

Safety by Design for European Railways

Case- “Safety at Level Crossing”

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25/01/2018

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Summary: *This document comprises an effort to develop a safety system for Railway system in order to improve its efficiency and to reduce the hazards caused due to accidents.*

1.INTRODUCTION

'Level crossing accidents' means any accident at level crossings involving at least one railway vehicle and one or more crossing vehicles, other crossing users such as pedestrians or other objects temporarily present on or near the track if lost by a crossing vehicle or user (Official Journal of the European Union)
There are currently about 120 000 level crossings in the EU. On average, there are five level crossings per 10 line-km in the EU; half of them are active level crossings with some sort of user-side warning. The reminder are passive level crossings typically only equipped with the St. Andrew's cross traffic sign.

2.SCOPE OF SYSTEM OF INTEREST(SOI).

2.1 "Level Crossing "

Every year, more than **330** people are killed in more than **1 200** accidents at road-rail level crossings in the European Union. Together with tunnels and specific road black spots, level crossings have been identified as being a particularly weak point in road infrastructure, seriously affecting road safety. In the case of rail transport, level crossings can represent as much as **50%** of all fatalities caused by railway operations.

Up to now, the only effective solution appears to involve upgrading level crossing safety systems even though in more than 90% of cases the primary accident cause is inadequate or improper human behaviour rather than any technical, rail-based issue. High safety requirements for level crossing systems required in European railway sector standards create a high cost hurdle which hinders the technological upgrade of existing systems. Railway standards already include a risk based definition of safety, according to which only unacceptable levels of risk must be eliminated by the technical system. **Nevertheless, the lack of an approved common safety methodology which would allow the industry to quantify the risk to be reduced still leads to the imposition of the highest safety integrity levels for technical solutions in most European countries.**

It is expected that this project will help to improve the level of safety engineers and policy makers throughout the European Union, leading to the identification of better and smarter solutions and investments designed to facilitate their implementation.

2.2. System Stakeholder Analysis

Any person who is directly or indirectly affected by the functioning of a company is a stakeholder. Stakeholders include the company's shareholders, creditors, employees, customers and the government

The railway network is divided into two parts: the central rail network and the regional rail network. The Ministry of Transport awards the concession for the central rail network to one party for several years. At this moment, NS has the exclusive right to exploit train services on the central rail network until 2015. The Ministry of Finance is the only shareholder of NS.

For the regional rail networks, provinces and city regions serve as a transport authority, awarding the specific concession to one of the market parties. Currently, five market parties are active on the regional rail net: NS, Arriva, Veolia, Connexxion and Syntus. ProRail is the company responsible for rail construction and maintenance on both rail networks.

International rail transport and freight transport fall outside the scope of this research. Provinces, city regions and municipalities also serve as a transport authority for the bus, tram and metro networks. The majority of the parties that is active on the regional rail networks is also active in this market.

Apart from the government and local authorities, freight users and passengers also have a stake in the overall safety of the system, since they are the people who use the railway system most frequently. In the Netherlands, the railways system is a public institution. However, private investors can be stakeholders in the railway system as well.

2.3 Components and functions of the system

In general, a level crossing is a crossing on one level without recourse to a bridge or tunnel of a railway line by a road or a path. An Automatic barrier crossing level is a level crossing which is automatically driven.

The main parts of the system are

- **Rail signals**-
  -Red flashing rail signal-when flashing the train has not the authorization to cross the level crossing
  -White flashing rail signal-when flashing the train can cross the level crossing
- **Train arriving sensor**-launched when the train approach towards the level crossing
- **Train leaving sensor**-launched when the train roll away from the level crossing
- **Road signals**
  -amber flashing road signal-flashes for a few seconds when the arriving train is detected, before the red road signal starts flashing and booms lower.
  -red flashing road signal-starts flashing immediately after the amber light stops flashing
- **Booms**- half barriers kept normally in the raised position and is pivoted on the right hand side of the road.
- **Boom lights**-used as additional visual indication for the road users during the boom lowering
- **Crossing simulated train headlights**-used as additional visual indication for road users .They are used when red road signals begin to flash and until the booms begin to rise .

- **Audible warning device**-is activated during the crossing closure cycle.
- **Plunger**-sometimes a train having initiated a closure sequence does not reach the crossing before the fixed time out, in this case the train driver has to re-initiate manually the closure cycle using the plunger

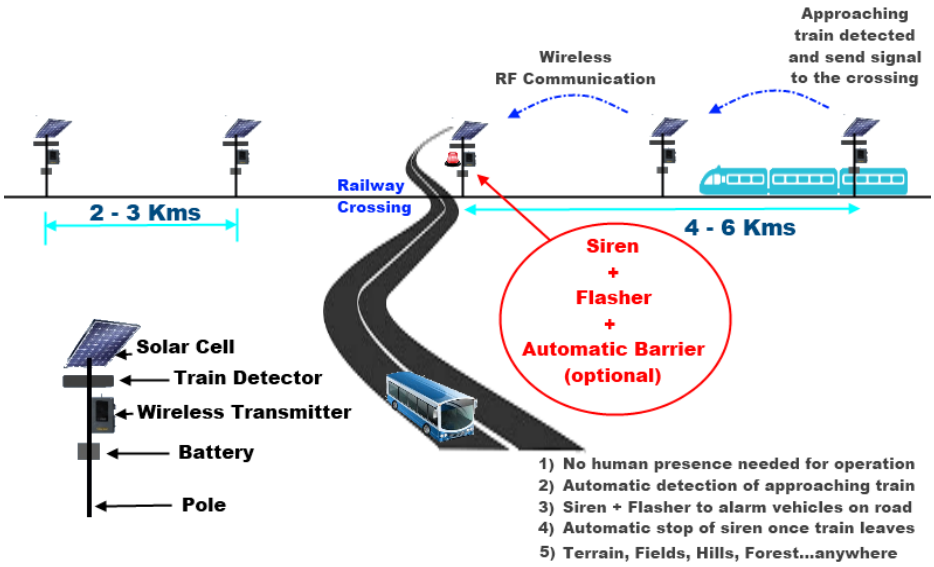
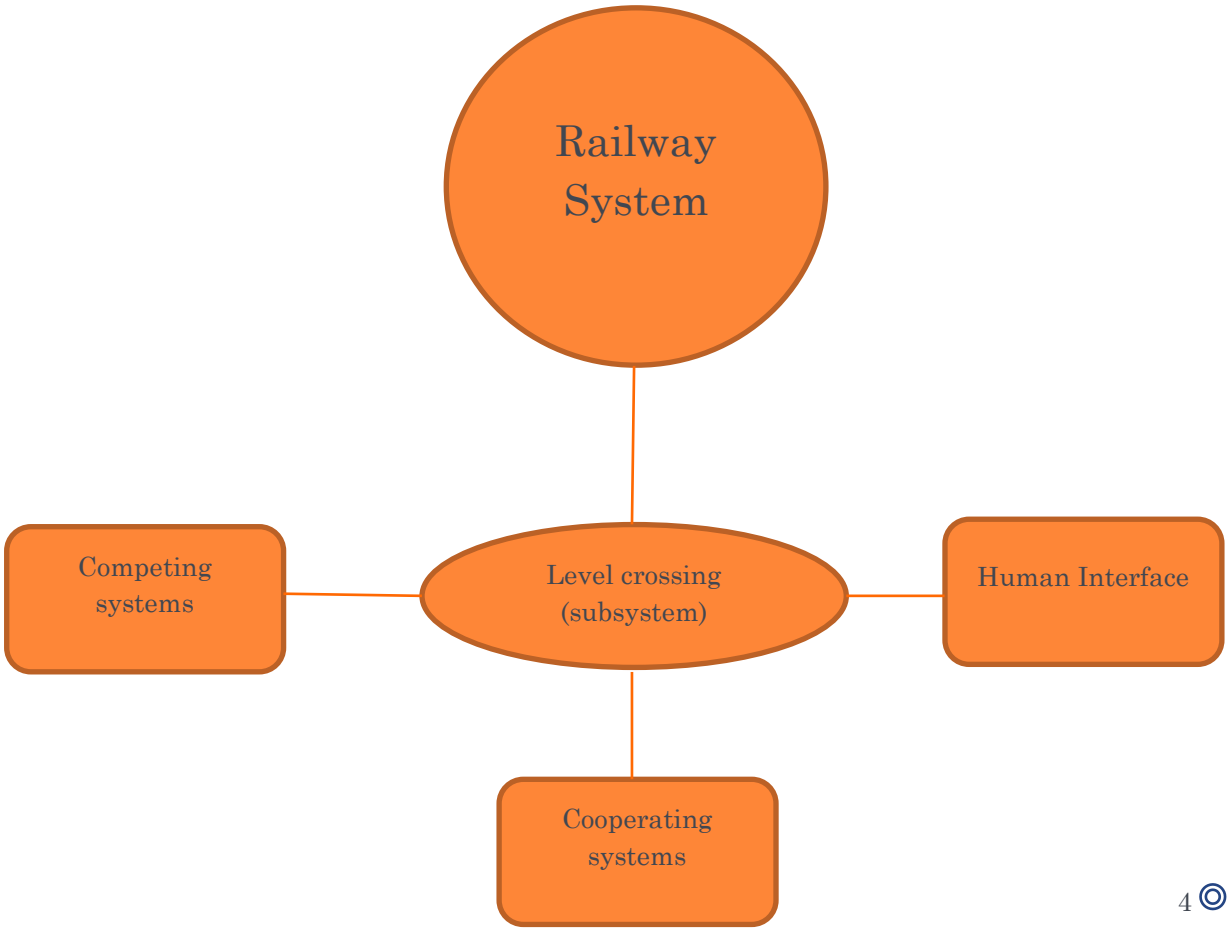


FIG-1-LEVEL CROSSING SUBSYSTEMS

2.4 Cooperating/Competing systems/ Human interactions (interfaces)



Competing system

Competition f or the system can be mainly due to the competing organization which are trying to dominate the rail industry since level crossing is a subsystem of railway system or due to the environmental conditions.

Firstly, the main competing organizations for NS and PRO-rail are – Abellio, Arriva and Veolia. Railway undertakings that operate on regional rail lines such as Veolia, Arriva, Connexxion and Syntus are too dependent on Dutch Railways NS and Trans Link Systems (TLS), which is the organization behind 'OV-chipkaart'.

The second competing system includes external factors such as environmental conditions which can affect the safety of the level crossing, traffic situation in the level crossing, location of the level crossing and other environmental conditions like harsh weather and so on.

Cooperating system

Similar to the competing system, cooperating system of the railway system can be considered for the subsystem selected for this particular sub system level crossing. ProRail is the company responsible for rail construction and maintenance, so the main cooperating system for this particular case is ProRail. All the organizations which is related to pro rail like NS, Railinfrabeheer (Rail Infrastructure Management, RIB), Railned (railway capacity allocation, Railverkeersleiding (Traffic Control) are the cooperating system for this particular case. The other cooperating system includes government of the country, municipalities ,and all the other non-government organizations who are directly or indirectly involved in the improvement of the usability and safety of the level crossing which includes individuals working in the respective organizations.

Human interface

There are a wide variety of people who can be considered as human interface with a level crossing. They include the operator of manned level crossing, technicians associated with unmanned level crossing, pedestrians who use level crossing, people who travel in private vehicles, drivers who cross the level crossing in public transport like bus, taxi etc. and commercial vehicle drivers who use the level crossing. Maintenance workers on level crossing can also be considered as human interface

3. SAFETY OBJECTIVES .

3.1 Desired level of safety, Safety standards and Safety Requirements (European railway safety legislation)

The objective of the Railway Safety Directive 2004/49/EC (as amended) is to create a common European regulatory framework for safety, in particular, the maintenance of safety management systems (SMS). It is intended that a common approach will help to break down barriers to the establishment of international transport operations and help create a single market for rail transport services in Europe.

The introduction of a certification scheme for entities in charge of maintenance (ECM) of freight wagons aims to improve the competitiveness of the freight sector in the UK and across the EU by reducing the administrative costs associated with establishing freight wagon safety. The purpose of the Railway Safety Directive is to:

- harmonize railway safety regulatory structures across Europe
- Define responsibilities between various players (operators, infrastructure, national safety authorities, ECMs, etc.)
- develop common safety targets and common safety methods (developed by a European Commission agency called the European Union Agency for Railways (ERA)
- establish safety authorities and accident investigation bodies
- Define common principles for the management, regulation and supervision of railway safety.

The desired safety level is expressed either quantitatively, by the decrease of "fatality risk" indicator or other indicators as defined by the European Railway Agency (ERA), or qualitatively by the change of "risk level", as defined by CENELEC. Research focuses on accidents and, more specifically, on accidents caused by the railway infrastructure

The system is considered by studying the most important railway safety issues, safety of the passengers, safety of the employees working on trains, stations and tracks and overall area of the railway. The main focus is to accomplish permanent improvement based on maximum reductions of fatalities, injuries and damage and making the system completely safer.

Recognition and acceptance of the risk should be very thorough to gain insight for the preventive measures and to control of these effects and incidents. Hence, objectives have been framed considering the whole railway system, for transport, work and life, which are:

- Probability of the materialization of the risk, which includes the probability and occurrence of hazards and occurrence of economic damage
- Effect of the materialization of the risk, which includes number of hazards and their effects on assets, life and environment
- Risk Reduction Potential, which relates to the safety improvements that can be accomplished in relation to the efforts and investments. This depends on factors including the amount to which the railway division can force an influence on the risk.

To meet the objectives, indicators have been specified to meet the objectives and to come to more specific discussion and results. These indicators are nothing but just a number showing effects of accidents, number of accidents, injuries, death and precursors of potential accidents. These indicators should be smart as possible which is specific, measurable, acceptable, realistic and time-bound. **Targets should be set which is at least less than or equal to current safety levels**.

The system should remain fully accountable for operational safety and achieving the desired safety outcomes as efficiently as possible. The result will be improved Railway Safety. To achieve this safety, there are certain norms, regulations and standards to follow, which is described in the subsequent section

3.2 History of accidents associated with Level crossing

Facts and figures

In 2015, there were 1 739 persons killed or seriously injured in railway accidents in the EU-28, 14 % less than in 2014. Suicides are in principle excluded from these statistics, but not all Member States can identify them in the statistics sent to Eurostat. A total of 2 269 significant train accidents were registered in the EU-28 in 2015, representing an increase of 3.7 % compared to 2014. The upturn observed in 2014 compared with the regular declining trend since 2004 is confirmed in 2015.

	Number of		Total number of accidents	Total number of persons killed or seriously injured in accidents
	tonne-kilometres (in million)	passenger-kilometres (in million)		
EU-28	**414 469**	**443 115**	**2 269**	**1 739**
Belgium (*)	6 500	10 300	21	19
Bulgaria	3 650	1 549	48	44
Czech Republic	15 261	8 125	94	82
Denmark (*)	2 273	6 827	17	16
Germany (*)	114 341	89 656	363	293
Estonia	3 117	286	14	14
Ireland	96	1 918	0	0
Greece (*)	294	1 263	29	29
Spain	11 131	26 247	48	34
France	34 252	91 653	150	95
Croatia	2 184	941	27	35
Italy	20 781	52 207	121	101
Cyprus	-	-	-	-
Latvia	18 906	590	25	26
Lithuania	14 036	262	12	11
Luxembourg	207	418	0	0
Hungary (*)	10 010	7 609	158	147
Malta	-	-	-	-
Netherlands (*)	6 545	17 523	37	17
Austria	20 266	12 104	98	99
Poland	50 603	17 240	639	324
Portugal	2 688	3 957	23	23
Romania	13 673	5 148	141	150
Slovenia	4 175	628	13	14
Slovakia	8 439	3 411	87	87
Finland (*)	8 468	4 114	13	14
Sweden	20 583	12 741	42	30
United Kingdom	21 990	66 399	49	35
Liechtenstein	13	1	0	0
Norway	3 498	3 555	20	7
Switzerland	12 431	20 311	52	46
Montenegro	112	81	8	2
FYR of Macedonia	278	177	115	35
Turkey	10 178	4 828	101	83

Note: No railway transport in Cyprus and Malta
(*) Tonne-kilometres and passenger-kilometres are based on 2012 quarterly data (detailed reporting)
(*) Passenger-kilometres are based on quarterly data (detailed reporting)
(*) Tonne-kilometres and passenger-kilometres are based on quarterly data (detailed reporting)

Table 1-EU accident counts

In absolute terms, Table shows that two countries accounted for more than one third of all rail victims registered in the EU-28 in 2015, namely Poland and Germany. When considering the average number of persons killed or injured per accident, the ratio is lower than 1.3 in all EU, EFTA and Candidate countries; the ratio at EU level being 0.8

History of rail accidents

The list of accidents associated with level crossing in whole Europe in figures has been discussed in the previous section .in this section, accidents occurred in The Netherlands are highlighted since it's not practical to consider accidents happening in different countries and do the study together because the safety norms are different in every country . Focusing on accidents happened in The Netherlands associated with level crossing, there are 7 officially reported accidents from 1994 to 2016. Official accident count only covers major accidents and one cannot argue that only 7 accidents has happened till date in level crossing. The major accidents happened in level crossing in The Netherlands are

- **February 17, 1944, Lisse**
  Truck with workers is pushed onto the crossing after a collision with another truck and gets hit by train, 9 killed, many injured
- **May 25, 1954, Zandbulten**
  Bus with wedding guests gets hit by train, 6 dead and ca. 20 injured
- **October 10, 1977, IJsselmuiden**
  Car gets hit by train on level crossing, 6 killed
- **July 22, 1986 – Brummen**
  Van, transporting mentally disabled, gets hit by train on level crossing, 6 dead, 2 injured.
- **June 16, 2000, Klarenbeek**
  Car with caravan drives a red light at a rail crossing and is struck by train, family of 5 killed.
- **February 23, 2016, Dalfsen train crash**
  Involving slow-moving elevated work platform on steel caterpillar tracks.



- **27th March 2017 Harlingen train crash**
  Two people have died after a train slammed into a car, believed to have been carrying school children.



3.3 Safety Critical Parts and Functions of Level Crossing

Prediction of possible failures or hazards as we claim theoretically is not always possible in practical situation. Sometimes the reason for a catastrophic accident can be due to the ignorance of the most negligible risk in the system. Proper functioning of all the parts is very important for the safety of the people .In the case of level crossing functioning of all the parts are important to keep the level crossing safe for the users, but there are few parts of the system if not working properly can cause major accidents and result in loss of life.

- **Train arriving sensor**
- **Audible warning device**
- **Rail signals**
- **Road signals**

The parts mentioned above are every critical in maintaining the safety of the level crossing. Any failure in the above components may result in accident and loss of life. If the level crossing fails to detect the incoming train due to the non-functionality of the train arriving sensors there is a good chance that the signal is not activated and the train might collide with the vehicle or pedestrians crossing the signal, similarly absence of an audible warning system for level crossing users because of incoming train and improper working of the rail signal will result in major accidents .if we go in detail to the history of the level crossing accidents we could see that most of the accidents are caused due to the failure or improper functioning of the above components .

4.IDENTIFICATION OF HAZARDS ASSOSCIATED WITH LEVE CROSSING

4.1 Description of system under study

'Level crossing accident' means any accident at level crossings involving at least one railway vehicle and one or more crossing vehicles, other crossing users such as pedestrians or other objects temporarily present on or near the track if lost by a crossing vehicle or user (Official Journal of the European Union)
There are currently about 120 000 level crossings in the EU. On average, there are five level crossings per 10 line-km in the EU; half of them are active level crossings with some sort of user-side warning. The reminder are passive level crossings typically only equipped with the St. Andrew's cross traffic sign.

Level crossings with automatic user-side warning (typically flashing lights and sound) are the most common type of active crossings (38 %) closely followed by the level crossings with automatic user-side protection and warning (barriers with lights) (34 %).

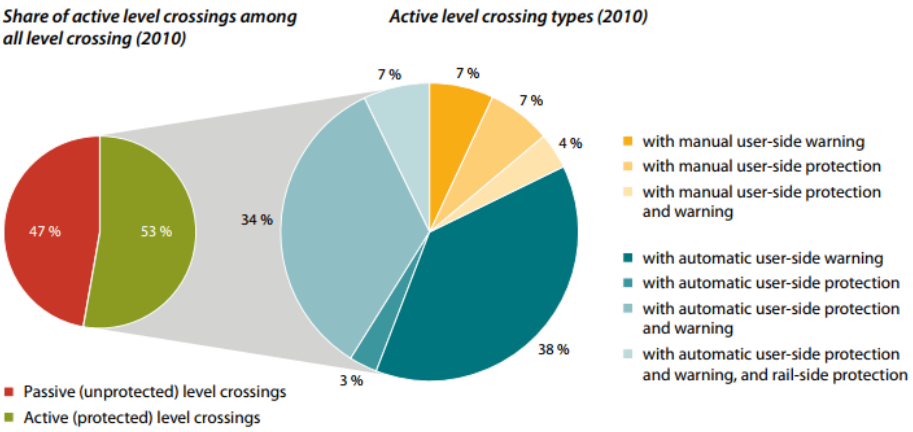


Fig 2- Types of level crossing

On average, there are five level crossings per 10 line-km in the EU; Sweden, Austria, the Czech Republic and the Netherlands have the highest density of level crossings in terms of level crossings per line-kilometer. Of these, the **Netherlands** has the highest ratio of active level crossings to all level crossings. A low ratio of active level crossings to all level crossings is typical for the less densely populated countries.

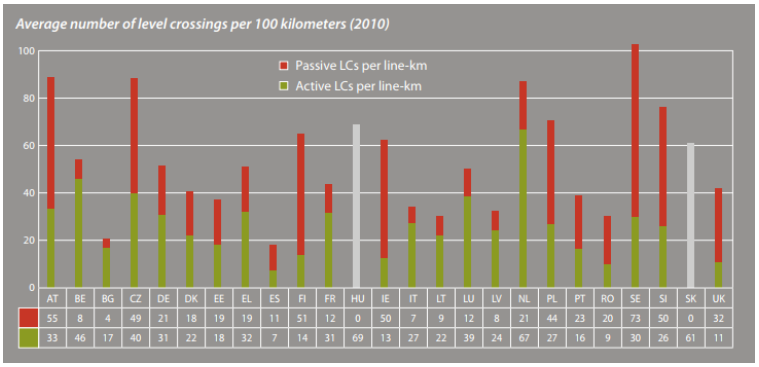


Fig 3-average number of level crossing per 100 km

4.2Hazard Identification

It is only in a minority of cases that the accident can be attributed solely to the road user. Very often, the underlying causes were related to the technical equipment or the layout of the level crossing. If identified, root causes were pointing to insufficiencies in the safety management systems of infrastructure managers and the framework of rules and regulations.

In order to identify the complete set of hazards surrounding the LC under study, we considered the different entities involved in the LC and the interactions between them described by functional diagrams. We also reviewed the operational specifications and considered all the environment factors around the LC. We considered the human and LC interface. We identified several hazards that can be classified into one of five categories, namely hazards related to the environment of the LC which affect visibility of LC users, hazards related to technical problems, hazards due to noncompliance with standards, hazards due to the human factors, and the fifth category includes all the other hazards. Several sub-categories constitute each hazard

Hazards for a level crossing can be categorized into 3 main categories-

1. **External world**

- The area close to the railway-road level crossing with the most exposed population may have a decisive impact on the way the problem is solved .
- The socially accepted level of individual safety in transport must be balanced to other fields of human activities.
- the level railway-road crossings present an economic impedance to the increased road traffic flows;
- The multi-fatality disasters trigger changes in the safety institutions.
- the state level of yearly financing improvement for railway-road crossings is often proportional to the fatality rate
- Due to the lack of ideas, the international professional audience needs common efforts or a research network.
- the society must take care of stimulating safer transport modes (which means stopping the shift from railway to the less safe road transport mode)

2. Railways

- the train mass, speed, and braking parameters are decisive in the safety design of a railway-road crossing;
- the train path has to be privileged in safety improvement on railway-road crossing
- the reasons for the increase of road flows do not come from the railway and consequently the railway share on railway-road level crossing with regard to the costs for solving the problem should be negligible various sources estimate this from 0 to 5% of the costs .
- It would be even less fair if the railway were burdened by the increase in the costs, which would eventually affect the rail fares, thus repelling passengers from the safer railway transfer making them to shift to the more risky road transport .
- the reliability of signaling and safety equipment is high and the related problems are small compared with other problems (e.g. unreliability of car drivers);
- the balises are considered to be the basic detector of the train locations;
- The so-called "hidden error's heritage and long history" within the safety and signaling equipment, seem to be a potential for disasters.

3. Road

- Road vehicle drivers and pedestrians (road users) have the main responsibility- therefore all kinds of influence are suitable: education, warning, and law enforcement.
- essential behavioral decisions depend on risk acceptance of the road motorists;
- traffic rule violation is the prevailing reason for drivers' involvement in accidents
- the increase of road traffic flows means greater exposure on railway-road crossings, therefore the road economy has to finance the solving of related risks
- road traffic control is responsible for proper guiding of road vehicles; - after multi-fatality disasters, and especially if school buses are involved, the public realises how big the risk is and often triggers a campaign for improvements
- the evaluated damage and indirect cost of injuries and fatalities are very high; from year to year the society is becoming more and more aware of these costs
- It is useless to plan safety improvement on railway-road crossings by means of the law and without determining the funding at the same time. A juridical obligation for any road or railway entity means nothing, if there is no investment money ensured by the same law.

The list of possible reasons for hazards include

- Failure of critical parts of level crossing like Train arriving sensor, Audible warning device
- Absence of Rail signals
- Absence of road signals

- Improperly closed gates when the train passes through the LC
- Road vehicles coming over the LC where barriers on the other side have been closed
- Drivers disregarding signals
- Low level of public discipline
- Poor road surface state causing the crossing of vehicles difficult
- Non-Compliance of road standards by the road authorities
- Non-Compliance of railway standards by the railway authorities
- Poor Maintenance of LC
- Barriers take too much time to close and some vehicles cross the LC while the train is near by
- Restricted Visibility of the Road signals by the drivers (due to the presence of physical obstructions)
- Restricted Visibility of the railway signals by the train driver (due to the presence of physical obstructions)
- Restricted Visibility of the Incoming Train (large turn angle or angle of the road)
- Absence of Road Warnings and Signals
- Motorcycles' Drivers ignore signals and pass under the closed LC barriers
- Light Signal is not working and do not alert both the LC keeper and its users
- Non luminescent barriers (of use at night)
- Train brakes do not work
- Non-activation of the detection system & Train Alarm does not work
- Car Drivers try to cross while the train approaches and the barriers are being lowered
- Signal Transmission between the activating arm of the Train detection system and the LC Control Board fails due to poor maintenance
- Non-activation of the audible and light signals by the Train Detection System
- Inaudible Alarm of the train that is meant to alert the LC keeper of its incoming
- Private level crossings which remains partially unguarded(Cause of Harlingen train crash)

The above list mentioned is the list of possible reason for hazard which could occur at any point of time. Not all the reason for hazards are predictable .There will be always a room for improvement for safety of a system. This can be achieved by carrying out a thorough investigation on the existing accidents so that the root cause of the accidents can be understood and improvement of the system can be done accordingly. From the investigations done on accidents it can be seen that most of the accidents are due to the ignorance of safety warnings by the level crossing users.

27th March 2017, Harlingen train crash is the most recent accident happened in a level crossing. Official investigation is ongoing to find out the possible cause of the hazard which involve the death of two people. A train hit another car in the same crossing in the month of February 2017. The second accident may have been avoided if there was a proper investigation happened on the minor accident happened in February. Dutch railway company Pro-Rail said in a statement that it had begun talks with the landowner about demolition of the crossing after the incident happened in February. But the slow pace of the process of demolition has resulted in loss of life of two people. **The main reason for these kinds of accidents is because of private level crossings which remains partially unguarded**. There are about 300 private level crossing in the Netherlands alone. The video footage of the accident scene is given as a link- https://www.youtube.com/watch?v=anUP_FN9wRQ

Dalfsen train crash happened on **February 23, 2016,** in dalfsen resulted in the death of the driver of the train. A passenger train collided with an elevated work platform at Dalfsen, Overijssel, Netherlands. It is reported that the crane from company Van den Brink in Barneveld, was slowly crossing the line when it was hit by the train. It had waited at the crossing while one train passed, but then started to cross and was hit by a

second train. The train involved was a Spurt GTW 2/8 train, travelling from Zwolle to Coevorden. All four vehicles were derailed. One person was killed; the driver of the train. There were fifteen passengers on board the train. Six of the survivors were injured, one person sustaining serious injuries. The video footage of the accident scene is given as a link- https://www.youtube.com/watch?v=jRr9pNCjQiQ

Details of level crossing accidents which has happened prior to the accidents mentioned above was limited since the occurrence was in late 90's and is out of the scope of this assignment since there has been lot of innovations in the field of technology and majority of the reasons for the accident has already been solved .



Fig 4- people ignoring level crossing signals

4.3 Risk Analysis (Severity and Probability of Hazards)

We used the frequency and consequence classification to rank each of the identified hazards and then categorized them based on ALARP. This revealed that 18% of the hazards are considered to have negligible risk, 35% have tolerable risk and they include mainly technical problems related to the train and the TDS. The remaining 47% hazards were associated with the intolerable risk category, and most of them were associated with the human factor and technical problems. The next logical step is to take actions to remove hazards with potential intolerable risk. These actions should target human factors and technical problems.

The mentioned hazards will be categorized based on the frequency of occurrence and severity class based on the tables given below

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

	Hazard	score
A	Failure of critical parts of level crossing like Train arriving sensor, Audible warning device	3
B	Absence of Rail signals	2
C	Absence of road signals	4
D	Improperly closed gates when the train passes through the LC	3
E	Road vehicles coming over the LC where barriers on the other side have been closed	2
F	Drivers disregarding signals	4
G	Low level of public discipline	3
H	Non-Compliance of road standards by the road authorities	1
I	Non-Compliance of railway standards by the railway authorities	1
J	Poor Maintenance of LC	4
K	Barriers take too much time to close and some vehicles cross the LC while the train is near by	1
L	Restricted Visibility of the railway signals by the train driver (due to the presence of physical obstructions)	2
M	Restricted Visibility of the Incoming Train (large turn angle or angle of the road)	3
N	Absence of Road Warnings and Signals	2
O	Motorcycles' Drivers ignore signals and pass under the closed LC barriers	5
P	Light Signal is not working and do not alert both the LC keeper and its users	3
Q	Non luminescent barriers (of use at night)	3
R	Train brakes do not work	1
S	Non-activation of the detection system & Train Alarm does not work	2
T	Car Drivers try to cross while the train approaches and the barriers are being lowered	3
U	Signal Transmission between the activating arm of the Train detection system and the LC Control Board fails due to poor maintenance	2
V	Non-activation of the audible and light signals by the Train Detection System	2
W	Inaudible Alarm of the train that is meant to alert the LC keeper of its incoming	2

Frequency rankings of the hazards

Score	Severity Class
1	Minor
2	Major
3	Critical
4	Catastrophic

	Hazard	score
A	Failure of critical parts of level crossing like Train arriving sensor, Audible warning device	4
B	Absence of Rail signals	4
C	Absence of road signals	4
D	Improperly closed gates when the train passes through the LC	2
E	Road vehicles coming over the LC where barriers on the other side have been closed	4
F	Drivers disregarding signals	3
G	Low level of public discipline	3
H	Non-Compliance of road standards by the road authorities	2
I	Non-Compliance of railway standards by the railway authorities	3
J	Poor Maintenance of LC	1
K	Barriers take too much time to close and some vehicles cross the LC while the train is near by	3
L	Restricted Visibility of the Road signals by the drivers (due to the presence of physical obstructions)	2
M	Restricted Visibility of the Incoming Train (large turn angle or angle of the road)	4
N	Absence of Road Warnings and Signals	4
O	Motorcycles' Drivers ignore signals and pass under the closed LC barriers	2
P	Light Signal is not working and do not alert both the LC keeper and its users	2
Q	Non luminescent barriers (of use at night)	3
R	Train brakes do not work	4
S	Non-activation of the detection system & Train Alarm does not work	4
T	Car Drivers try to cross while the train approaches and the barriers are being lowered	3
U	Signal Transmission between the activating arm of the Train detection system and the LC Control Board fails due to poor maintenance	4
V	Non-activation of the audible and light signals by the Train Detection System	3
W	Inaudible Alarm of the train that is meant to alert the LC keeper of its incoming	4

Ranking based on consequences

Frequency/ Consequence	Very unlikely 1	Remote 2	Occasional 3	Probable 4	Frequent 5
Catastrophic 4	R	B,E,S,U,W	A,M,N	C	
Critical 3	I,K	V	G,Q,T	F,J	
Major 2	H	L	D,P		O
Minor 1					
Negligible risk		Tolerable risk		Intolerable risk	

Table 2: Hazard categorization based on ALARP principle

The output of the above hazard analysis on the basis of severity and probability is the proper categorization of all possible hazards.by studying those hazards we could eliminate, reduce or neglect certain hazards .according to the above study the intolerable hazards which has to be eliminated by any cost are

- Absence of Rail signals
- Road vehicles coming over the LC where barriers on the other side have been closed
- Non-activation of the detection system & Train Alarm does not work
- Signal Transmission between the activating arm of the Train detection system and the LC Control Board fails due to poor maintenance
- Inaudible Alarm of the train that is meant to alert the LC keeper of its incoming
- Failure of critical parts of level crossing like Train arriving sensor, Audible warning device
- Restricted Visibility of the Incoming Train (large turn angle or angle of the road)
- Absence of Road Warnings and Signals
- Absence of road signals
- Drivers disregarding signals
- Poor Maintenance of LC
- Motorcycles' Drivers ignore signals and pass under the closed LC barriers

And the tolerable risks are

- Improperly closed gates when the train passes through the LC
- Low level of public discipline
- Light Signal is not working and do not alert both the LC keeper and its users
- Non luminescent barriers (of use at night)
- Train brakes do not work

- Car Drivers try to cross while the train approaches and the barriers are being lowered
- Non-activation of the audible and light signals by the Train Detection System

5. CONTROL HAZARDS

When evaluating the risks associated with specific hazards, the results of this evaluation should guide the researcher in the selection of risk management techniques including elimination, substitution, engineering controls, administrative controls, and personal protective equipment. Controlling hazard depends the cooperation from government and the people as well. For eliminating the intolerable hazards the following suggestions can be considered.

- Proper inspection of level crossing on a regular interval to make sure that the different components of the level crossing which includes the critical parts mentioned in the previous section are working properly.
- Meeting with the authorized user to discuss his legal responsibilities for invited crossing users, and to discuss how risks could be managed;
- Producing a briefing pack for the authorized user to enable him to brief his contractors;
- Discussing with the authorized user the options for the closure of the crossing;
- Reviewing the crossing's signs and approaches to determine any enhancements to highlight the risks
- Identifying the effects of skewed alignment at passive level crossings on user behavior, including the sighting of approaching trains;
- Reviewing the processes and guidance for level crossing risk management to determine whether the impact of skewed alignment is sufficiently taken into account;
- Making necessary changes to the processes, guidance and training given to level crossing managers. Reviewing the criteria for determining when it is appropriate to include an allowance for vulnerable users when calculating the required warning time at level crossings used by pedestrians.
- A dedicated user support line which works 24/7 and deals with all the problems and confusions in the level crossing so that the level crossing users can reach out to the authorities in case if they needed any help
- Design changes in the railway line or instructions to reduce speed of the trains when there is restricted visibility of the level crossing due to large turn angle in the railway track.
- Promote socially desirable attitudes, raise awareness of threats posed by inappropriate behavior whilst going through the railway area.

Active warning systems for level crossings have traditionally been train-oriented and geared more towards protecting railway assets than helping vehicles and pedestrians make better split-second decisions. The following improvements are three important ways improved data accuracy can make level crossings smarter and prevent accidents.

1. Advanced Obstacle Detection

Exposed to the elements, the clearance zone of a level crossing is shared by trains, vehicles, pedestrians, and even wildlife and wind-blown debris. Although we always want to avoid collisions between a train and a stranded vehicle or pedestrian, it may not be necessary to

stop a speeding locomotive each time an agile deer leaps across the tracks. As a result, smart level crossing systems are now adopting the latest in CCTV surveillance and image processing technology to visually inspect boom gate conditions, identify trapped objects, and monitor the movements of the object in real time. In particular, industrial-grade network video recorders—installed inside a wayside cabinet to process high quality images streamed from rugged IP video cameras—are used to help railway operators determine if a real obstacle exists by checking the detected object's entry and dwell time in the clearance zone.

2. Real-Time Equipment Status

Smart railroad crossings also need to keep track of vital parameters and constantly changing conditions for many different kinds of assets. Increasingly sophisticated data acquisition systems—comprised of the latest RTU (remote terminal unit) controllers—are now used to provide around-the-clock monitoring for wayside equipment, operating statistics, and environmental conditions. Tucked inside a space-saving wayside cabinet, compact RTU controllers can connect all the myriad I/O, Ethernet, and serial interface sensors at a level crossing to an integrated wayside monitoring system. More specifically, by sending error messages about potentially malfunctioning barriers, motors, lights, and alarms from a far-flung railroad crossing to the OCC, advanced RTU controllers enable railway operators to instruct a speeding train to slow down or stop well before it reaches an intersection.

3. Variable Message Warning Signs

Besides providing real-time data to warn railway operators and train drivers about potential obstacles on the tracks and malfunctioning equipment, smart level crossings are also deploying LED variable message signs to display important information about approaching trains so vehicle drivers and pedestrians can make better decisions on the spot. For example, if an impatient driver knows that a speeding train will arrive at the intersection in less than 3 seconds, he or she may think twice before trying to "run" the crossing. As a result, "smart" warning signs should also provide real-time status updates about an approaching train to help drivers and pedestrians answer the following questions:

- How much time before the train reaches the level crossing?
- Which direction is the train coming from?
- What is the speed of the train?
- How far away is the train?

Smart vehicle, smart user and smart infrastructure will lead us to decrease number of pedestrian-train collision and to employ intelligent transportation systems to improve safety at level crossings and make them smarter. Smart phones and smart watches are increasingly using by people and they can be used to aware them from danger of hit and help to reduce collisions, death and injuries.

Railway-road crossing in a narrow sense

- Video surveillance and enforcement drastically reduce the number of accidents in tests;
- Elimination of crossings (to convince the opponents, obtain permissions, and close the crossing) is a hard job, often a "discouraging" one. For a long term the closure can be efficient in 25% cases.
- low-cost train detection may reduce the cost of active warning protection;
- intelligent solutions have to be incorporated in the railway information system as well as in the road and vehicle systems;
- the equipment redundancy can be used to cover the less reliable human actions

Safety procedures

Most of the hazards associated with level crossing are cause due to the ignorance or lack of knowledge on the practices to be followed in level crossing. The basic practices one should follow are -

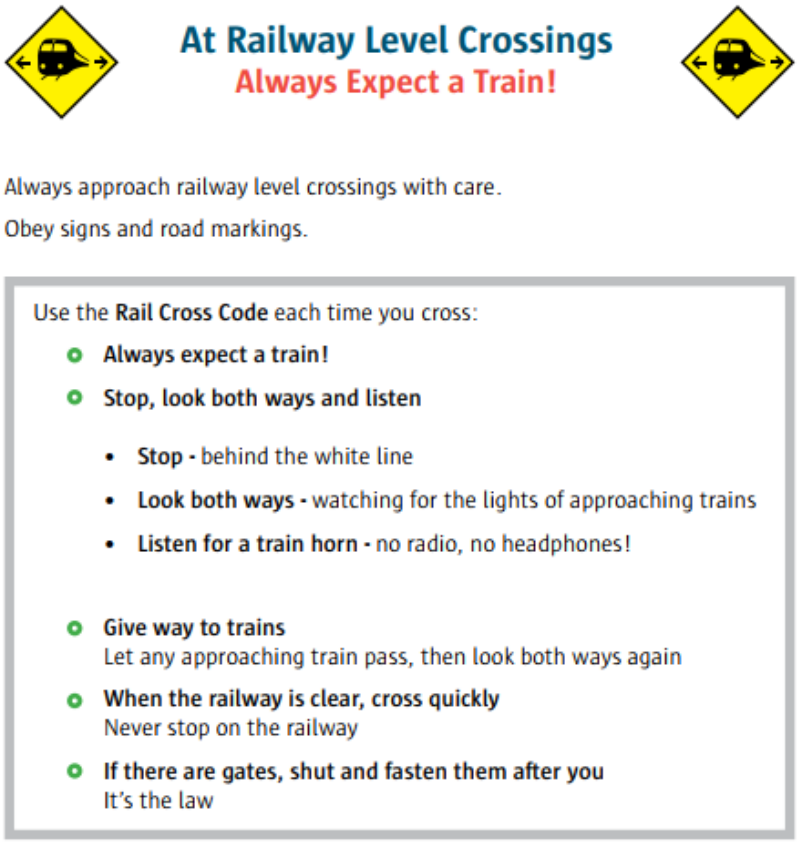


Fig 4-safety procedures

Detailed information on safety procedures, safety labels while using different type of level crossing is given in the appendix.

6.SAFETY CASE

A safety case is a document produced by the operator of a facility which: Identifies the hazards and risks. Describes how the risks are controlled. Describes the safety management system in place to ensure the controls are effectively and consistently applied.

A safety case requires a structure as well as evidence. The structure shows the logical developments and relationships that constitute the argument that the evidence provided justifies the top-level safety claim. It is the skeleton on which the flesh of specific evidence is hung. The larger and more complex the safety case, the more important it is that the structure is carefully developed and defined. Given below is a very basic safety case representation for a level crossing .The depth of details is limited for the assignment sake.

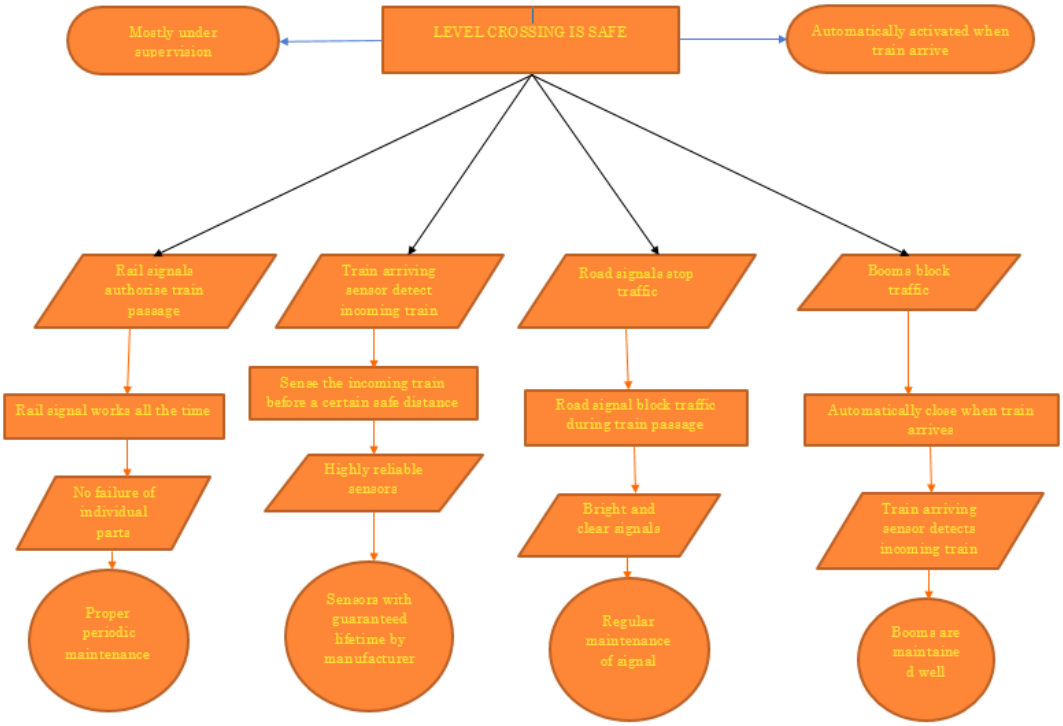


fig 5-safety case

7.MONITER SYSTEM

Safety indicators

SPIs is a key performance indicators that pertain to safety. Although safety orientated, they often have financial implications – it has often been said 'safety is good businesses'. Measuring and monitoring SPIs enables an organisation to demonstrate the effectiveness of its safety management system (SMS). That is, they show how well an organisation is implementing its safety management policies, processes and procedures and how well it is preventing accidents from occurring. Traditionally this has been done by counting how many accidents or incidents have occurred. However, that means that action is only taken after something has gone wrong. But what if no accidents have been recorded. Take train collisions, for example. It does not mean that all is well.

There are 2 main safety indicators which we are supposed to follow .they are leading and lagging safety indicators**. Lagging indicators** measure a company's incidents in the form of past accident statistics. A **leading indicator** is a measure preceding or indicating a future event used to drive and measure activities carried out to prevent and control injury. **While considering the safety indicator one is not supposed to stick on to leading or lagging indicators alone .studies has to be done on previous accidents and those data will(lagging indicator) always be helpful for maintaining safety of an organization along with foreseeing hazards (leading indicator) and trying to eliminate those .**

System Monitoring

This section gives an overview of the common safety method (CSM) for monitoring, which has been adopted and published by the European Commission. Common safety methods are developed by the European Commission and the European Union Agency for Railways (ERA) to support the single market in the rail sector.

European Commission Regulation 1078/2012 (the CSM for monitoring) started to apply from 7 June 2013. It provides a common approach for mainline transport operators and ECMs for all vehicles to control risks through their contractors. It requires them to ensure that

- the risk control measures implemented by their contractors are monitored using the process in the CSM; and
- Their contractors apply the same process through contractual arrangements.

Mainline transport operators are required to report their experience of using the CSM in their annual safety report. ECMs for freight wagons are required to report their experience of using the CSM for monitoring in their annual maintenance report. ERA has produced a guide for the application of the CSM for monitoring and the Rail Safety and Standards Board has produced a short guide on the CSM for monitoring.

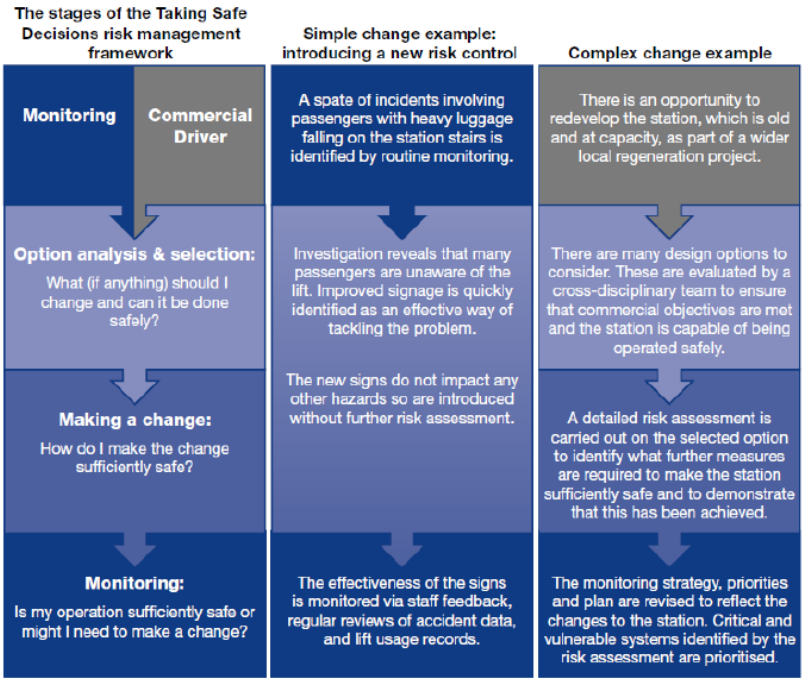


Fig 6-monitering procedure

The above picture shows how the safety changes and modifications will be monitored. Enlarged image is given in the appendix.

Safety culture

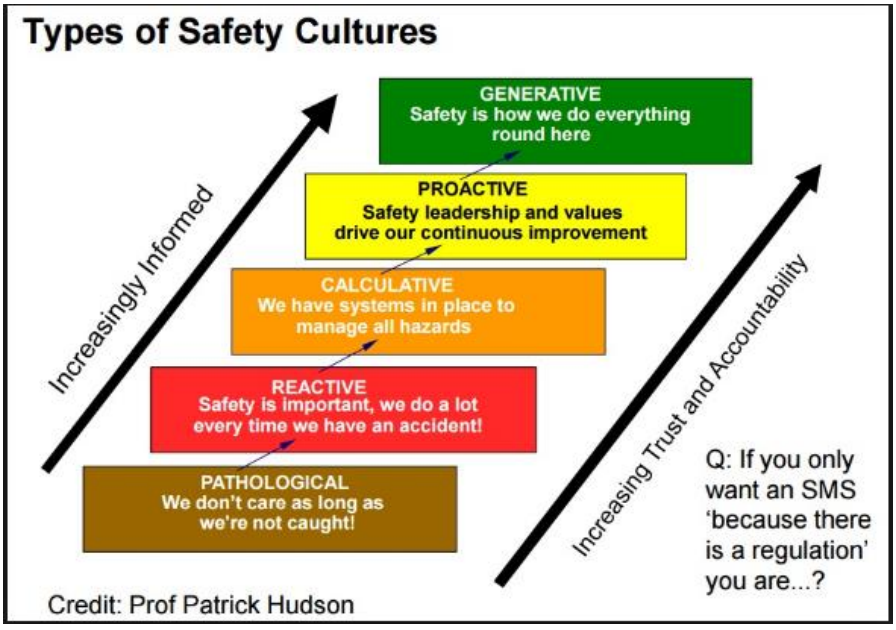


Fig 7-safety culture

An organisation's culture can have as big an influence on safety outcomes as the safety management system. 'Safety culture' is a subset of the overall company culture Safety culture of an organization is one of the parameter which measure how an organization is dealing with the safety of its users. All the companies usually come under 5 categories based on safety culture.

- Pathological
- Reactive
- Calculative
- Pro-active
- Progressive (Generative)

Achieving highest safety culture is a progressive approach .one cannot jump from pathological to progressive safety culture directly. The safety culture achieved now for railway system is reactive.so the main aim should be to achieve the next level of safety within a short time so that the safety standards are high enough and hazards can be reduced as low as possible.

JOURNEY THROUGH THE COURSE SAFETY BY DESIGN

There has been so many exciting learning experience throughout the course. before starting the course my concept of safety was very different .but through the proper guidance of the professor who handled the course I think the whole class know the basics on how safety is considered in an organization .it was a great learning experience .It would have been better if the course is extended to two quartiles because I personally feel that the knowledge gained from the extended course will surely help in developing the career of a student .one highlight of this subject course is the excursion part .Not only we came to know theoretically about the concepts but we got an opportunity to see practically how safety is carried out in industry through the excursion

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[24] https://en.wikipedia.org/wiki/List_of_rail_accidents_(2010%E2%80%93present)
[25] http://orr.gov.uk/__data/assets/pdf_file/0016/2158/level_crossings_guidance.pdf
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APPENDICES

DOs ✓	DON'Ts ×
Always expect a train	Don't ever think it's safe to predict when the next train will come
Always use the Rail Cross Code at unattended railway crossings	Don't drive onto the railway until you can see enough free space on the other side
Always obey road signs and markings	Don't blindly follow a vehicle across the railway crossing
Always switch off music systems and put away mobile phones	Don't stop on the railway crossing
Always control children and animals in your care	Don't park and leave your vehicle near the railway crossing
Always dismount if you are a cyclist or horse rider	Don't overtake another vehicle on or when approaching the railway crossing
Always shut and fasten the gates after crossing the railway	Don't play, or wear hoods or headphones, on or near the railway tracks

REMEMBER

Stop, Look and Listen

Give way to trains

Never trespass onto the railway

Have you shut the crossing gates?

THINK SAFETY

Remember, always shut and fasten the iron gates. Failure to do so is an offence and you could be prosecuted.

Pedestrians crossing the railway

- what you **should** do at unattended railway crossings



Always expect a train!

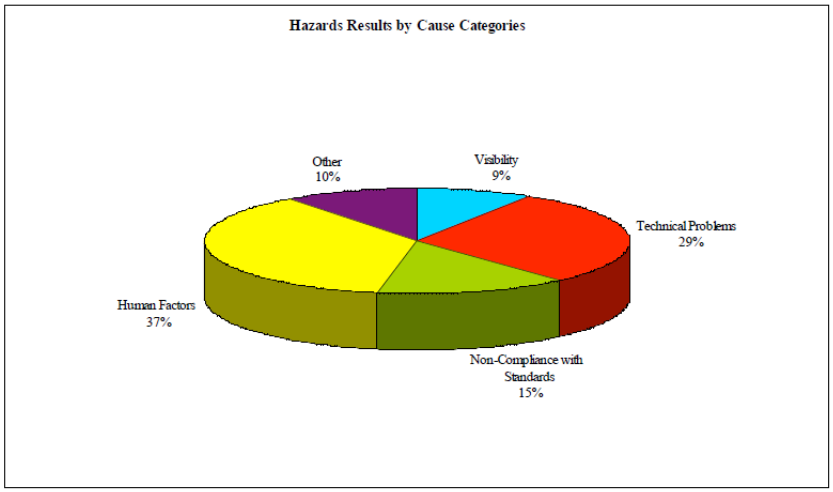
Trains can come at any time. It is dangerous to try to 'predict' when a train might come by relying on the railway schedule, a railway signal or the position of the gates at a nearby railway crossing. A railway signal of any colour, or even an attended railway crossing gate placed across the railway, cannot tell you that it is safe to cross.

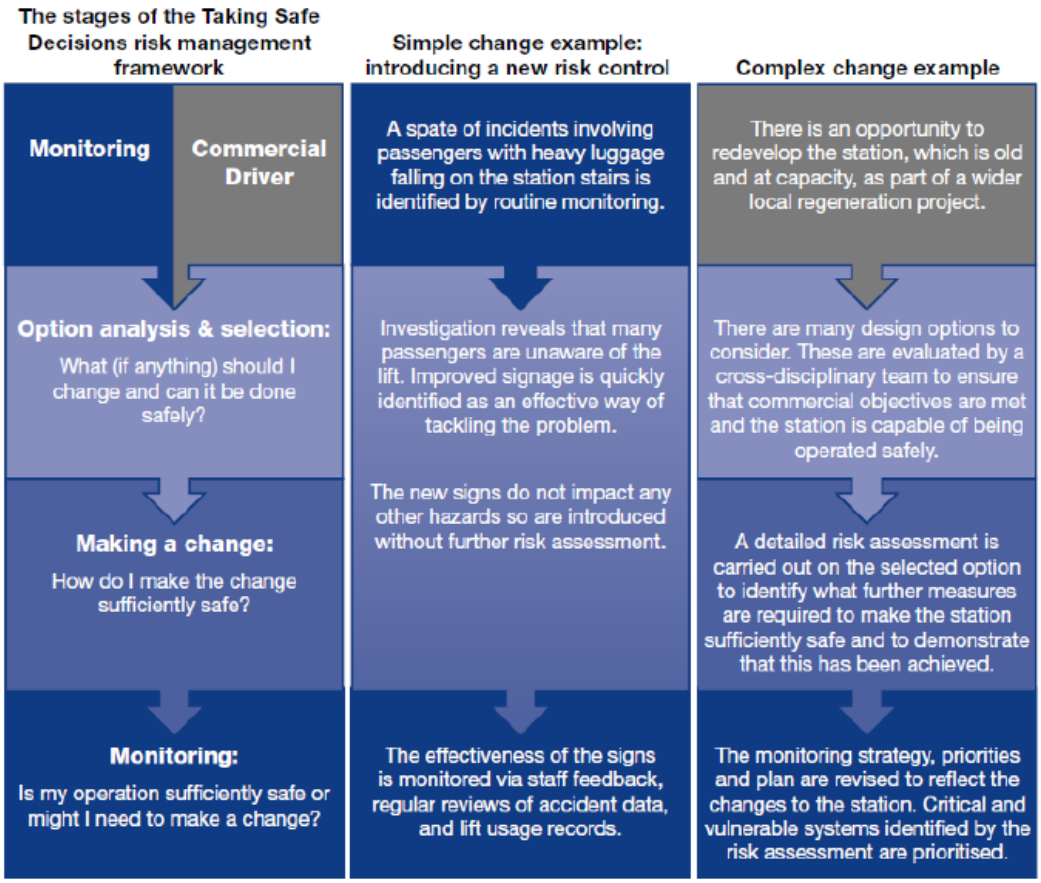
Prepare

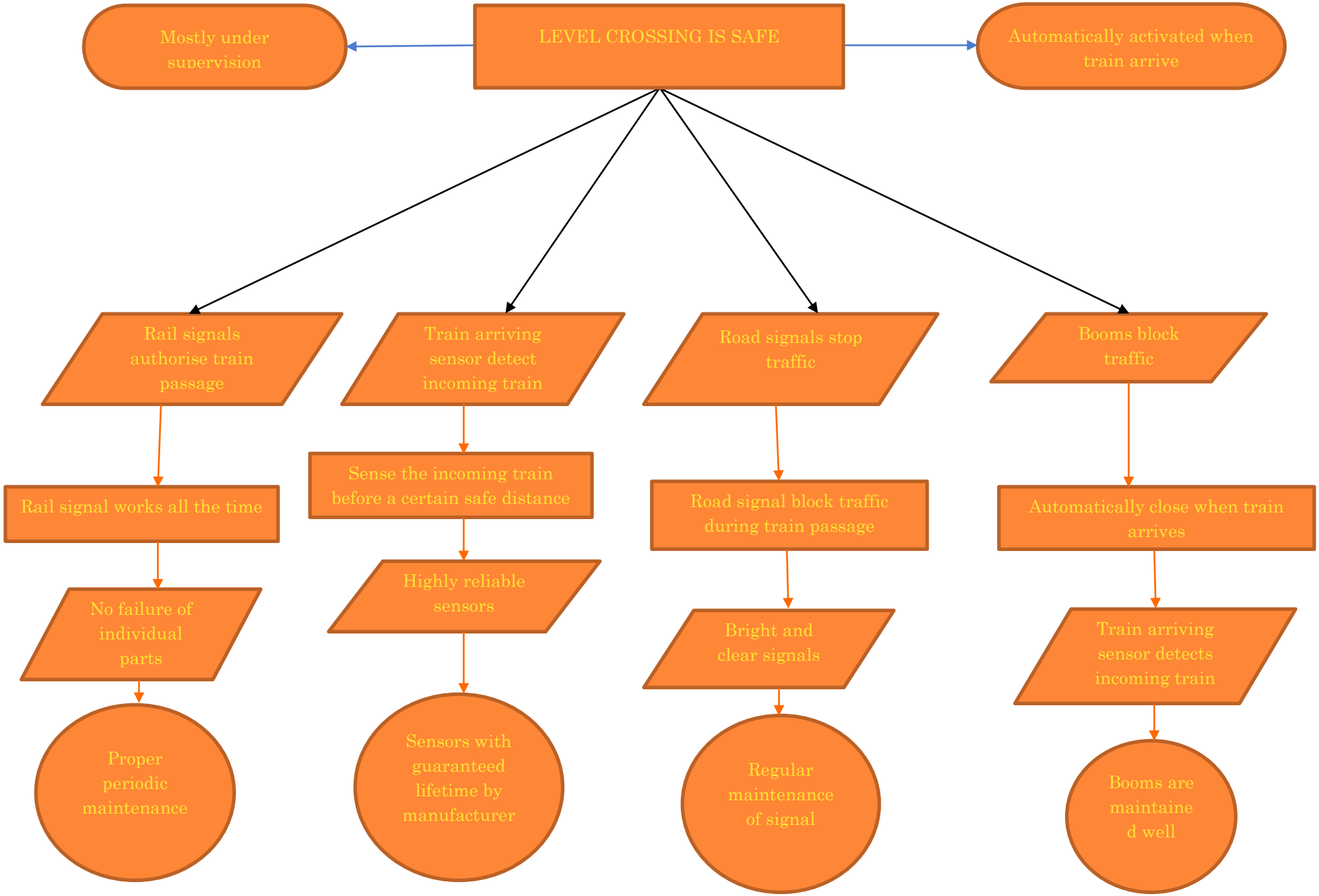
If you are crossing with a crowd of people or a herd of animals, contact the railway signalman for advice. You will find the phone number on the instruction sign at the entrance to the railway crossing.

In all cases, you must:

- Read all the signs at the crossing
- Remove your headphones, hood or any clothing that might affect your sight or hearing
- Put away your mobile phone
- Use the **Rail Cross Code** each time you cross




The stages of the Taking Safe Decisions risk management framework
Simple change example: introducing a new risk control
Complex change example
Monitoring
Commercial Driver
A spate of incidents involving passengers with heavy luggage falling on the station stairs is identified by routine monitoring.
There is an opportunity to redevelop the station, which is old and at capacity, as part of a wider local regeneration project.
Option analysis & selection:
What (if anything) should I change and can it be done safely?
Investigation reveals that many passengers are unaware of the lift. Improved signage is quickly identified as an effective way of tackling the problem.
There are many design options to consider. These are evaluated by a cross-disciplinary team to ensure that commercial objectives are met and the station is capable of being operated safely.
Making a change:
How do I make the change sufficiently safe?
The new signs do not impact any other hazards so are introduced without further risk assessment.
A detailed risk assessment is carried out on the selected option to identify what further measures are required to make the station sufficiently safe and to demonstrate that this has been achieved.
Monitoring:
Is my operation sufficiently safe or might I need to make a change?
The effectiveness of the signs is monitored via staff feedback, regular reviews of accident data, and lift usage records.
The monitoring strategy, priorities and plan are revised to reflect the changes to the station. Critical and vulnerable systems identified by the risk assessment are prioritised.


LEVEL CROSSING IS SAFE
Mostly under supervision
Automatically activated when train arrive
Rail signals authorise train passage
Train arriving sensor detect incoming train
Road signals stop traffic
Booms block traffic
Rail signal works all the time
Sense the incoming train before a certain safe distance
Road signal block traffic during train passage
Automatically close when train arrives
No failure of individual parts
Highly reliable sensors
Bright and clear signals
Train arriving sensor detects incoming train
Proper periodic maintenance
Sensors with guaranteed lifetime by manufacturer
Regular maintenance of signal
Booms are maintaine d well