European Commission

European Road Safety Observatory

Road Safety Thematic Report

Railway level crossings

This document is part of a series of 20 thematic reports on road safety. The purpose is to give road safety practitioners an overview of the most important research questions and results on the topic in question. The level of detail is intermediate, with more detailed papers or reports suggested for further reading. Each report has a 1-page summary.

Contract	This document has been prepared in the framework of the EC Service Contract MOVE/C2/SER/2019-100/SI2.822066 with Vias institute (BE) and SWOV Institute for Road Safety Research (NL).
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Referencing	Reproduction of this document is allowed with due acknowledgement. Please refer to the document as follows: European Commission (2021) Road safety thematic report – Railway level crossings. European Road Safety Observatory. Brussels, European Commission, Directorate General for Transport.
Source	The document is based on and partly cites SWOV fact sheet *Railway level crossings* of December 2020: https://www.swov.nl/en/facts-figures.

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Summary

Railway level crossing crashes

Fatalities resulting from level crossing (LC) crashes make up for a small percentage (1%) of all road-related fatalities but a large percentage (~30%) of railway-related fatalities. This makes level crossing crashes the second largest cause of death in railway fatalities. In the EU, almost 300 people die annually due to crashes on level crossings. Level crossing crashes often lead to serious or even fatal injuries on the part of level crossing users because the train is heavy, travels fast and has no means of evading them. Even though the number of crashes and the resulting casualties have annually decreased by 3% and 4% respectively, there is room for improvement.

There are two general types of level crossings: passive and active. Passive level crossings are often only equipped with warning signs, a St. Andrews cross and road markings. On these crossings, it is for the road user to determine when it is safe to cross. Active level crossings are, in addition, equipped with barriers and warning systems such as flashing lights and sounds.

In a safe system, countermeasures should prevent human error from leading to serious crashes. The fact that human behaviour plays a key role proves that the efficiency of these measures needs to be improved – this is particularly the case on passive level crossings where there are no barriers to physically prevent road users from entering the LC when a train passes. On active LC, the crash is often the result of road users trying to cross while the barriers are already closing. Some other reasons for crashes are: lack of warning lights or poor visibility of trains, crossing designs leading to stopping or stranded road vehicles, or the failure to convey the danger of the level crossing to road users. In 2016, 60 % of all LC crashes in EU-28 countries took place on active LCs. In most level crossing crashes, passenger cars are involved (45%), followed by pedestrians (22%) and heavy vehicles (20%).

Countermeasures

For passive crossings, blinking lights to the sides of LCs and an array of speed bumps combined with flashing posts in front of the LC can prevent road users from overlooking the LC. In-vehicle devices can warn drivers that they are nearing a LC. Blinking lights to the front of the train make it more conspicuous to road users.

For active crossings, sound warning systems, reduced waiting times at LCs and red light cameras can reduce illegal crossing. “Blocking back” signs can warn road users not to remain on the LC when confronted with a traffic jam on the opposite side of the LC. Camera observation also has the potential to reduce illegal crossing behaviour of pedestrians.

Object detection can be used to detect and warn the train driver about vehicles/persons still on the LC.

Campaigns might help to raise awareness about the dangers of LCs among road users.

1 Highlights

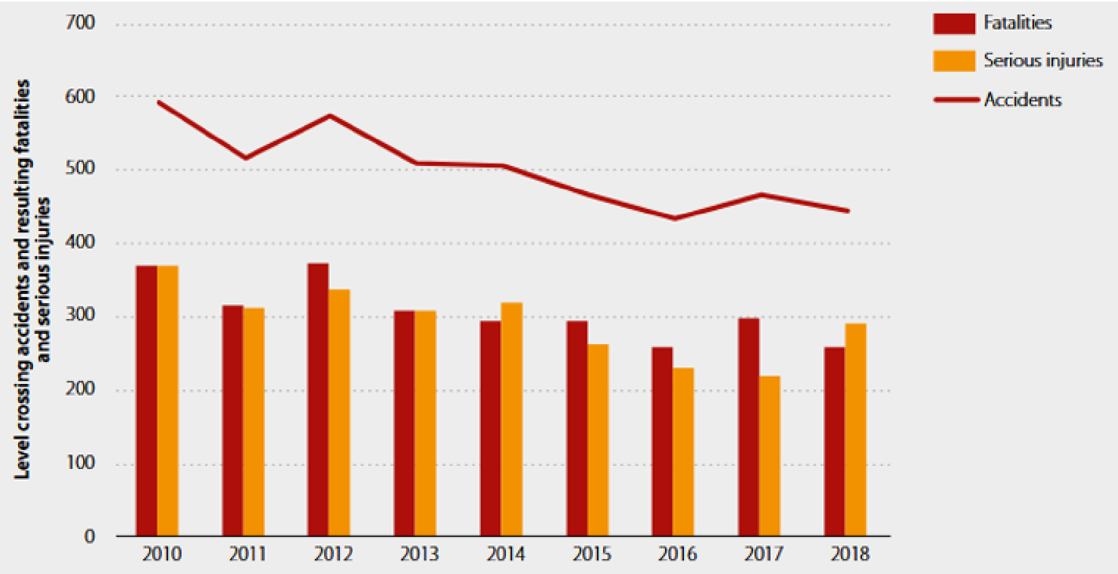
- In 2018, 29% of all railway-related deaths in the EU were caused by crashes on level crossings (Eurostat, 2020).
- Almost 300 people die annually as a result of a level crossing crash in the EU (ERA, 2020)
- In 2016, 60% of all LC crashes in EU-28 countries took place on active LCs. In most level crossing crashes, passenger cars are involved (45%), followed by pedestrians (22%) and heavy vehicles (20%).

2 What is the problem?

A level crossing (LC) is an intersection between a railway line and a road, where the train always has priority. Trains, due to their high travelling speed, are unable to stop in time in case a road user crosses when the train nears the LC. The result of a collision is often fatal for the crash opponent due to the speed and weight of the train. In 2018, 29% of all railway-related deaths in the EU were due to crashes on level crossings (Eurostat, 2020).

In Figure 1, an overview of significant LC crashes[1] and the resulting serious injuries and fatalities at LCs from 2010 – 2018 is presented. The results show that the number of crashes and casualties, on average, decreased from 2010 to 2018, an annual reduction of 3% for crashes and 4% for fatalities (ERA, 2020).

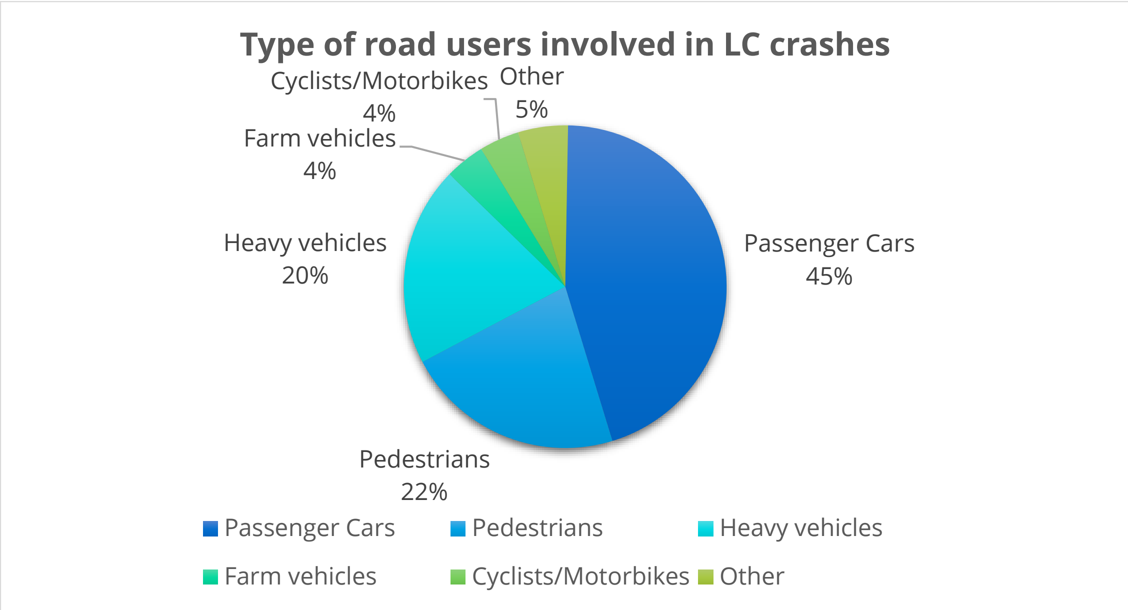
Figure 1. Level crossing crashes and resulting casualties (EU-28, 2010-2018) as reported by National Safety Authorities. Source: ERA, 2020.



[1] Crashes in which: 1) a person is seriously injured or killed, 2) the total damage exceeds €150,000,- or 3) leads to a delay of 6 hours or longer on the main railway track.

LC crashes in the EU mostly involve passenger cars (45%), followed by pedestrians (22%) and heavy vehicles (20%) – see Figure 2 (Watson, Ali & Bayatti, 2020). Despite the fact that the number of crashes at LCs is relatively low, their severity is often high compared to other crashes in terms of injury level, total damage and time loss.

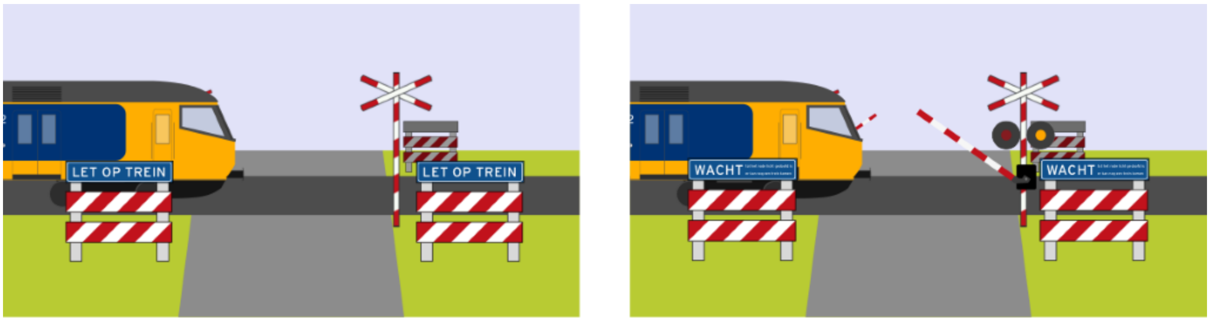
Figure 2. Share of road users involved in LC crashes in the EU (Watson, Ali & Bayatti, 2020).



3 What do level crossings look like and how are they distributed?

Level crossings are divided into active and passive level crossings. Passive LCs are often only equipped with warning signs such as a “STOP”-sign, a St. Andrew’s cross and road markings. Active LCs, in addition, are equipped with barriers, which prevent the road user from crossing when a train is approaching, and warning systems such as flashing lights and sounds (Watson, Ali & Bayyati, 2015) (see Figure 3).

Figure 3. Left: example of a passive LC with a St. Andrew’s cross and warning signs. The warning signs state: “watch out for the train”. Right: example of an active LC equipped with a St. Andrew’s cross, warning signs, light/sound warnings and halfway barriers. The warning signs state: “wait for the lights to go out, another train might pass”.



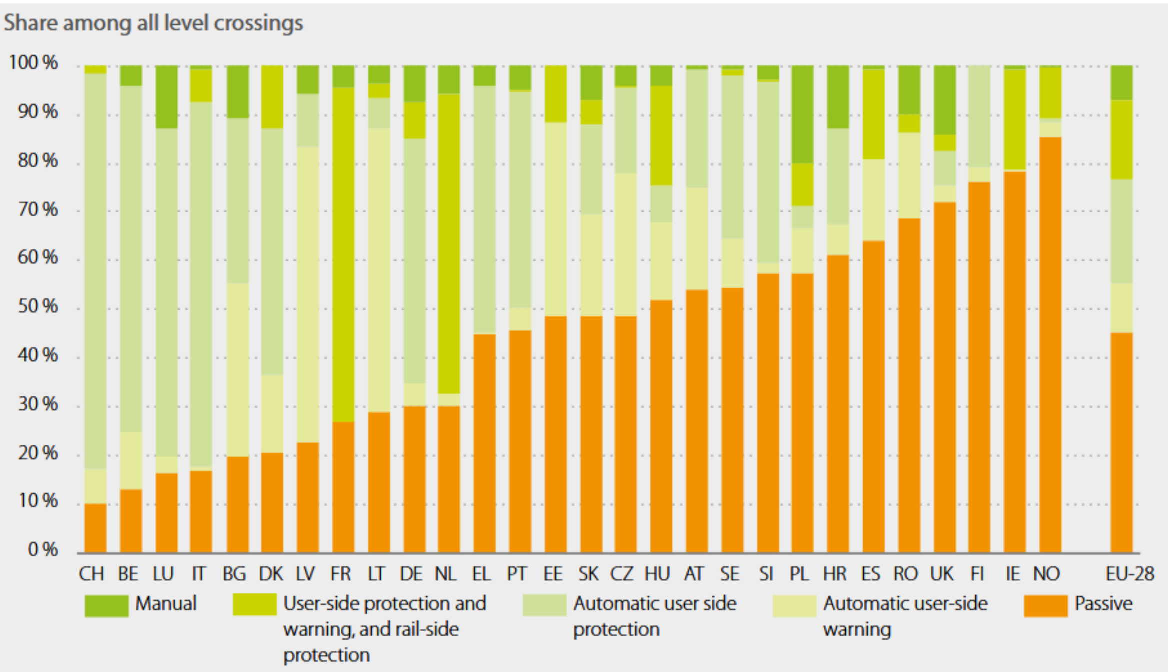
At the moment there are about 105.000 level crossings in the EU-28 countries[2], 49% of these LCs are passive (ERA, 2020). The distribution of passive and active level crossings in the EU-28 countries is presented in Figure 4.

The Active level crossings in Figure 4 are classified as: (EU directive 2014/88)

1. Manual: a level crossing where user-side protection or warning is manually activated by a railway employee.
2. Automatic with user-side warning: a level crossing where user-side protection is activated by the approaching train.
   Automatic with user-side protection: a level crossing where user-side protection is activated by the approaching train.
3. Rail-side protected: a level crossing where a signal or other train protection system permits a train to proceed once the level crossing is fully user-side protected and is free from incursion.

Large differences in the distribution of LCs can be seen between countries, Switzerland having the smallest share of passive LCs (~10 %) and Norway having the largest share (~85%). The most common type of active LC is user-side protected with barriers and flashing lights (45%).

Figure 4. Level crossings per type of protection per country as reported by National Safety Authorities. Source: ERA, 2020.



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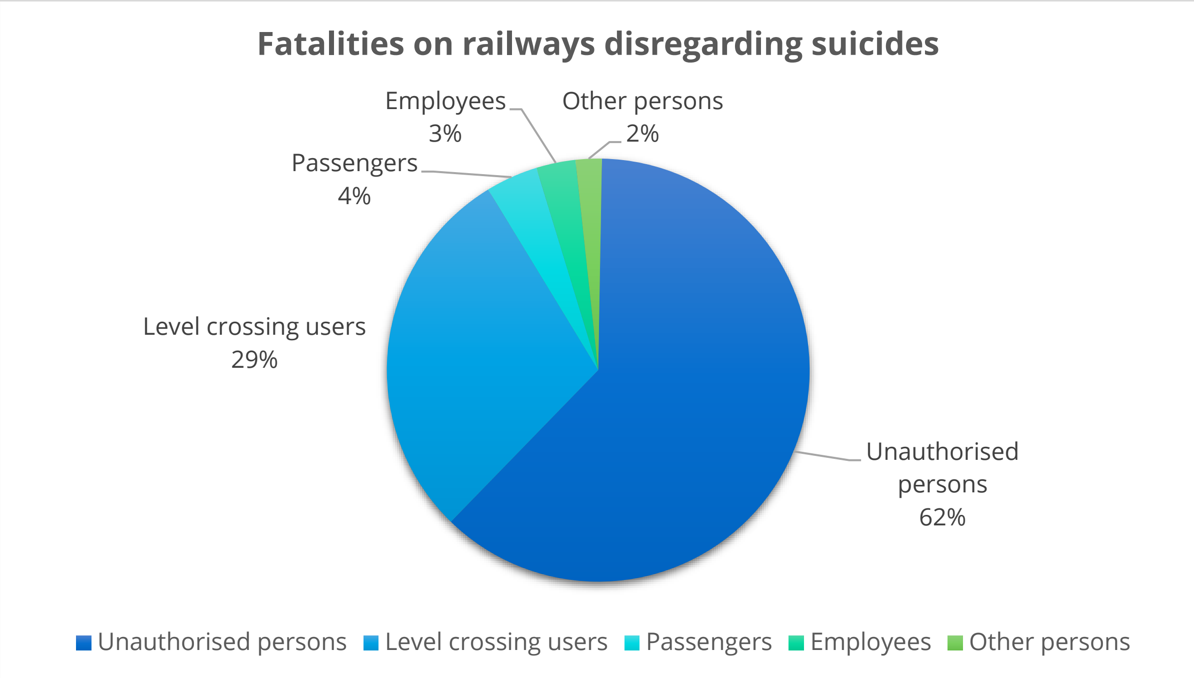
[2] Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.

4 Prevalence of crashes on level crossings

Crashes on LCs account for a limited proportion of road crashes and make up 'only' around 1% of all road fatalities (European Commission, 2020a). LC fatalities do however make up around 30% of all railway fatalities in Europe, making it the second biggest cause of death in railway-related fatalities (excluding suicides) – see Figure 5. Unauthorised persons represent the largest victim group in railway-related deaths. These fatalities occur when a person walks along or crosses the train tracks and subsequently gets hit by a train.

Figure 5. Share of fatalities per victim category among all railway fatalities in the EU from 2012 – 2016 (ERA, 2018)



5 Why do level crossing crashes occur?

5.1 Infrastructure issues

Ideally, regulations and infrastructural measures prevent human errors from leading to crashes. The fact that human behaviour plays a key role in almost all level crossing crashes (Starčević, Barić & Pilko, 2016) proves that the efficiency of these measures needs to be improved. While on passive LCs a lack of awareness can lead to a crash already; on active LCs, crashes appear to involve deliberate risk taking as one of the main causes (Joustra et al., 2018; Laapotti, 2015). In 2016, SAFER-LC reported that 40% of all LC crashes in EU-28 countries[4] took place on passive LCs (SAFER-LC, 2020). In this chapter, level crossing crashes are divided into three categories: violations, errors and technical issues.

5.2 Violations

Level crossing crashes can occur when road users violate traffic safety rules. Road users may for example try to pass under or by closed or closing barriers due to impatience. Grippenkoven, Giesemann & Dietsch (2012) found this to be the most prevalent violation. The number of these violations can be reduced by ensuring the LC does not stay closed for longer than 3 minutes (Larue, Blackman & Freeman, 2020). Especially LCs near stations tend to stay closed for longer, since the proximity of the train at the station prevents the barriers from opening. In other cases, road users cross shortly after the first train passes but before the warning lights/sounds are off, which can lead to second-train crashes (Joustra et al., 2018). A driver may also decide to enter the LC even though a traffic jam on the opposite side prevents the driver from immediately clearing the crossing. Lastly, drivers are sometimes not able to stop in time due to speeding (Joustra et al., 2018).

5.3 Errors

Level crossing crashes also occur when there are non-deliberate road user mistakes.

5.3.1 Inattention of the road user

Crashes often occur when a road user is inattentive or distracted (Joustra et al., 2018; Laapotti, 2015; Watson, Ali & Bayatti, 2020). This inattentiveness may be explained by the fact that drivers spend roughly 50% of their travel time engaging in distracting activities (SWOV, 2018). In some cases, inattentiveness results in road users failing to notice the warning lights and closing barriers, thereby ending up on the LC while the train approaches. Road users also sometimes mistakenly approach the LC on the wrong side of the road. If they do so at an LC that is equipped with halfway barriers, they are not confronted with barriers soon enough and end up on the pathway of the train. Research by Watson, Ali & Bayatti, (2020) showed that local drivers in rural areas do not recognise that the risk of rural passive crossings is high and they are often overconfident that the LC can be crossed safely. This causes them to be inattentive and not careful enough before crossing, thereby risking getting hit by the crossing train.

5.3.2 Getting stuck on the pathway of the train

In some cases, road users are unable to clear the LC in time. Pedestrians may walk too slowly (e.g. with a rollator) or fall while crossing. As mentioned before, a driver might enter the pathway of the train even though there is a traffic jam on the opposite side. If a train then approaches, the barriers will close, trapping the driver on the LC. Large and heavy vehicles sometimes have trouble clearing the level crossing in time, especially if it is preceded or followed by a sharp turn. Failing to make the turn forces the driver to manoeuvre the vehicle into position while still on the LC (Joustra et al., 2018). These errors could have been prevented if the barriers would not be permitted to close when the LC is still occupied and no sharp turns preceded or followed the LC.

5.3.3 Not seeing or hearing the train

It is important that the road user can see and hear the train approaching to decide on the safest way to proceed. The view from the road on the railway track should therefore be clear of obstructions, as obstructed sighting lines are associated with train-vehicle crashes (Laapotti, 2015). This is of particular importance to passive level crossings as the road user, while judging if it is safe to cross, is not guided by warning lights and barriers. Also the maximum speed on roads connected to passive LCs is generally higher than on roads connected to active LCs, requiring a greater viewing distance (Laapotti, 2015).

If the train is spotted too late, this can lead to crashes, especially considering that drivers generally underestimate the speed of and distance to trains (Larue et al., 2018; Watson, Ali & Bayatti, 2020). Spotting or hearing the train approaching can also be more difficult due to weather conditions, the use of headphones, mobile phones and vehicle music systems (Watson, Ali & Bayatti, 2020). However, Joustra et al. (2018) also mention situations in which the driver was consciously looking but failed to see the train. The train might not have been conspicuous enough to the driver to distinguish it from its surroundings.

5.4 Technical Issues

Lastly, technical issues can cause LC crashes. These may include technical difficulties with the vehicle of the road user, the LC itself (technical failures are unlikely but not impossible) or the user-side/train protection. For example, a car may break down on the pathway of the train, preventing the driver from clearing the LC.

6 Rules and legislation to prevent LC crashes

The Directive on EU-wide rail safety aims to enhance and maintain railway safety across the EU. The European law defines common safety indicators[3] for railway safety which are, annualy, to be reported on by Member States[4] to the European Agency for Railways (ERA) (European Union, 2016). To this end, the Member States appoint a national safety authority and investigation body for railway crashes and incidents. Most indicators pertain to the number of victims caused by crashes with railway vehicles in motion. On the one hand, crashes are divided by type (e.g. level crossing crash or derailing crash) and on the other, by casualty type (e.g. level crossing user or employee). The reported indicators are compared to common safety targets using the common safety method; the targets are the minimal safety levels that have to be achieved by the EU and each member state (European Commission, 2009). ERA then assesses and reports on whether or not the targets have been met within the EU and in individual member states. ERA develops targets and common safety methods with the aim of obviating the need for national rules by developing a single European railway area. European law does not strictly dictate how the targets are to be met, rather the system aims to continuously improve

[3] EU Directive 2016/798

[4] 26 member states that have a railway plus Norway

railway safety in general. In that sense, railway safety, and by inclusion LC safety, is governed more by guidelines than by strict regulation.

7 Countermeasures

7.1 Regulation/enforcement

The influence of camera observation, police presence and educational campaigns on illegal crossing behaviours of pedestrians and cyclists was researched in Croatia by Starčević, Barić & Pilko (2016). They found that the combination of fining bad behaviour and having a police officer present at LCs eliminated illegal crossing almost entirely. It is however costly and therefore unpractical to have a police officer present at every LC. The research also showed promising results of combining educational measures (distributing folders about the dangers of LCs) and (visible) camera observation. This reduced the number of illegal crossings at LCs by almost 60%. Furthermore, red light running cameras reduce the number of road users that run a red light at LCs (Networkrail, 2020a; Nieuwsblad.be, 2017; NOS, 2018). Camera observation at level crossings increases both traffic safety and can also be cost-effective, as a single radar installation allows for a profit estimated at more than 2 million euros per year in terms of fine income (Aoun, El Koursi & Lemaire, 2010).

7.2 Education and information

The International Level Crossing Awareness Day (ILCAD) is an awareness campaign on level crossing safety launched in 2009 and led by the UIC, the international union of railways. The aim of the campaign is to change the behaviour of road users and pedestrians so that they act safely on LCs. Each year, one of the participating countries hosts the event and shares its projects on further increasing the safety of LCs and lowering the number of crashes (ILCAD, 2020).

There are also several national campaigns: examples are the 'Bossing the crossing'-campaign in the UK, on raising awareness of the dangers of LCs for pedestrians (Networkrail, 2020b) and the 'Safe railroad level crossing' campaign in Poland on raising awareness of the dangers of level crossings and the significance of being cautious and complying with the traffic regulations (Bezpieczny przejard, 2020).

7.3 Infrastructure

As LCs represent a considerable risk for road users, closing unnecessary or unsafe LCs can increase road safety. Removing LCs is however expensive and therefore not always an option. Grade separation, which means building an over- or underpass that separates the road and rail traffic on different levels effectively removes the LC without restricting mobility in the area. If every LC were grade-separated, no level crossing crashes would take place. However building an over- or underpass again is very expensive and not always economically viable (Watson, Ali & Bayatti, 2020) or practically possible (e.g. in urban areas). Some countries choose to improve the safety of passive level crossings by removing them altogether or by adding protection in the form of barriers and light/sound warnings, thereby changing them to active LCs (Joustra et al., 2018).

Kallberg & Silla (2017) analysed whether sound warning systems could reduce the number of illegal crossings at two sites in Finland where an illegal footpath crossed the railway tracks. The systems used infrared sensors that triggered a warning message once someone passed by. At these sites, trespassing was reduced by 18% and 44%. A similar system might prove valuable for preventing illegal crossings of LCs. Reducing closing times of LCs near stations by closing the LC only when the train is ready to leave, can reduce road user impatience and prevent risk-taking behaviour (Networkrail, 2016).

Figure 6. Blocking back-sign (VRT.be, 2019).

Informing road users about the dangers of LCs by adding signs can potentially prevent crashes. In a Belgian pilot, “blocking back” signs were added to LCs (see Figure 6). Blocking back occurs when road users do not have priority past the LC due to a roundabout or traffic lights. This can make road users queue up and eventually block the pathway of the train. The sign warns the road user not to enter the pathway of the train if the queue reaches the LC (Nieuwsblad.be, 2019).

Furthermore, the SAFER-LC project identified innovative LC safety measures and piloted the ones with the most potential at eight pilot test sites. Several measures were estimated to have a high safety potential, two of which specifically relate to road infrastructure.
The first measure added blinking lights to passive LCs. The blinking lights were positioned in the peripheral vision drivers, to the left and right of the LC. These lights activated when the road user approached the LC and supported the visual scanning of tracks for approaching trains at passive LCs. Safety potential calculations suggest this measure could prevent 2 - 8% of LC crashes. Assuming a high-effect scenario in which a 20% reduction in crashes is achieved, the benefit-cost ratio (BCR) is estimated to be 1.18, which is higher than 1, indicating that the investment would then be economically sound (SAFER-LC, 2020).
The second measure added an array of speed bumps (150, 100 and 50 meters) before a passive LC. The speed bumps were coupled with red flashing posts to increase effectiveness. This safety measure has the potential to prevent 2 - 8% of LC crashes (Nordic, 2020). The costs of this measure are low (<10,000 euro per LC), the BCR for this measure however was not calculated (SAFER-LC, 2020).

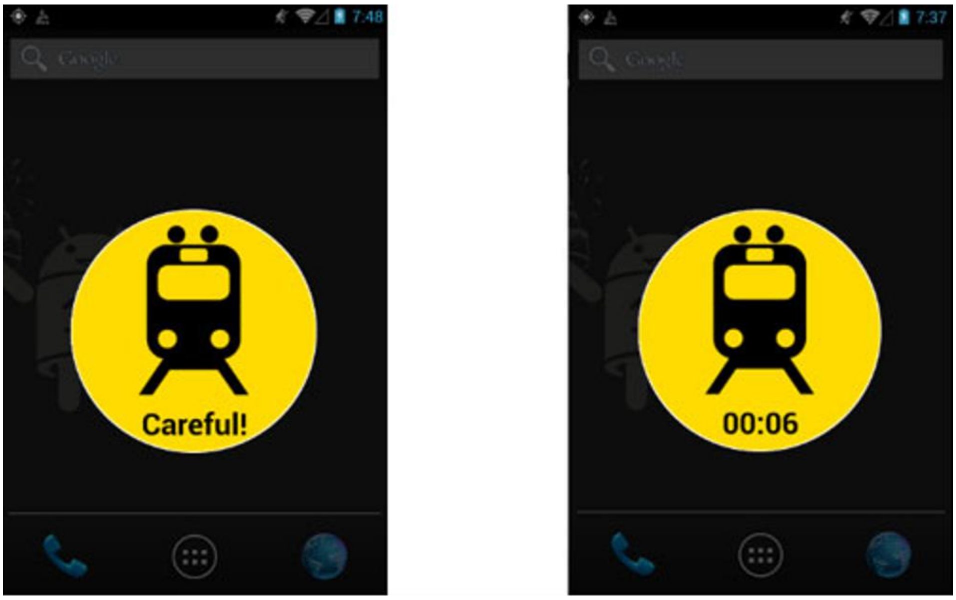
7.4 Vehicle technology

7.4.1 Cooperative Intelligent Transport Systems

Helping vehicles safely navigate railway crossings is a good example of cooperative intelligent transport services. This particular services is already harmonized by the C-

ROADS platform and deployed in the Czech Republic, see https://www.c-roads.eu/pilots/core-members/czech-republic/Partner/project/show/c-roads-czech-republic.html. Safety at LC can be increased by alerting drivers to upcoming LCs and incoming trains. Drivers receive a pop-up window and a short audio alert via an in-vehicle device when an LC is nearby. This window also alerts drivers when a train is estimated to pass the LC within one minute – see Figure 7. This measure potentially prevents 4-15% of LC crashes according to safety potential calculation within the SAFER-LC project (Nordic, 2020). BCR was calculated to be 1.11 indicating the investment would be sound (SAFER-LC, 2020).

Figure 7. Illustration of the static visual LC warning (left) and the dynamic LC warning when the train is expected to travel past the upcoming LC in 6 seconds (right) (Salanova et al., 2020; Nordic, 2020).



7.4.2 Assistance systems for train drivers

Based on their research, Dent & Marinov (2017) propose a combination of thermal imaging and LIDAR (Light Detection And Ranging) to effectively detect obstacles (e.g. a car or pedestrian) on the LC after the barriers have closed. Once the obstacle is detected, train drivers are automatically alerted, thereby enabling them to brake immediately to avoid collision or to mitigate the consequences of a crash (Dent & Marinov, 2017). It is emphasized that this detection method works best with full barriers. Halfway barriers would still allow for zigzagging behaviour of road users, thereby increasing risk and also potential injury for train passengers due to heavy braking (Dent & Marinov, 2017). Another assistance system is ERTMS ("European Rail Traffic Management System"), which is the result of a large industrial EU project aimed at improving railway safety. ERTMS helps to integrate the safety measures around the level crossing within the regular exploitation of railways, by means of speed restrictions and signaling status, thus improving the safe use of the LC (European Commission, 2020b).

7.4.3 Visibility of trains

LC safety may also be further improved by increasing the visibility of trains with the help of additional blinking lights on the locomotive. These blinking lights activate when the train approaches an LC. This potentially prevents between 6 and 30% of LC crashes (Nordic, 2020). The BCR (benefit-cost ratio) was calculated to be 1.73 which shows the investment would be sound (SAFER-LC, 2020).

8 Further reading

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