

Swinging type barriers afford a generally greater level of protection than lifting barriers against breakthroughs, but particularly when installed at double track level crossings they must be equipped with efficient locking systems.

(d) Train detectors

Automatic devices of this type detect the presence *and speed* of a train in block sections at the approach to a level crossing. They are installed only near unmanned level crossings and usually consist of a series of transponders inserted in track at certain intervals and interlocked with level crossing barriers and warning signals. Such devices must be capable of detecting train speeds since the elapsed time between a train's detection and its arrival at a crossing will be a function of its speed.

The alternative to installation of automatic train detectors is to have train starting signals at stations interlocked with level crossing barriers and warning signals. These signals have the capability of identifying the type and hence speed of different trains and will transmit the appropriate signal to the level crossing protection system in order to activate it at a specified time before the arrival of a train.

In the case of manned level crossings the function of the train detector is substituted by level crossing staff, who receive advance warning by telephone or telegraph from the nearest station of the arrival of a train.

(e) Obstruction warning devices for level crossings

These types of devices are usually only installed at unmanned level crossings. Their function is to provide signal warnings to train drivers when level crossings are blocked by motor vehicles or other obstructions. They mainly consist of phototubes, supersonic wave emitting devices or laser beam transmitters which detect obstructions on crossings and are interlocked with distant signals before level crossings. When activated by the presence of obstructions (e.g. stalled motor vehicles), they transmit a flare indication to distant signals via short track circuits, allowing train drivers to apply emergency braking and to stop their trains short of the crossing.

(f) Equipment costs

Indicative costs of the various systems currently available for the protection of level crossings are given in Table 4.7. They are based on costs applicable in Japan in 1999.

Table 4.7: Level crossing warning and protection system costs

Item No.	Description of device (s)	Equipment Cost (US$)	Installation cost (US$)	Total cost (US$)	Remarks
(i)	Crossing warning signal, train approach indicator, crossing failure indicator for single track or multiple tracks	2,100	2,900	5,000	Includes speaker system for transmission of audible warnings
(ii)	Crossing warning signal, crossing failure indicator	2,000	2,400	4,400	
(iii)	Crossing warning signal, train approach indicator for single or multiple tracks	2,100	2,900	5,000	
(iv)	Crossing warning signal	1,400	2,400	3,800	Flashing lights installed on both sides of crossing
(v)	Automatic half barrier installation	7,600	4,400	12,000	
(vi)	Automatic full barrier installation	15,200	8,700	23,900	
(vii)	Obstruction warning device for single track crossing	550	550	1,100	Includes switch set in concrete pillow (for emergency application by drivers of vehicles obstructing crossings)
(viii)	Obstruction warning device for multiple track crossing	1,000	1,100	2,100	As above
(ix)	Crossing obstruction detector - phototube system on single track	38,100	9,800	47,900	3 pairs required
(x)	Crossing obstruction detector - phototube system on double track	54,400	27,200	81,600	5 pairs required

Sources: JR Tokai and JR East.

Notes: (1) All costs in this table have been based on an exchange rate of US$ 1 – 103 yen.

(2) Not included in the above costs is the price of installed cable (including both the material price and installation cost) which is about US$ 11 per lineal metre, as well as the price of concrete shielding for the cable which is about US$ 40 per lineal metre.

4.5.2 Future systems for level crossing protection

Systems likely to be available in future for the protection of level crossings are of types:

(a) Advanced radio-based train control system – general features

The American and Canadian Railway Associations began to study Advanced Train Control Systems (ATCS) in 1984. The systems then investigated involved the use of radio, satellite and radar communications. Following the lengthy appraisal of this technology, it will at last enter operational service with San Francisco's Bay Area Rapid Transit System (BART) in 2001.

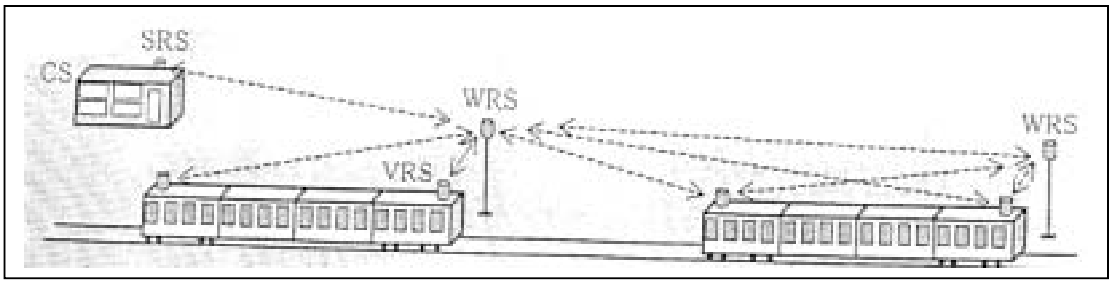
Transmission Based Train Control Systems (TBTC) which are similar to ATCS have been under study by the French National Railway (SNCF) and in Japan by the JR Technology Research Institute. This type of control system is close to practical application in Japan.

Further, the Indian Railways has been evaluating a radio-based ATC system designed by Siemens but similar to the system being introduced by BART. Pilot testing of the system will commence on the IR network during 2001.

Application of ATCS will allow elimination of track circuits and signals and in future will facilitate high density and unmanned train operations.

This system provides for the detection of a train's position by means of a radio transmitter installed on the locomotive which then transmits this information to a wayside base (Figure 4.3). The wayside radio base determines the velocity at which the train will be able to run safely within the section given information inputs as to the gradient curvature and condition of the track. It then transmits this information back to the train either as data displayed within the cab or as direct commands to the train's throttle and braking systems. For operation through level crossings, the train on-board computer calculates the time at which the level crossing warning lights or bells are switched in, based on the train velocity and level crossing position. This system may be overridden by train controllers in the event of equipment malfunction.

Figure 4.3: ATCS Concept



SRS: Station Radio Set
WRS: Wayside Radio Set
VRS: Vehicle Radio Set
CS: Control Station

In addition, the system has blocking control, level crossing control and the functions of ATC (Automatic Train Control) and CTC (Central Train Control) systems. The basic components of the ATCS are a Train Radio Set (TRS), a Wayside Radio Set (WRS), a Station Radio Set (SRS) at Control Stations, a Level Crossing Controller (LCC) and connecting systems between the train, wayside locations, level crossings and control stations. TRS are installed at both ends of each train. WRS are installed at the trackside (at intervals of 500m to 1500m on the BART system). SRS are installed at 20 station locations on the BART system. *Signals and track circuits between stations are not needed at this system.*

(b) ATCS - level crossing safety features

Existing level crossing systems represent a weak point of safety management and control on railways. Adequate warning time is needed for safe level crossing operation. Existing systems having electronic train detectors work on the basis of short track circuits installed in the track approaches on either side of level crossings. These systems control the beginning and end of the warning indication. The disadvantage of this system is that the warning interval becomes disproportionately long with slow trains, because maximum train speeds normally determine the interval between the beginning and end points of track circuited sections, and thus a train operating at slow speed will take significantly longer to pass between these two points. Further, existing crossing obstruction detectors do not stop trains automatically if crossings are obstructed - they merely provide a wayside signal indication of such obstructions to the train driver, leaving the responsibility for brake application to the driver.

With new ATCS systems, warning indications begin from the position at which an emergency brake application would be needed in order to bring a train to rest before a crossing, the braking distance being calculated automatically by the system on the basis of a train's speed past the radio relay point. The computers on board trains calculate their position and send the train number, train position and time until beginning of the warning indication to the Level Crossing Controller (LCC) through the Wayside Radio Station (WRS). The WRS picks up signals from the closest approaching trains, but only begin to transmit the signal to the LCC in order to activate the warning indication *at the calculated control time*. If no level crossing obstruction indication has been received by this time, the WRS will permit the approaching train to pass and will transmit crossing warning and barrier activation messages to the LCC. The train will then be permitted to pass through the level crossing on schedule. However, if an obstruction warning indication is received, the WRS will transmit a signal to the train receiver (TRS) in order to activate emergency braking.

(c) ATCS – financial benefits

With financial efficiency being one of the major objectives of railways, opportunities to minimize costs are of fundamental importance to railway managements. In this context ATCS, by eliminating devices on and along the track, substantially reduces both installation and maintenance expenses. Because the system has no wiring or trackside signals (all warning indications being transmitted to the locomotive cab), hardware installation costs and inspection and adjustment costs are significantly lower than for the conventional track-circuited system. Further, the system will allow trains to operate through level crossings consistently at normal speed.

The functions of CTC and ATC are added easily to the system for a relatively low additional cost. Indeed, the addition of CTC or ATC is estimated to comprise less than 50 per cent of the total system installation cost.

An automatic level crossing warning/protection system based on conventional track circuiting is estimated to cost US$ 45,000 per level crossing in Japan. By contrast, the cost of a BART-style ATCS[23] is estimated to cost only about US$ 22,000 per level crossing.

(d) GPS-based Advanced Train Control System

Global Positioning Satellite (GPS) communications systems are now in common use for sea, air and land transport navigation applications. GPS uses communications links with number of satellites to establish the navigation coordinates of aircraft or surface transport receivers. GPS systems are on the whole very inexpensive – a receiver for an automobile now costing as little as US$ 500.

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[23] The BART system, known as an AATCS (Advanced Automatic Train Control system) was developed by Nippon Signal in conjunction with Hughes and Harmon of the United States.

As compared with ATCS, the advantage of using GPS for train control functions is that it entirely eliminates the need for Wayside Radio transmitter links. However, the system does have some shortcomings, the most significant of which is that in civilian applications it is subject to significant error. GPS was originally developed for military use with links to satellites reserved for military communications. In military applications, the error is no more than several centimetres, but in civilian applications (using less reliable satellite fixes) the error can be as much as 30 metres – certainly excessive for locating trains in relation to level crossings. If it were possible to obtain access to military satellites, considerably more accurate navigational information would be available at minimal cost.

Another problem associated with GPS is that of setting the marks for revision of distance errors. These marks must be set accurately on maps or route charts. In the case of ATCS lines, trackside receivers may be used as markers for validating GPS co-ordinates, but in the case of lines not equipped with ATCS, new markers must be established within reasonable margins of error on maps or route charts. Comparing the cost of radio-based and GPS-based ATCS, currently radio-based ATCS is the cheaper alternative, but in future it is highly likely that GPS-based systems will overtake the radio-based systems to become the cheapest form of train control system available.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 General

This chapter presents the conclusions and main recommendations flowing from the analysis of level crossing systems and safety performance in several developed and developing countries. Among other things, this analysis compared and contrasted level crossing safety performance in selected countries of Western Europe, in North America and in Japan against the corresponding performance in the developing countries of the ESCAP region in an effort to establish whether lessons could be drawn from the experience of the former group of countries.

5.2 Conclusions

5.2.1 Comparative level crossing safety performance

Table 5.1 presents a comparison of the level crossing characteristics and safety performance of a selection of developed and developing countries.

The principal conclusions, which may be drawn from this comparison are that:

(i) *those countries which performed best in terms of having a low incidence, per rail traffic unit, of accidents, fatalities and injuries at level crossings are countries which have a high proportion of their level crossings protected against infringement by road traffic, either by manually operated or automatic barriers*[24]*;*

(ii) *automatic barriers are* ***not always*** *a fully effective form of protection against collisions between trains and road vehicles at level crossings (the relatively high rates of accident and casualty occurrence in the Netherlands due to S-moves through half barrier protected crossings provide ample evidence of this);*

(iii) *of the seven countries participating in this level crossing study, the three which have both the greatest level crossing density and the lowest percentage of protected level crossings (Viet Nam, Thailand and Bangladesh) also have the highest accident and casualty rates; and*

(iv) *those participating countries which have a relatively* ***high proportion of manned level crossings*** *(i.e. India and the Islamic Republic of Iran) also perform best in terms of level crossing accident and casualty occurrence.*

5.2.2 Comparative costs of level crossing systems

In addition to the conclusions drawn from the comparative analysis, the study demonstrated that the costs of installing manually operated barriers are significantly lower than those associated with the installation of automatically activated barriers.

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[24] The major exception to this observation is the Russian Federation, which ostensibly has the lowest accident and casualty rates of any of the countries compared, yet has more than half of its level crossings without any form of barrier protection.

There are two main reasons for this – that automatic barriers will require the installation of costly level crossing obstruction detectors and that simple manual barriers can usually be manufactured domestically, whereas the more sophisticated automatic barrier equipment will usually need to be imported.

Based on Japanese data, the cost of installing automatic full width barriers with road and rail warning lights and crossing obstruction detectors at a level crossing on a single track section is approximately US$ 77,000, whereas the cost of installing manually operated barriers with flashing warning lights at the same crossing (based on Indian data) is approximately half this amount, or US$ 39,000. Based on Indian data, the annual costs of operating and maintaining automatic and manual barrier installations are about US$ 1,100 and US$ 6,300, respectively. If the capital cost of these installations is to be written off over a period of 15 years, the saving in O&M cost associated with an automatic barrier system would be insufficient to cover its additional capital cost.

5.2.3 Do the railway systems of the region have an adequate information base for setting level crossing upgrading priorities?

In general, the answer to this question is "no". In none of the railway systems participating in this study was it apparent that any regular analysis of risks was undertaken in respect of level crossings, or indeed of any other type of railway accident.

Moreover, few of these railway systems appear to have an adequate safety information system, which would support any rigorous assessment of safety hazards and risks. While several appear to have a computerized inventory of their level crossing installations, very few if any appear to have an accident reporting system capable of providing detailed accident information in respect of individual level crossings.

Regular risk assessment is an essential foundation for establishing priorities for level crossing grade separation or protection works. This is especially true for railway systems, which face severe capital funding restrictions, but have both a high level crossing density and a low proportion of protected level crossings. Such systems do not have the resources to be able to grade separate or to protect a majority of their level crossings and must therefore concentrate their expenditures on safety enhancements which will produce the greatest returns in the form of reduced safety risk and accident occurrence. Thus, they need to be able to identify and prioritise these projects on the basis of systematic risk assessments. For this, they will need *at minimum* an information system which can provide updated information on: the physical environment and equipment of individual level crossings; the daily level of road and rail traffic through individual crossings; and the detailed accident histories of these crossings.

5.2.4 Are the railways of the region committed to road user education programmes and potentially how effective are these programmes?

The overwhelming majority of all collisions between trains and road vehicles at level crossings are caused by the negligence, incompetence or incapacity of road vehicle drivers. That fact having been established, it would appear that education of road vehicle drivers should have priority in the expenditure budgets of railway organizations. However, at this point in time, such is not generally the case.

Table 5.1: Comparative analysis of level crossing characteristics and safety performance in selected developed and developing countries

Country/Railway System	*Route – km*	*Number of level crossings*	*Level crossing density (crossings/ km)*	*Predominant type of level crossing*	*Accident rate (per mill.train-km)*	*Fatality rate (deaths/mill. Train-km)*	*Injury rate (per mill.train-km)*
France	31,200	17,514	0.56	Automatic half width barrier, unmanned (64%)	0.33	0.05	0.05
Netherlands	2,808	2,964	1.06	Automatic half width barrier, unmanned (68%)	1.01	0.28	0.29
United States	212,400	259,435	1.22	Unprotected and unmanned, equipped only with fixed road warning signs	2.01	0.25	0.75
Japan	27,230	37,326	1.37	Automatic full width barrier, unmanned (83%)	0.36	0.10	0.12
Bangladesh	2,734	2,149	0.79	Official unprotected, unmanned (43%)	0.74	0.66	2.46
India	62,495	40,445	0.65	Official unprotected, unmanned (51%)	0.10	0.21	0.28
Islamic Republic of Iran	5,995	418	0.07	Manual full width lifting barriers (48%)	0.64	0.11	0.17
Philippines	484	308	0.64	Official, unprotected and unmanned, equipped with fixed road warning signs (52%)	Not available	Not available	Not available
Russian Federation	86,151	13,581	0.16	Official, unprotected and unmanned, but equipped with automatic flashing road warning lights (41%)	0.04	0.01	0.02
Thailand	4,041	2,237	0.55	Official, unprotected and unmanned, equipped with fixed road warning signs (51%)	12.9	1.05	3.00
Viet Nam	2,712	4,842	1.79	Unofficial, unprotected, and unmanned (75%)	Not available	5.29	10.40

Sources: Country reports; UIC; Railway system information booklets; "Operation Lifesaver" website; AAR website.

Notes:
(1) "Protected" level crossings are at grade rail over road crossings which have some form of barrier protection against road vehicle infringement.
(2) All data relate to 1998, except for France (1997), Netherlands (1996) and Bangladesh, Philippines and Thailand (period 1988-1998).
(3) US accident and casualty rates were derived from Association of American Railroads (AAR) data which for 1998 show an overall railway accident rate of 3.6 accidents per million train-miles and about 90 per cent of all railway accidents occurring at level crossing.

The Indian Railways, for one, participates in driver safety education programmes with an emphasis on level crossing safety. However, level crossing accidents account for only 15 per cent of all railway accidents in India and an infinitesimally small proportion of all road traffic accidents. Consequently, there is little incentive for the Indian Railways, and even less incentive for the Indian highways authorities, to allocate a large budget to level crossing user education programmes.

Additionally, low levels of general education and safety awareness throughout the developing countries of Asia have tended in the past to minimize the effectiveness of level crossing user education programmes. Nevertheless, increasing disposable incomes and motorization levels in India and in the other developing countries of the region suggests that these education programmes should receive greater priority in future.

5.2.5 Traffic threshold criteria for level crossing improvement

Most of the region's railways apply traffic threshold criteria as a basis for determining the type of level crossing installations, which should be provided at individual road/rail intersections. In most cases, these criteria are based on the combined daily rail and road traffic passing through level crossings and are designated "Traffic Moment" indicators. They are computed as the product of daily train numbers and the daily numbers of road vehicles using the crossing. At the bottom end of the TM scale, minimal level crossing installations are indicated. At the top end of the TM scale, grade separation of crossings is indicated.

In some cases (for example in Viet Nam) the TM indicators have been set at unrealistically low levels and consequently are not capable of practical application. In other cases (for example in India), while the TM indicators have been set at realistic levels, budget restrictions have prevented full application of the TM criteria. Thus, in India for example, where a TM value of 100,000 indicates that a crossing should be grade separated, there are many level crossings which have long since passed this threshold level, yet have still not been grade separated.

In Japan, the JR West Railway Company has recently introduced a composite index based on allocated scores to determine the standard of level crossing protection required at individual locations. In addition to road and rail traffic densities, other factors to which scores are assigned include the accident histories and physical characteristics of individual crossings. High aggregate scores will indicate priority for grade separation. Low aggregate scores will suggest minimal standards of level crossing protection. Still other criteria have been developed which incorporate scores for level crossing closure time (high = low closure time; low = high closure time). While a case may be made out for improving the criteria applied to level crossing improvement, it is unlikely that there would be a better substitute for TM indicators set at realistic levels***, supplemented by accident risk assessments***.

5.2.6 Level crossing safety and operational efficiency

While level crossing safety must be a paramount consideration for railway managements, it is equally important that they should not loose sight of their operational objectives, including making most efficient use of the line capacity provided by current infrastructure and signalling configurations. Thus, it should be the objective of railway managements to ensure that train speed restrictions at level crossings do not unduly restrict a system's train throughput capacity. Barrier closing devices and warning systems should be compatible with the operation of trains through crossings at normal speeds.

On the other hand, long barrier closure times can have an adverse impact on safety on densely trafficked crossings, if they produce road traffic build-up to such an extent that crossings cannot be cleared of road traffic before the next train arrival. Long barrier closure times can also incite driver impatience and lead to barrier breakthroughs, which might easily result in collisions.

Invariably, a requirement for reduced barrier closure times will mean that existing manually operated barriers should be converted to electrical operation. It may also mean that signalling systems requiring long barrier closure times (such as the outdated Absolute Block systems) should be replaced by more modern signalling systems which can accept shorter crossing closure times.

5.3 Recommendations

From these conclusions a number of possible courses of action may be identified. The following recommendations are offered as guidelines for consideration and possible application by the railway managements of the region in dealing effectively with their level crossing problems:

(i) ***The railway managements of the region should re-evaluate their approach to monitoring level crossing safety and to setting priorities for implementing safety enhancement measures for level crossings on their respective systems.***

In particular, they should give careful consideration to introducing effective Safety Management Systems along the lines of the model system described in Chapter 4.

(ii) ***Wherever justified by the combined density of road and rail traffic, the railway systems of the region should give first priority to the grade separation of their level crossings.***

While grade separation is undeniably the most effective means of enhancing level crossing safety, the cost of constructing road under or over-passes is very high and often beyond the financial means of some of the railways of the region. Choice of this solution must therefore be influenced strongly by a realistic assessment of the combined density of the road and rail traffic likely to use current road/rail intersections.

(iii) ***Desirably, all railway systems of the region should carry out regular safety audits and risk assessments for all of their level crossing installations.***

Use of a Safety Management Information System supplemented by application of risk evaluation techniques along the lines of those described in Chapter 4 will improve the capability of railway managements to identify and prioritise level crossing safety enhancement measures.

(iv) ***Railway managements should take action either to close, or to provide effective protection for, all "unofficial" level crossings on their systems.***

In the case of some railway systems of the region (notably that of Viet Nam) substantial improvement of level crossing safety will simply not be possible unless the unofficial crossing problem is addressed effectively.

(v) ***Rather than committing scarce capital funds for the acquisition of sophisticated automatic systems of level crossing protection, railway managements should adopt a policy of manning currently unprotected crossings and equipping them with inexpensive locally manufactured barrier and warning systems wherever this is indicated by assessments of traffic density and/or adverse physical factors at specific crossings.***

While labour costs are still inexpensive in most countries of the region, manually operated level crossing barriers and warning systems (perhaps complemented by electrical activation mechanisms) provide the most cost effective method of providing a maximum level of safety at all but the most densely trafficked crossings, which in any event would normally qualify for grade separation. Alternative automatic protection systems (especially the half-barrier systems widely used in Europe) do not have a particularly good record of safe operation and, in the absence of crossing protection staff, require the installation of expensive crossing obstruction detectors in order to guarantee minimum levels of safety.

(vi) ***Railway managements should actively seek funding assistance for level crossing improvements or grade separation from road authorities.***

There is a particularly strong argument for such an approach when road traffic is shown to be growing at a faster rate than rail traffic.

(vii) ***Railway managements should be prepared to develop carefully targeted campaigns directed at the education of level crossing users and to ensure that adequate priority is attached to the funding of these campaigns.***

Particularly as disposable incomes and motorization levels are increasing throughout the region, the railways of the region should intensify their efforts to improve level crossing safety awareness throughout the communities they serve. While wide use should be made of the mass media (newspapers and television), note should be taken of simpler, but effective, methods of delivering public education programmes. In India, the use of *punjayat,* or local village council, offices as a vehicle for disseminating level crossing safety information appears to have proven effective and is recommended as a model for adoption by other railways of the region.