Guarantee of constant train approach warning time at level crossing system

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ABSTRACT

This paper deals with an optimisation problem of train approach warning time at an automatic level crossing system. It discusses possibilities for reducing the train approach warning time and benefits resulting from speed discriminators application

KEYWORDS: level crossing, train approach warning time, speed discriminator, safety

1. Introduction

Level crossing of railway and road traffic always was and also will be a problematic place for both types of traffic. Road transport user's wrong reaction, as as a result of long waiting time in front of the closed level crossing is one of factors influencing the traffic safety. The waiting time mostly depends on two factors:

- Geometric configuration of the level crossing;
- Line speed.

Both of these two factors have cardinal influence on the train approach warning time and the length of resulting approach section.

The geometric configuration of a level crossing is fixed. Its change is problematic and in most cases not possible.

The length of the approach section (distance of a control place from a level crossing, where warning at the level crossing system (LCS) is activated), is calculated based on the maximum speed of a train (line speed) in the crucial section before the level crossing. For this reason, level crossings for trains approaching at a speed slower than the maximal will be closed longer than necessary. The more trains velocities differ, the longer is the excessive waiting time for road transport users at level crossings.

The traffic on railway is not homogeneous, trains move at different speeds. Although speed differences are not so important now, in the future they could considerably change with the application of technologies provided to drive at higher speeds.

Most of the traffic accidents are caused by non-respecting of the warning signal and passing a closed level crossing. Long waiting times at level crossings do not only have negative effect on the road traffic flow, but also influence car drivers psychology to cross level crossing even when warning is activated. Therefore the reduction of excessive closing time of level crossings can contribute to general safety at level crossings.

This is the reason why for warning activation we should not use the approach warning time, which is calculated based on the line speed. We should rather consider reducing the approach warning time, depending on the instantaneous speed of the train. A device, which takes this

into account, is named a speed discriminator (SD). The implementation of this device can result in the level crossing closing for a time, which is almost constant for different speeds of the train. SD would contribute to increasing the flow and road traffic safety.

The principle of speed discriminator operation is not new. In the past, a suitable technologic solution, which would provide the realization of speed discriminator on required safety and reliability level did not exist. Today, such resources already exist, but it is debatable, if the SD is still applicable.

2. Principle of speed discriminator operation

The information about instantaneous speed of the train in a crucial section before the level crossing is the main information input for correct SD operation. On the basis of this information (and other information), SD determines the point on the railway line or time moment, where the warning at the level crossing is activated. Speed discriminators can work on different principles:

- Choice of fixed operating point principle [1];
- Warning delay activation principle [1];
- Warning in advance activation principle;
- Train speed continuous control principle.

2.1. Systems working on the choice of fixed operating point principle

"SDs with choice of fixed operating point" determine speed of the train before the level crossing generally by measuring the passage time trough the section of well-know length. Then according to measured speed of the train they choose one of the predetermined operating points so that its distance from the level crossing is longer or at least equal to the relevant distance corresponding to the directive time for measuring the length of reduced approach section. Speed discriminators of this type do not fulfil the condition of constant approach warning time to the point, but try to maximally approach it. The condition for correct SD operation is that after the speed determination the train is forbidden to accelerate. "Systems with choice of fixed operating point" are already obsolete today and not used anymore at modern railways.

2.2. Systems working on the warning delay activation principle

These are autonomous devices working on "warning delay principle" for trains going at lower speeds than the line speed. In contrast to "systems with choice of fixed operating point", "an SD with warning delay activation" realizes

the constant approach warning time in an ideal case, where the ideal case is a constant approach speed of the train in the crucial section before the level crossing. "SD with warning delay activation" formerly worked on: disc cam principle, electromechanical principle, stepping switch principle or Miller integrator principle. The SD developed by Westinghouse Rail Systems Ltd (WRSL), which is applied in the UK under the name of WESTeX level crossing predictor, is representative of current systems. WRLS developed this system with aim to reduce the investment costs for LCS implementation. WESTeX is described in more detail in [2].

2.3. Systems working on the warning in advance activation principle

As a complement to the previous solution we can consider advancing of warning. SD that works based on this principle is a device interacting with trains going at higher speeds. In the case of a slow train, the warning is activated like usual, by means of the predetermined activation point. In the case of a fast train, the warning will be activated in advance, i.e. so it will guarantee that the level crossing is closed before this train arrival.

2.4. Systems working on the train speed continuous control principle

The specific case of "SD with warning delay activation" are "systems working on train speed continuous control principle". The speed of the train is continuously checked in the whole section before the level crossing. When the train reaches the distance from the level crossing, where train's current speed still allows a safe passing of the level crossing before the train arrival for the slowest and the longest vehicle, the warning at the level crossing is activated. After the warning activation moment, the train acceleration is forbidden.

3. Analysis of SD application relevance

A positive result of SD application should be shown by a sharp reduction of waiting times for road transport users in the case of slow trains. For this reason, the analysis has to be focused on increasing the warning time duration at LCS depending on the speed of the train. The analysis has to be done for different types of level crossings. Not only the area of level crossing arrangement, but also the speed conditions of the track have to be analyzed.

The total time of level crossing closing depends also on the length of the train. Because trains have different lengths, the directive value for analysis is the warning time duration at level crossing, from the LCS influence

**Table 1. Parameters of the level crossing**

n	number of lines	1
Dn [m]	dangerous area boundaries distance	5
α [°]	crossing angle of road and railway line	60
S_j [m]	width of road traffic lane	5
$D2$ [m]	road warning board axis distance before the level crossing from the dangerous area	1,5
$D7$ [m]	face distance of road warning board lights from its axis	1
$D8$ [m]	car distance from face of road warning board lights	1
v_t [km.h^{-1}]	line speed	80
–	type of mechanical warning	without barrier
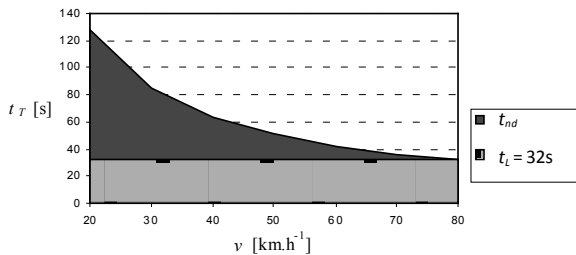
Fig. 1. Warning time duration at LCS for considered level crossing
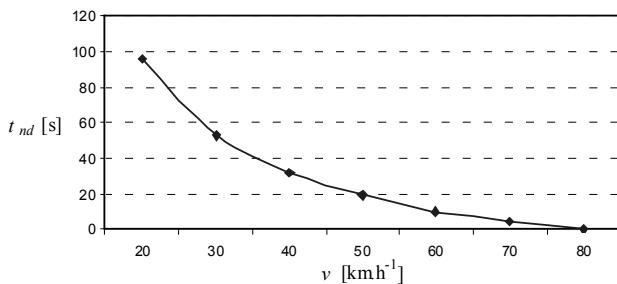
Fig. 2. Excessive warning time duration for considered level crossing
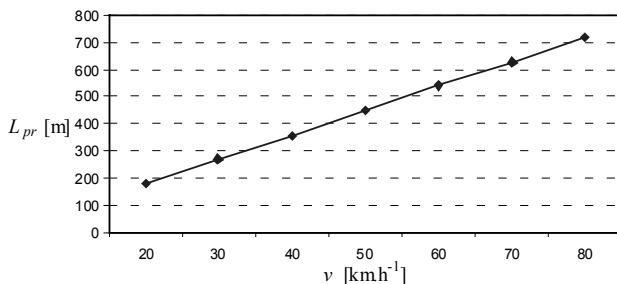
Fig. 3. Length of reduced approach section for considered level crossing

moment, to the moment when the train enters the level crossing area (from the moment when the train enters the approach section to its level crossing boundary arrival). Formulas used for directive lengths and times for specific different types of level crossings calculation are published in the standard [4]. Example calculations for three specific level crossings are presented below.

3.1. Level crossing of a single track line with 80 km.h^{-1} line speed

In this case the considered level crossing is situated at a single track line with 80 km.h^{-1} line speed. The level crossing is equipped with LCS without barriers. The crossing angle between the railway line and the road is 60°. The axis of road warning board is 1.5 m from the dangerous area. LCS is not equipped with barrier signals. All values describing the geometric arrangement of level crossing considered that are necessary for monitored values calculation are defined in table 1. Level crossing parameters in table 1 are marked with symbols according to the standard [4].

Warning time duration t_T versus the train speed is shown in fig.1. The grey part of graph corresponds to the directive time t_L for the length of approach section calculation. The red part of graph corresponds to the excessive time of level crossing closing t_{nd}. The dependence of excessive time of level crossing closing (warning duration) on the train speed is separately shown in fig. 2.

For the safety purpose it is sufficient, that warning at LCS is activated when the train enters the reduced approach section, which length is not set on the basis of the line speed, but is set on the instantaneous speed of the train basis. The length of the reduced approach section L_{pr} versus the train speed is shown in fig. 3.

3.2. Level crossing on a double track line with 120 km.h^{-1} line speed

In this case the level crossing considered is situated on a double track line with 120 km.h^{-1} line speed. The level crossing is equipped with LCS with half-barriers. The crossing angle between the railway line and the road is 40°. The axis of road warning board is 1.5 m from the dangerous area. LCS is equipped with barrier signals, which inform the approaching train's engine-driver about the operating status of LCS. All values describing the geometric arrangement of level crossing considered that are necessary for monitored values calculation are defined in table 2. Parameters of the level crossing considered in table 2 are marked with symbols according to the standard [4].

Warning time duration t_T versus the train speed is shown in fig. 4. The grey part of graph corresponds to directive time t_L for the length of approach section calculation.

**Table 2. Parameters of the level crossing**

n	number of lines	2
Dk [m]	axis distance of neighbor railway lines	5
α [°]	crossing angle of road and railway line	40
Db [m]	length of barrier	3,5
β [°]	crossing angle of barrier and road axis	40
S_j [m]	width of road traffic lane	5
$D2$ [m]	road warning board axis distance before the level crossing from the dangerous area	1,5
$D7$ [m]	face distance of road warning board lights from its axis	1
$D8$ [m]	car distance from face of road warning board lights distance	1
v_t [km.h^{-1}]	line speed	120
–	type of mechanical warning	half-barrier
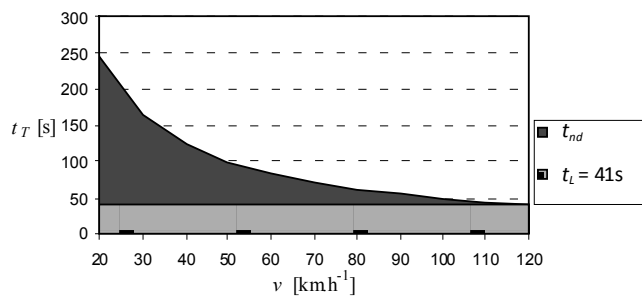
Fig. 4. Warning time duration at LCS for considered level crossing
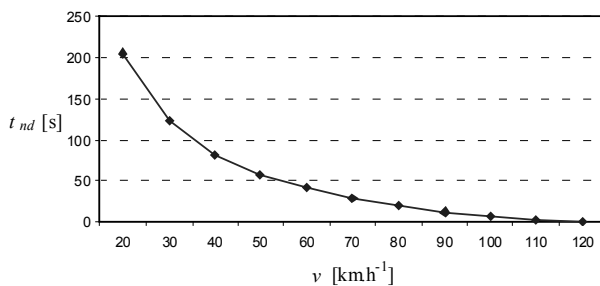
Fig. 5. Excessive warning time duration for consider level crossing
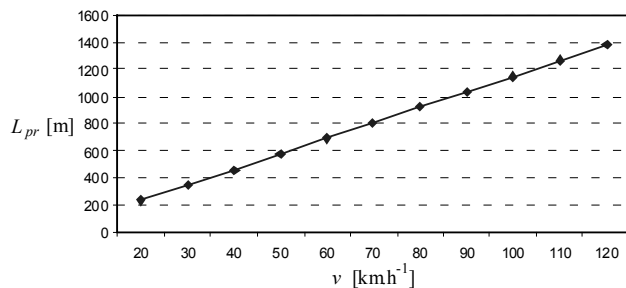
Fig. 6. Length of reduced approach section for considered level crossing

The red part of graph corresponds to the excessive time of level crossing closing tnd. The dependence of excessive time of level crossing closing (warning duration) on the train speed is separately shown in fig. 5.

For the safety purpose it is sufficient, that warning at LCS is activated when the train enters the reduced approach section, which length is not set on the basis of the line speed, but is set on the instantaneous speed of the train basis. The length of the reduced approach section L_{pr} versus the train speed is shown in fig. 6.

3.3. Level crossing of double track line with 160 km.h^{-1} line speed

In this case the level crossing considered is situated on a double track line with 160 km.h^{-1} line speed. The level crossing is equipped with LCS with full-barriers. The crossing angle between the railway line and the road is 90°.

The axis of road warning board is 1.5 m from the dangerous area. LCS is equipped with barrier signals, which inform the approaching train's engine-driver about the operating status of LCS. All values describing the geometric arrangement of level crossing considered that are necessary for monitored values calculation are defined in table 3. Parameters of the level crossing considered in table 3 are marked with symbols according to the standard [4].

Warning time duration t_T versus the train speed is shown in fig. 7. The grey part of graph corresponds to directive time t_L for the length of approach section calculation. The red part of graph corresponds to the excessive time of level crossing closing tnd. The dependence of excessive time of level crossing closing (warning duration) on the train speed is separately shown in fig. 8.

For the safety purpose it is sufficient, that warning at LCS is activated when the train enters the reduced approach section, which length is not set on the basis of the line speed, but is set on the instantaneous speed of the train basis. The length of the reduced approach section Lpr versus the train speed is shown in fig. 9.

4. Conclusion

In general, we can say that excessive warning time duration depends on two parameters. In the first place it is the train speed (difference between line speed and instantaneous speed of the train). In the second place it is the length of the approach section as a result of configuration of the level crossing (type of barrier, number of lines, crossing angle …). The dependence of excessive time for a level crossing of a double track line with 160 km.h^{-1} line speed is shown in fig. 10.

**Table 3. Parameters of the level crossing**

n	number of lines	2
Dk [m]	axis distance of neighbor railway lines	5
α [°]	crossing angle of road and railway line	90
Db [m]	length of barrier	3,5
β [°]	crossing angle of barrier and road axis	90
$\check{S}_j$ [m]	width of road traffic lane	5
$D2$ [m]	road warning board axis distance before the level crossing from the dangerous area	1,5
$D3$ [m]	road warning board axis distance behind the level crossing from dangerous area	1,5
$D7$ [m]	Face distance of road warning board lights from its axis	1
$D8$ [m]	car distance from face of road warning board lights distance	1
v_t [km.h^{-1}]	line speed	160
–	type of mechanical warning	full-barrier
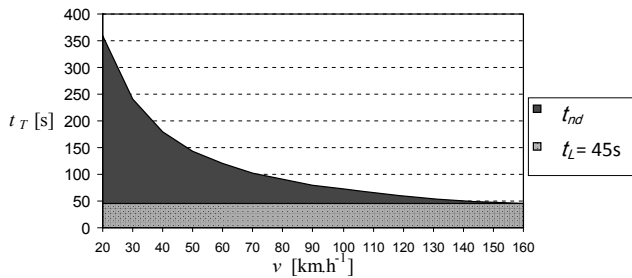
Fig. 7. Warning time duration at LCS for considered level crossing
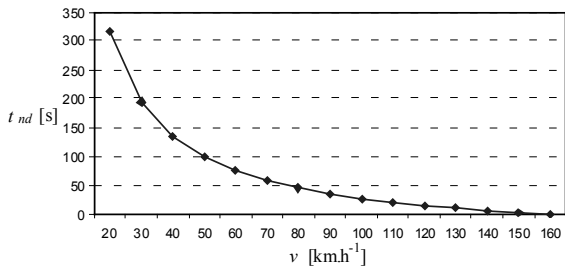
Fig. 8. Excessive warning time duration for considered level crossing
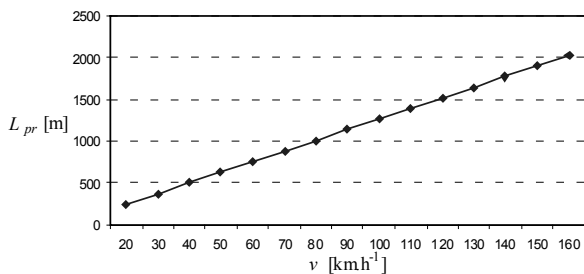
Fig. 9. Length of reduced approach section for considered level crossing

Results of analysis have shown that:
- for regional traffic lines (low traffic lines) where there is a low intensity of railway traffic and difference between speeds of trains is not large, benefits resulting from SD application is minimal;
- for main lines, for which combined traffic and high intensity of railway traffic is characteristic, SD application can considerably contribute to the increase in road and railway traffic safety and hence to the increase in the road traffic flow.

SD application is important for railway lines, where trains drive at different speeds. SD has to respond to instantaneous speed and direction of the train in the approach section while respecting principles of safety-related technology. Advantages of SD implementation become evident especially in the increase in road traffic safety and flow.

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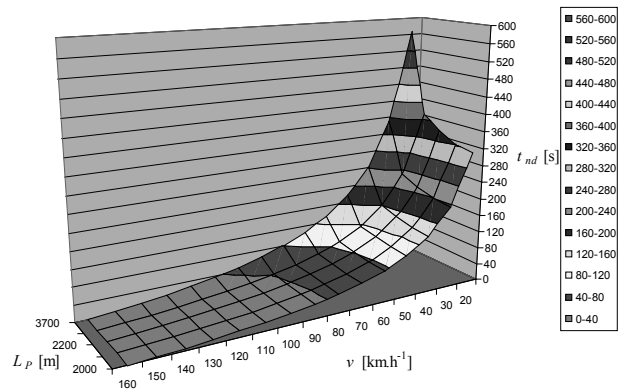
Fig. 10. Excessive warning time duration vs. the train speed and the length of approach section