

Transport safety of Slovak Railways level crossings

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ABSTRACT

Railway transport is one of processes controlled with a certain level of risk. It is apparent that due to a limited level of our knowledge, the technical level and limited funds we cannot count on absolute safety (zero risk) but we must admit that in a real technical system some error or fault may occur and its occurrence may mean a certain risk for the controlled process. The authors focus on proposing and presenting potentially usable measures that could increase the safety of traffic operation at the level crossings operated by the ŽSR (Slovak Railways). Technical and organizational measures are discussed separately. Some of proposed measures are specific for Slovak conditions only, however, to a certain extent some findings can be generalized and possibly applied in other countries, too.

KEYWORDS: safety, level crossing, accidents, transport, ZSR, technical measures, organizational measures

1. Introduction

Currently, there are 2220 level crossings (LC) on the ŽSR railway lines. Out of this number there are 1076 level crossings equipped with level crossing signalling (LCS) and 1144 not equipped with LCSs [1].

If a level crossing is not equipped with an LCS, then the safety of road users in the area of the level crossing is assured by organisational measures. The level crossing must be unmistakably marked by a warning cross (St Andrews cross) and the driver of a road vehicle is informed by a road sign that the vehicle is approaching the level crossing. Road drivers are required by law [2] to act with extreme caution when approaching and crossing the LC and make sure that it is safe to pass the level crossing. Maximum speed limit for road users in the area 30 m ahead of the LC and on the LC is 30 km/h.

When a level crossing is equipped with an LCS, there are more ways to inform the road users about a train approaching the level crossing:

- acoustic warning (mechanical or electric device producing audible signal – a bell, horn or electronic bell);
- light warning (two red complementary flashing lights);
- mechanical warning (half-barriers across a part of the road or full barriers across the whole roadway width).

Only the LCS with a light warning as a basic warning and optional mechanical warning as a supplementary warning are discussed in the paper. Those types of LCS are used on ŽSR lines with a line speed less than 140 km/h. On lines with a line speed equal to 140 km/h or higher only the LCSs with a mechanical warning along with a light warning as a basic warning are used. The construction of new level crossings on ŽSR lines with a line speed exceeding 160 km/h is strongly discouraged (currently there is only one level crossing on the line with the line speed of 160 km/h).

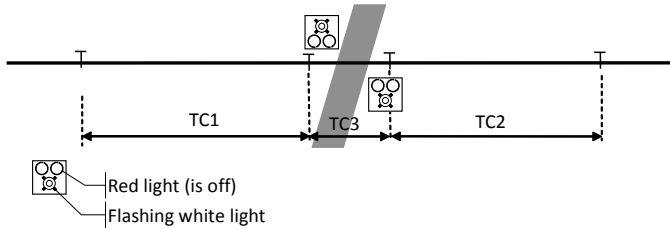


Fig. 1. Level crossing with closed track circuits
Source: [own work]

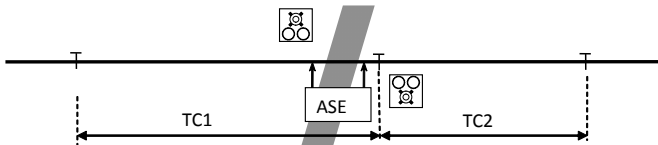


Fig. 2. Level crossing equipped with an ASE
Source: [own work]

In order to keep road users reliably informed about movements of railway vehicles in a level crossing area, it is necessary to:

- provide them unambiguous information;
- keep LCS in operation in accordance with functional specifications (standard [3]);
- achieve maximum possible availability of the system.

There are some ŽSR specific problems that need to be solved in order to fulfil these basic requirements. Some of these problems are identified in this paper.

2. LCS actuation by a train movement

A concurrent operation of LCS and technical equipment that checks up on a presence of a railway vehicle in the control section of a level crossing is required. A pass of a railway vehicle over a level crossing is also monitored. The following devices are used for these purposes:

- Continual technical equipment (track circuits, axle counters);
- Point technical equipment (rail contacts, rail loops).

2.1. Track circuits

At least three closed track circuits are needed to have road users unambiguously informed about the traffic in a level crossing area with bi-directional traffic. (Fig. 1).

The configuration shown in Fig. 1 is common for ŽSR lines, except that the middle closed track circuit that checks up on a movement of a railway vehicle over a level crossing is replaced by ASE equipment – Annulment

Electronic Set (Fig. 2). ASE equipment is composed of two partially overlapping jointless track circuits [8].

Track circuits operation depends on a drop shunt of a track, which is affected by many variables (e.g. weather, railway traffic intensity, trains weight). Low intensity secondary tracks are seriously threatened by a loss of the shunt, which causes that no warning is started before approaching train. This is the main reason that no LCSs controlled by track circuits have been built on ŽSR lines within recent at least 10 years.

2.2. Axle counters

Due to a recent strategic resolution that no new LCS controlled by track circuits shall be built, the replacement of track circuits, which were formerly used by LCS, is a current problem. The use of two axle counters with overlapping counting sections is a possible solution to this problem. Section overlapping makes checking up on a movement of a railway vehicle over a level crossing possible and subsequently, with respect to this information, a warning state of the LCS can be safely terminated.

A hazard caused by two trains running in opposite directions on a bidirectional railway track has been recognised during the analysis of various process situations (Fig. 3). Figs. 4 to 6 illustrate this problem.

Let us assume that train T1 enters track section TS1. As a consequence, LCS goes from the initial to warning state (Fig. 4.). Furthermore, let us assume that train T2 enters track section TS2. The level crossing remains in the warning state, but the LCS logic evaluates the situation as if train T1 entered section TS2, therefore occupying section TS1 as well as TS2, which does not correspond to the situation on the track (Fig. 5.). Now if due to any

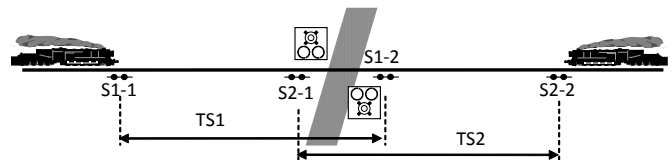


Fig. 3. Two trains running in a level crossing area – initial state
Source: [own work]

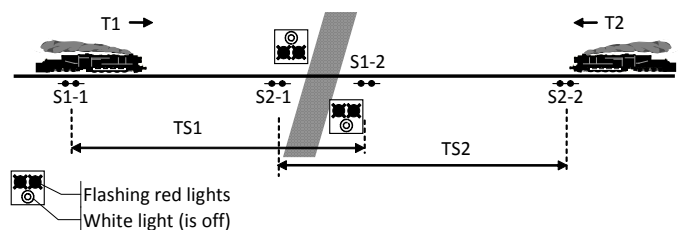


Fig. 4. Two trains running in a level crossing area – track section TS1 is occupied
Source: [own work]

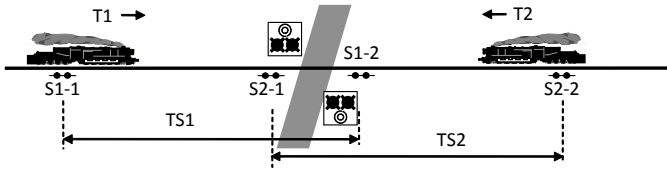


Fig. 5. Two trains running in a level crossing area – track sections TS1 and TS2 are occupied
Source: [own work]

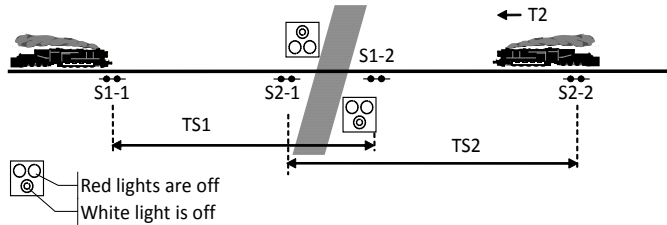


Fig. 6. Two trains running in a level crossing area – clearing of section TS1, while section TS2 remains occupied
Source: [own work]

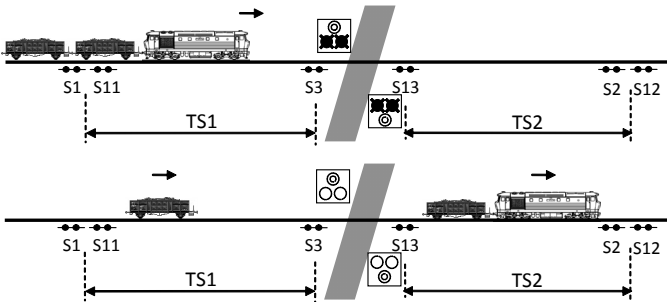


Fig. 7. LCS controlled by point devices
Source: [own work]

reason train T1 changes its direction of movement and clears track section T1, the LCS will go to the annulment state that terminates warning. Train T2 will subsequently approach the level crossing with no noticeable warning whatsoever – which is a hazardous state. A similar outcome results from the analysis of the opposite direction. This operation of the LCS is contradictory to requirements stated in the standard [3] and also with essentials of interlocking systems in general.

The risk related to the situation mentioned above could be reduced if the LCS had relevant information about a direction of running trains. On the other hand, the LCS logic must reckon with the possibility of a failure of axle counter. No possible failure of an axle counter should cause a potential hazardous situation.

2.3. Point technical equipment

The standard [3] allows the use of point technical equipment to control LCSs. However, these devices have no means to check safely the clearance of an approach section or the

movement of whole train over a level crossing. For instance, there is a chance (Fig. 7) that in the case of disconnection of a wagon(s) from the train, by the time the decoupled section enters a level crossing, it will have been in an annulling state, therefore with no warning activated (because the train have passed level crossing already). The risk resulting from this situation could be partially reduced by setting off the warning in the case of unexpected occupancy of the S3 sensor (or S13 in the opposite direction). However, the risk resulting from this situation has been rated as tolerable.

From the safety point of view it is necessary to check the direction of a train movement in the level crossing area by technical equipment (point devices in this case).

3. Active signal

An active signalisation is specific to the ŽSR. An active signal is represented by a flashing white light located on a warning board. Its sole purpose is to inform a road vehicle driver about clearance of all sections of the level crossing. There are some major downsides of the active signalisation using:

- Majority of foreign drivers are not familiar with this sort of signal.
- Standard [3] states that every LCS has to be equipped with an active signal save for exceptions declared in this standard. It is a fact, that approximately 40% of all ŽSR LCSs are not equipped with active signals. An incorrect interpretation of the previous standard (the predecessor of [3]) has led to the practice that the use of an active signal has justified insufficient range of vision on a level crossing. Former road law, that was valid until 1990, suggested that a railway company is responsible for safety of the traffic when the active signal flashes. Road users were not required to make sure if the passage through a level crossing is safe. A lot of drivers (especially older) still claim that, even though the currently binding law [2] stipulates otherwise. If there is a flashing white light activated on a warning board, it is compulsory for a driver to drive at the maximum speed of 50 km/h through a level crossing and 50 m ahead of it.
- Ambiguity in meaning of information provided to a road user. The white signal (active signal) is located on a warning board along with two red signals (basic light warning). If an LCS is not equipped with an active signal, then a disabled state of the LCS (in this state LCS is not capable of warning road users about an approaching train) could be misinterpreted as a default state (no train in the level crossing area that could endanger safety of the road traffic). Furthermore, in some cases (at night for instance) drivers are not able to distinguish whether the LCS is equipped with an active signal or not.

4. Information for a driver

There are few ways how a driver could be informed about a state of an LCS. An engine-driver could be informed via:

- an employee at an operation control point (e.g. the nearest railway station);
- a main signal;
- a special engine-driver's indication signal.
- a locomotive signal through special transmission channel (this solution is not applicable due to economical reasons).

A common drawback of these solutions (except for the last one) is that relevant information is transmitted at certain points on the track. If such a failure occurs that it prevents an LCS from launching a warning and a train has already passed a transmitting point, then the train will approach an opened level crossing.

4.1. Informing by means of an employee at an operation control point

This is the most imperfect way how to inform a driver about the state of a level crossing. Its typical use is on a track with a semi-automatic block or on a track without a line signalling system at all. An extra communication line is needed to ensure communication between an operation control point (OCP) and LCS. The employee is not only informed about the state of the LCS but also has means for a remote control (open or close) of the level crossing. If an emergency lockout of the LCS occurred due to a critical failure, the level crossing can be remotely opened only if all passing engine-drivers have been previously informed about the failure. If the train has already passed the OCP, then the level crossing cannot be remotely opened unless the train safely clears the level crossing section (this information could be sent to the OCP from the next OCP for instance). Considering the fact that the distance between the LCS and corresponding OCP is up to 20 km, another drawback to this solution is that the warning time of the level crossing could be very long.

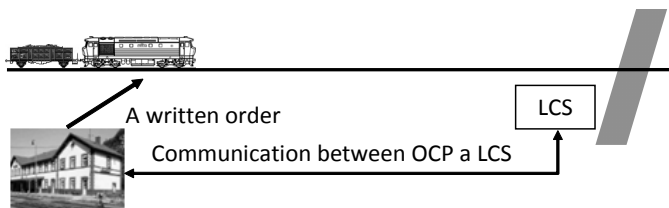


Fig. 8. Informing an engine-driver via an employee

Source: [own work]

4.2. Informing via a main signal

Solution shown in Fig. 9 is used on tracks equipped with an automatic block system. The block section signal ahead of an LC in the direction of moving trains is situated at a breaking-down distance from the LC. The section signal is coupled with the LCS. In the case of a critical failure of the LCS, the section signal shows a stop signal with permissive meaning. A similar solution is also used if the level crossing section overlaps an adjacent station section (where LCS is coupled with an entry or departure signal). In the case of a critical failure of the LCS, the absolute stop is signalled and the next train movement is possible only after a station dispatcher has given the train a permission to continue.

4.3. Informing via a gate signal

One possible solution how to avoid the possibility of the train to approach an open level crossing is to transmit the information about the LCS state the directly to the engine-driver on a locomotive. A special signal is used for this purpose – a driver's indication signal (which is sometimes referred to as a gate signal).

Former function of the gate signal was to inform a driver that the LCS went to the warning state as the train had entered the level crossing approaching section. In that case the gate signal had to be located somewhere inside the approaching section, but not closer to the level crossing than a braking distance DB . The diagram in Fig. 10 clarifies this principle. Distance DV is the minimum required signal visibility distance between gate signal and the approaching section boundary.

The solution mentioned above is safe, but it is not applicable at high-intensity traffic tracks where it could lead to problems with the train traffic schedule. The same problem arises if there is high level crossings penetration in the area or mixed passenger and freight traffic. Also the financial aspect of this solution is not negligible. Another considered problem is caused by the approaching section required length DA . Those are serious problems that discouraged the ŽSR from a wide use of this application of the gate signal.

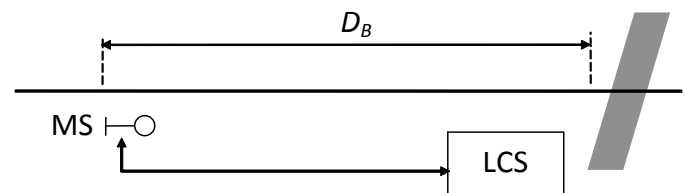


Fig. 9. Main signal and LCS coupling

Source: [own work]

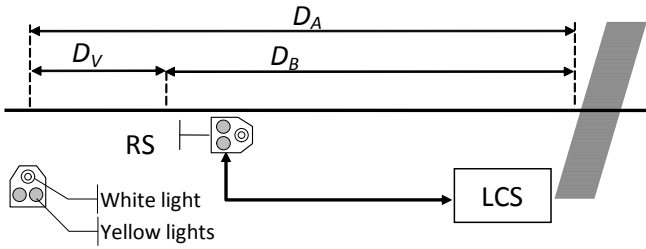


Fig. 10. Position of the gate signal inside the approaching section
Source: [own work]

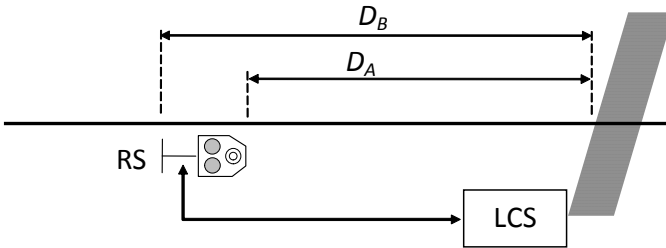


Fig. 11. Position of the gate signal outside the approaching section
Source: [own work]

Currently valid standards and laws allow the gate signal to be used in a way in which the driver is notified whether the LCS is in an operational state or not. Therefore it is possible (but not necessary) to position the gate signal outside the approaching section (Fig. 11). The requirement on minimum braking distance D_B (between the gate signal and the level crossing) still has to be fulfilled. However, in this case the length of the approaching section is independent of the distance between the gate signal and the level crossing. The advantage of this approach is obvious: the level crossing closed time can be shorter in comparison with the previous mentioned method. Another major advantage of this approach emerges when more than one level crossing is protected by just one gate signal.

A critical condition of this approach is that the LCS must start warning immediately after an approaching section is occupied. The actual level of technical equipment fulfils this requirement. An example would be the LCS with a multi-channel structure and periodic tests of a warning lights board, in which just one order from one channel is sufficient for the warning to begin. On the other hand only a few newly built LCS systems meet this condition.

The application of this solution should be well considered before using it with an older, relay based LCS systems that are used on ŽSR lines. Those systems do not facilitate any periodical checking procedures capable of checking the warning lights circuit integrity. The ability of the LCS to reach a warning state immediately after an approaching section has been occupied has to be proved by safety pass.

Figs. 12 and 13 show functions of the level crossing closed time versus both the gate signal operation and the track and road crossing angle. The level crossing closed times are valid for the LCS without barriers operating on an unidirectional track.

5. Possibilities of level crossing safety improvement

Transport safety on level crossings depends upon technical measures and organisational measures. The main task of technical measures is a risk reduction, whereas organisational measures are supposed to regulate road users and road users are supposed to adhere to these measures in return. The operation policies of a railway transport at level crossings are summarised in rules [4]. Technical requirements on LCS are specified by the standard [3].

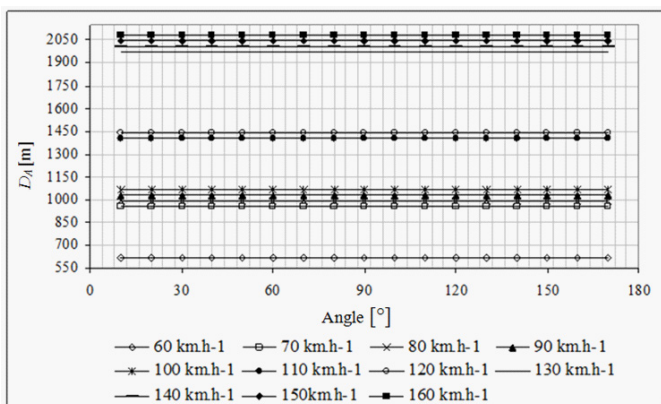


Fig. 12. The level crossing closed times when the gate signal informs about a warning state
Source: [own work]

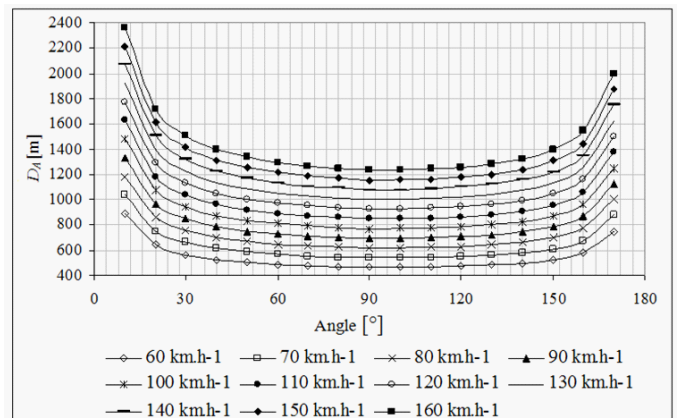


Fig. 13. The level crossing closed times when the gate signal informs about an operating state
Source: [own work]

5.1. Technical measures

All functions performed by current LCSs are realised with the level 4 of the safety integrity level (SIL4). Increasing the SIL is highly ineffective given a massive disproportion between the SIL improvement and funds needed to achieve this improvement. In addition, the improvement in SIL does not necessarily lead to the improvement in transport safety at LCs. The contribution of LCS systems failures to accidents at level crossings is insignificant – only 0.1 per cent of all accidents are caused by LCs at ŽSR. On the contrary, modifications of LCS or addition of new functions to LCS that primarily do not affect SIL in any way (do not increase technical safety) could enhance transport safety at LCs. Such modifications improve the observance of rules declared by organisational measures and also may compel road users to follow these rules. All these measures may eventually contribute to safety at level crossings or, might at least unify information (range, content, form) provided to road users. A few suggestions, how to ensure increase in transport safety at LCs, comprise:

- Installation of barriers wherever possible, even though it demands more financial resources during the whole life cycle (vandalism, maintenance). Level crossing closed time is also longer [5], nevertheless the application of barriers is well justified. Given statistics [7], the number of accidents at LCs with barriers is markedly lower as compared with the number of accidents at LCs without barriers.
- An LC should be closed for the time necessary for the longest and slowest road vehicle to pass the LC. This requirement poses a problem especially at tracks with mixed freight and passenger transport (high-speed tracks, where trains are moving with notably different speeds). If those tracks are installed with LCS with conventional approaching control principle (point starting), then the LC is pointlessly closed for an unnecessary long time when slow trains approach. Therefore road users are often tempted to cross even a closed LC. This problem could be effectively solved by means of a speed discriminator [6].
- Informing an engine-driver with the aim of minimizing a possibility of a train approach to an open level crossing. If the driver is aware of the LC failure mode, he can adjust the train speed to be able to stop ahead an unexpected obstacle. A gate signal or coupled main signal informing about an operative state of the LC (not about a warning state) could be used to cope with this problem.
- Level crossing area check by a closed-circuit TV system. This solution is practicable only if the driver is provided with relevant information about an obstacle so that he can effectively brake and stop before an

accident could happen. The reliability is the issue in this case, because false warning and consequent emergency brake activation could lead to injuries among passengers.

- Unambiguous interpretation of the information provided to road users. If there is a critical failure of a ŽSR level crossing, then the LC is closed unless the driver has been already informed about failed LC. Meanwhile the LC is in the warning state (if technically possible). If the engine-driver is informed about the failure, then the LC must not be in the warning state and it is possible to open it. The transport safety requires closed LC until the approaching driver is informed about the failed LC. He must be informed at a sufficient distance so that he can decelerate or even stop if necessary. The LC that is closed for a long time negatively affects the road drivers and leads to a situation that they cross the LC in the warning state.
- Different design of warning board layout with different signalling of the warning state is used in the countries of the EU, which leads to confusion of the foreign drivers. However that is the problem that no technology could ever solve. An active signal is a similar problem, which is the speciality of the ŽSR railways. In addition, not all LCs are equipped with warning boards with active signals; its effect to the transport safety is more negative than positive.
- High availability of the LCS that minimize the chance of a disabled state of an LC, in which safety at the LC depends only on adherence to the rules (whether by ŽSR employees or road users). There are some cases of LCs with poor geographical layout, so road user's complaints of insufficient range of vision are sometimes rightfully justified.

5.2. Organisational measures

In accordance with [2] road drivers are bound to act with extreme caution when approaching an LC and when crossing it. They are also bound to verify that the LC is safe to pass. Given this interpretation of the law it is virtually impossible to make organisational measures any stricter. An absolute verification of adherence to the organisational measures and strict disciplinary action when those measures are violated by road users are the key to the safety enhancement at level crossings. A systematic preparation and further education of users of road transport is required.

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