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First light barriers at level crossings in the Czech Republic

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Abstract

Number of accidents at level crossings in the Czech Republic remains constantly high, particularly at crossings protected with warning lights without additional barriers. Inspections revealed wide range of safety defects here, namely visibility problems. One of possible solutions is modern device called light barrier; it improves conspicuousness of level crossing, enhances significance of warning lights, and increases vigilance of drivers. Currently, the device is used in larger extent only in Austria, serving as cheaper alternative of complementary mechanical barrier.

In the Czech Republic, the light barrier was experimentally installed at three level crossings within R&D project “Research on the applicability and effectiveness of the so-called light barrier at level crossings in the CR” (the project supported by Technology Agency of the CR). After three years of monitoring, we can confirm that the device is effective in terms of influencing drivers’ behaviour and safety. Functional reliability and resistance to winter maintenance or heavy traffic proved to be satisfactory, as well as public acceptance of the light barrier.

Introduction

Inspections of level crossings and researches aimed to circumstances of level crossing accidents in the Czech Republic revealed frequent occurrence of visibility problems and at many crossings also inadequate level of protection. One of the solutions for both problems is so called light barrier. The device, originally defined in Austria, is able to serve as cheaper alternative to mechanical barriers and improves the conspicuousness of level crossing in terrain significantly. Within SVEZA project (Research on the applicability and effectiveness of the so-called light barrier at level crossings in the CR), new possibilities of use are explored and conditions of application of light barrier in the Czech Republic investigated, including concrete technical arrangements.

1 SITUATION IN THE CZECH REPUBLIC

1.1 Number of level crossings, categories of protection

The Czech Republic belongs to the countries with the highest density of both road and railway net and so is the level of intersection of both transport modes: on the area of 78 867 km^2, we can find, only under maintenance of SŽDC, 8041 level crossings. Most of them (4298, 53,5%) are protected only with Andrew's cross and the stop sign; 2182 (27,1%) level crossings have warning lights, 1150 (14,3%) warning lights with barriers, 375 (4,7%) mechanical barriers and 36 (0.4%) other kinds of barriers (Railway Infrastructure Administration, situation to 31st December 2013). There are also level crossings administered by private operators; these crossings are not systematically registered in any database, their number is estimated at several thousands.

1.2 Accidents

According to the total and relative numbers, the most risky seem to be the level crossings with warning lights without additional barriers (see tables 1 and 2); the riskiness of the level crossings with Andrew's cross should not be nevertheless underestimated. Although the relative number of accidents and namely the consequences are not so high and serious as in the case of level crossings equipped with warning lights without barriers, their small transport importance must be considered, as well as lower track speed.

Table 1. Accidents at level crossings in CR 2013 by type of protection

2013	number of level crossings		number of accidents		number of injuries		number of fatalities	
Andrew's cross	4298	**53,5%**	81	45,0%	28	32,2%	4	17,4%
Warning lights without barriers	2182	27,1%	82	**45,6%**	45	**51,7%**	12	**52,2%**
Warning lights with barriers	1150	14,3%	17	9,4%	14	16,1%	7	30,4%
Mechanical barriers	375	4,7%	0	0,0%	0	0,0%	0	0,0%
Other protection	36	0,4%	0	0,0%	0	0,0%	0	0,0%
Total	8041	100,0%	180	100,0%	87	100,0%	23	100,0%

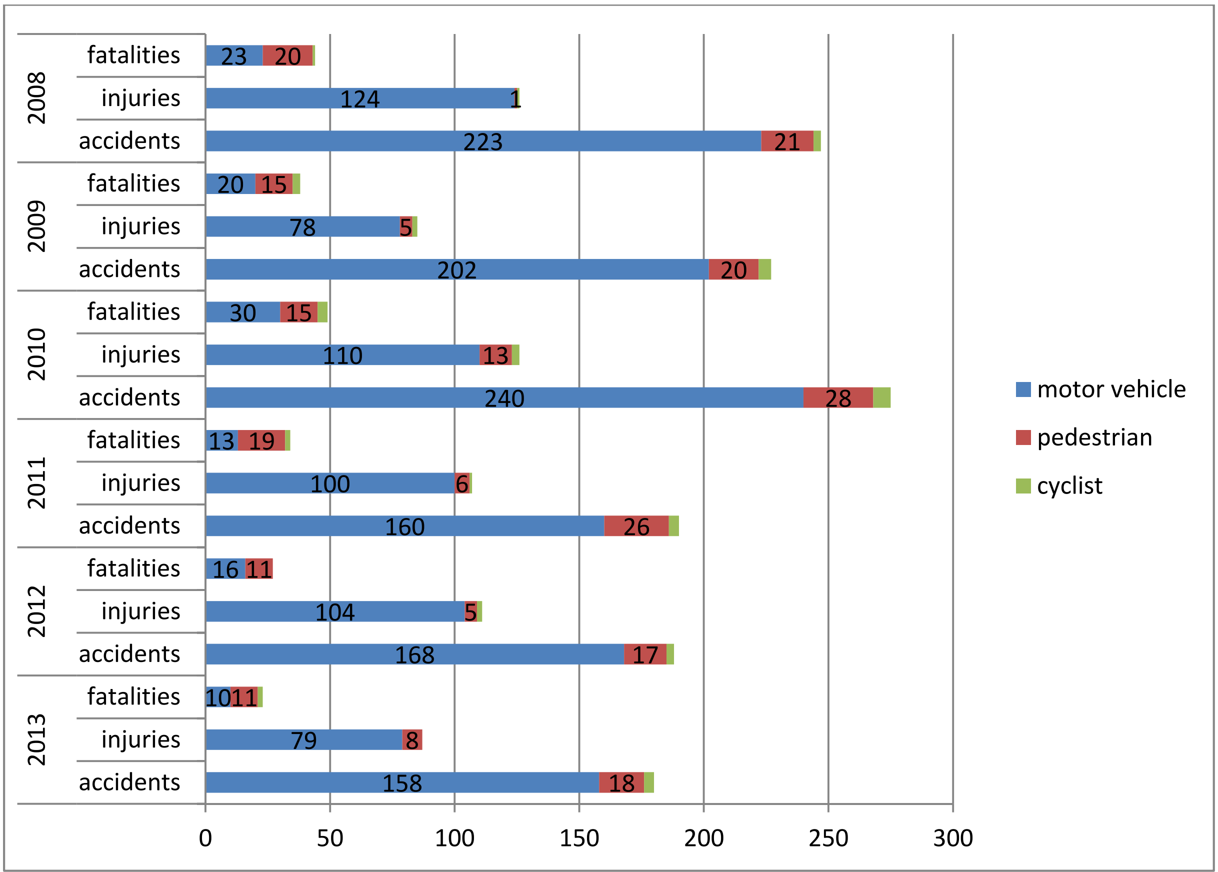
(Source: Rail Safety Inspection)

Table 2. Accidents at level crossings in CR 2008 – 2013 by type of protection

2008 - 2013	number of accidents		number of injuries		number of fatalities	
Andrew's cross	591	**45,2%**	217	33,8%	46	21,4%
Warning lights without barriers	590	**45,1%**	394	**61,4%**	116	**54,0%**
Warning lights with barriers	123	9,4%	31	4,8%	51	23,7%
Mechanical barriers	3	0,2%	0	0,0%	2	0,9%
Other protection	0	0,0%	0	0,0%	0	0,0%
Total	1307	100,0%	642	100,0%	215	100,0%

(Source: Rail Safety Inspection)

Figure 1. Accidents at level crossings in CR 2008 – 2013 by road users



(Source: Rail Safety Inspection)

1.3 Inspections and investigations: the most frequent defects of level crossings, accident factor

Regarding the actual development of accident rate at the time, researches concerning safety parameters of level crossings were initiated in 2008. AGATHA project (Analysis of situation in level crossings safety and proposal of measures) included, among other activities, safety inspections of about 60 selected level crossings and analysis of 10 black spots.

The inspections revealed wide range of defects in road signing and marking, adequacy of protection, layout and maintenance of level crossings, combined with the presence of erring human factor. From road user's point of view, most of these defects show as variety of visibility problems: obstacles in view, view point too close to the crossing, "invisible" crossing, wrong position or poor luminance of warning lights, acute angle, or optical delusion. Also analysis of testimonies of level crossing accidents survivors, carried out in frame of following project ARIANA (The research of drivers' motivation for traffic rules' breaking in proximity of level crossings, and survey of further possibilities of automatic camera systems for prevention and repression), proved the visibility problems as frequent accident factor.

There exist many solutions of visibility problems, from basic maintenance through improvement of traffic signing and marking to technological solutions. One of them is so called light barrier. The idea has the origins in Austria, where the device is defined in legislation and only here we can find dozens of applications. Within current SVEZA project (Research on the applicability and effectiveness of the so-called light barrier at level crossings in the CR), new possibilities of use are explored and conditions of application of light barrier in the Czech Republic investigated, including concrete technical arrangements.

2 LIGHT BARRIER

2.1 General description and conditions of use

Technically, the light barrier is another form of the additional warning, just like the acoustic signal or the mechanical barrier in addition to the basic warning signal. It is a device consisting of the set of red traffic light studs placed crosswise on the road surface before a level crossing. These studs light up flashing red lights simultaneously with the basic warning lights, creating an optical barrier in front of approaching vehicles. The light barrier is activated by non-potential contact of the crossing signaling device relay, which gives information to the electronic control unit of the light barrier that warning lights at the level crossing were initiated. The circuit of the light barrier is safely separated from the crossing signaling device so that in case of any failure of the light barrier, the basic warning light signal of the crossing signaling device cannot be affected.

Light barrier is primarily aimed to car drivers [5] for its optimum visibility from the position of driver, but it is helpful also for other road users. Installation of the device is advisable namely at level crossings with following features:

- The level crossing is inconspicuous in the terrain (e.g. a track in a cut, complex urban environment with many stimuli, etc.) and there is the risk of overlooking basic warning lights,
- Direct road line, high speeds, wide open view through a level crossing,
- Risk of overlooking the basic warning lights due to low sun (especially when the road intersects the track in east-west direction),
- Great importance of road transport and low importance of railway, which may decrease vigilance of drivers toward rail traffic.

Although light barriers were originally used as a cheaper option for additional mechanical barriers at level crossings secured by warning lights, in the Czech Republic, our research team in frame of SVEZA research project is testing the hypothesis that the use of light barriers can be effective also at level crossings with warning lights and complementary mechanical barriers.

2.2 Technical parameters

Standard light barrier consists of five traffic light studs, and in case of narrow roads without dividing line, we can also find light barriers consisting of four studs. Studs are usually placed 20 cm before continuous transverse line (see figure 2).

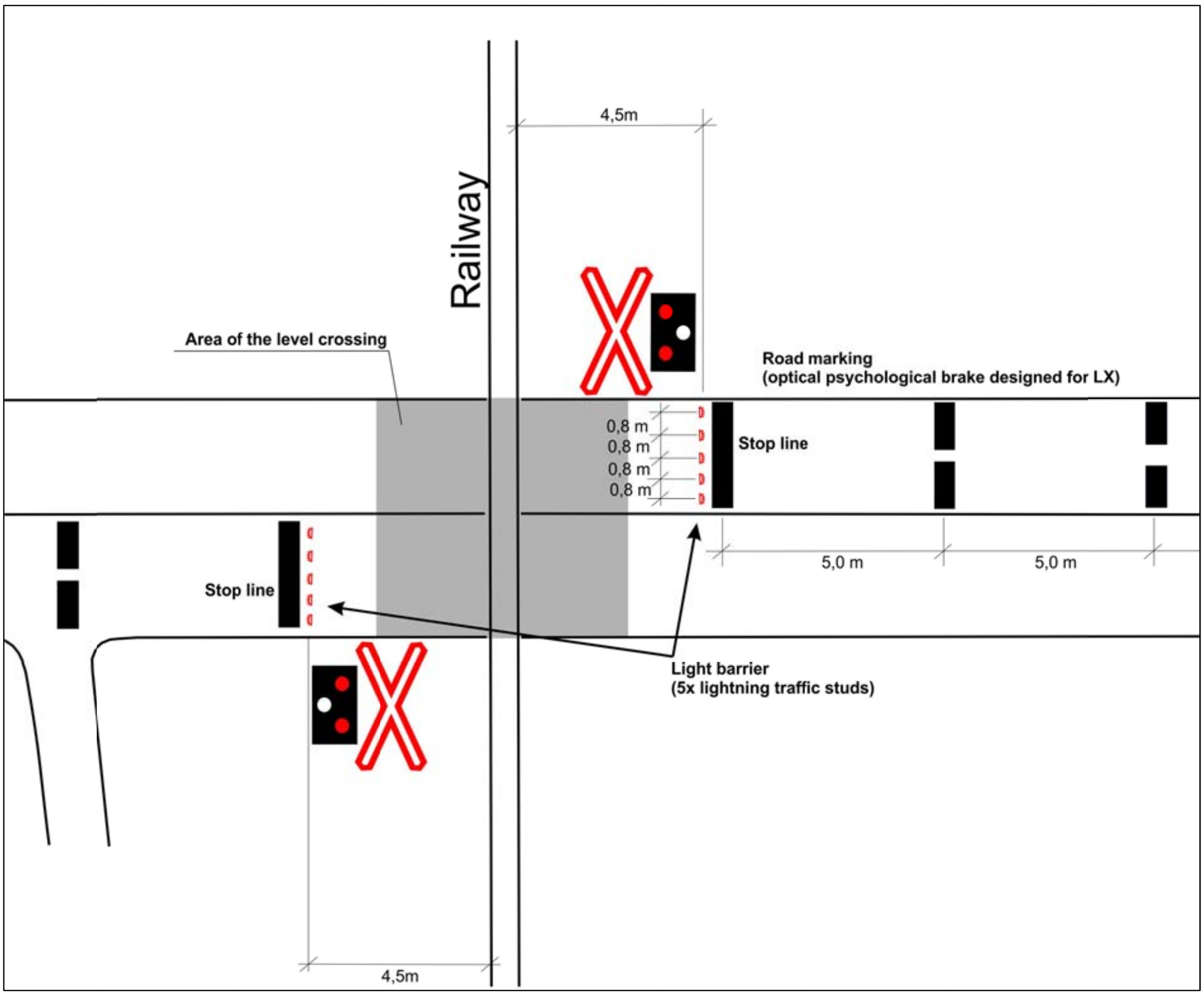
On principle, light barrier is arranged only on the approach lane in front of the level crossing, not over the whole width of the road. In addition to higher prices, more complicated installation and maintenance, such arrangement would not bring any safety benefits.

Connecting to the crossing signalling device is very simple. The only element to be provided by the level crossing administrator is the non-potential contact of the activation relay of the crossing signalling device. This contact gives information to the control unit of the light barrier that a warning state of the level crossing has been initiated.

Electronic control unit of a light barrier is normally located in the level crossing house (Austrian practice). In the Czech pilot installations, the control unit is placed in separated switchboard next to the crossing house.

Light barriers are powered from the network (electric connection is always available at crossings with a crossing signalling device). Actual power consumption of traffic light studs with LEDs, however, is very low (supply current for two light barriers at a level crossing is only about 20 mA).

Figure 2. Arrangement of the light barrier on the pavement



2.3 Pilot installations in the CR

There are three pilot installations of the light barrier at the moment: two at level crossings of local narrow-gauged railway, both with warning lights without complementary mechanical barrier, in built-up areas, and one at level crossing equipped with warning lights and complementary barrier, out of town. Components from two different producers were used. During the pilot testing, several quality criteria and parameters are examined:

- Public acceptance (questionnaire survey),
- Impact on road users' behaviour (observation),
- Evaluation of visibility under different light conditions,

- Measurement of luminance and other light-technical parameters, stability in time,
- Reliability in terms of electricity (possible existence of error messages and their form),
- Mechanical reliability – resistance to heavy traffic and winter maintenance,
- Traffic accident rate (evaluation is expected after 3 years of operation.

2.3.1 Nová Včelnice

First light barrier in the CR was installed at level crossing in Nová Včelnice in June 2011 and put into operation in July 2011. The choice was given both by characteristics of the crossing and facility of the realization.

This crossing is under administration of smaller railway company (JHMD, a. s.), of which the management is inclined to technical innovations and experimental solutions, and moreover, the reconstruction of the level crossing (addition of warning lights) was planned at the time.

Equipped only with Andrew's cross and the stop sign, the place had been known as a black spot with about 1 accident per year. It has been inconspicuous in the terrain and visually disappearing in its surrounds, with crossing road straight, comfortable (10 m wide) and inspiring drivers to high speed. The type of track generally gives the impression of being very subtle (760 mm narrow gauge track) and insignificant, with small risk of collision (objectively the railway traffic is quite intense – more than 20 trains per day).

Making use of proceeding reconstruction, CDV carried out the installation of the light barrier as well as funneled psychological brake. Both measures improved the markedness of the level crossing significantly (see figure 3).

Figure 3. Light barrier and funneled psychological brake in Nová Včelnice

Since July 2011, visual checks of the device have been carried out regularly. The checks include functionality of the light barrier, physical state of all components (LED diodes shine, state of the studs – cracks or scratches on cover glass, waterproofing), state of the joint materials and fillers, state of the funneled psychological brake.

Until now, no functionality errors were identified. There were minor damages on the cover glasses of the studs due to winter maintenance (use of rough spreading), and at the end of the testing period, on LED diode ceased shining.

At this site, measurement of the traffic stud's luminance was carried out after 20 months of operation, using the illuminance meter Minolta T1. The purpose of this activity was specification of distribution of luminance in relation to the approaching eyes of drivers. The measurement was carried out in regime of constant shining within the range of horizontal angles 0° – 20° and vertical angles 0°-15°above surface (see table 3).

Table 3: Luminance of traffic stud used in Nová Včelnice (in cd)

horizontal angle vertical angle	20°	15°	10°	5°	0°	5°	10°	15°	20°
15°		1,9	2,4	3,9	4,5	3,4	2,0	1,4	
10°	1,7	3,4	7,3	15,4	16,7	11,8	4,7	2,7	1,0
5°	2,7	8,2	23,2	66,0	79,1	51,8	16,7	5,1	1,3
2° 20′	3,1	10,6	33,5	84,0	113	69,5	25,3	5,9	1,5

We can see that (considering the position e.g. of personal car driver's eyes about 1,20 m above road surface) the luminance is higher from longer distances; when the vehicle approaches to immediate distance from the device, the luminance drops rapidly, so that there is no risk of dazzling. The aspect of illumination of eyes by concrete products should be considered when choosing the components from more producers; the traffic studs of which the luminance does not drop enough with increasing vertical angle are more suitable for level crossing with prevalence of other road users (pedestrians, cyclists, or lorries).

The impact on road users' behavior and public acceptance has been then the part of testing (see chapters 2.4 and 2.5); concerning accidents' occurrence, there were not any accidents since.

2.3.2 Kamenice nad Lipou

At the same railway, another pilot site was selected, in Kamenice nad Lipou. Situation of the level crossing was similar – originally equipped only with Andrew's cross and stop sign, later with warning lights, the crossing was still poorly visible in its surround, with bad view conditions. After success of the light barrier in Nová Včelnice, the management of the railway company initiated second installation here, in June 2013 (see figure 4).

Figure 4. Light barrier in Kamenice nad Lipou

The same criteria have been followed during visual checks at this site as in Nová Včelnice. Until now, no functional or technical defects appeared, and no accidents. The survey of public acceptance was carried out as a part of the testing (see chapter 2.5).

2.3.3 Otice

As the third locality for pilot testing, level crossing in Otice was chosen. This crossing is located at regional railway under administration of main railway caretaker, SŽDC (Railway Infrastructure Administration), state organization. Unlike other two testing localities, and unlike the usual practice in Austria, this level crossing is equipped with warning lights and complementary mechanical barrier.

Basic idea of such solution was enhancement of significance of warning lights; according to the results of previous researches (ARIANA, ALICE), road users strongly tend to adjust their behavior rather to complementary mechanical barrier then basic warning signal. The barriers recline certain time after the beginning of the warning, which is logical and road users more or less accept it, but also rise before the end of the warning and during the process, they may quickly drop again, when another train is coming. Entering the level crossing before the end of warning is therefore extremely risky, but practiced by about 50 % of drivers and 90 % of pedestrians [2].

The level crossing in Otice used to be placed on insignificant local road with minor traffic. It was equipped only with Andrew's cross. The traffic importance of the road increased after reconstruction of adjacent roads; now it serves as connection of two first class roads and practically as the bypass of the town Opava. Although this crossing was not known as a black spot, expected increased road traffic induced the need of higher level of the level crossing protection, so it was equipped with warning lights and complementary mechanical barrier. As a part of the reconstruction, the administrator agreed with experimental installation of the light barrier (see figure 5). It was installed in September 2012 during the reconstruction, and, after complicated administrative proceedings, put into operation in June 2013.

Figure 5. Light barrier combined with additional mechanical barrier in Otice

Apart from regular checks of technical condition of the device (no malfunctions or defects until now), camera observations of behaviour of drivers before and after were carried out (see chapter 2.4).

2.4 Observations of behaviour

Behaviour of road users was observed in Nová Včelnice and Otice. Congruently, camera recordings were used at both localities. The research unit was interaction of road user and warning, and solely uninfluenced behaviour was taken into account (e.g. only the first car in the column).

Otherwise, different approaches had to be used. In Nová Včelnice, observation was carried out both before and after installation of the light barrier, but data could not be compared as the situation "before" meant level crossing with completely different protection (only Andrew's cross); this data was used as a part of groundwork. The results of the subsequent observation were then compared with data from selected level crossings protected with warning lights without complementary mechanical barrier.

In Otice, the lapse of time between installation of device and its putting into operation allowed to carry out first the observation of situation with new protection without operating light barrier and then with it.

2.4.1 Observation of behaviour after the installation of light barrier in Nová Včelnice

The camera, taking both directions, was used. It was activated only during the warnings. The recordings were then evaluated and relevant cases elaborated in IBM SPSS Statistics. Following categories of behaviour were distinguished: the road user stopped and waited till the end of warning; the road user could not stop being too close to the crossing when the warning started; the road user could not stop because of speeding; the road user ignored the warning; the road user stopped but continued before the end of warning. During the recording, 254 cases of interaction between road user and warning had been collected.

The cases represented equally both directions (126 and 128). Categories of road users were represented as follows: 92,1 % car drivers, 2,4 % pedestrians, 4,3 % cyclists, 1,2 % motorcyclists. For the purpose of analysis and comparison, pedestrians, cyclists and motorcyclists were excluded (the light barrier is primarily aimed at car drivers), and the cases when the driver was unable to stop, being too close to the crossing, as these cases are irrelevant for analysis. After that, we had 226 cases left, of which 88,5 % stopped and properly waited till the end of warning, 0,4 % could not stop because of speeding, 2,2 % ignored the warning completely and 8,8 % stopped but continued before the end of warning. As most of users are residents, this relatively high proportion of untimely entering at the crossing is rooted behaviour that can be hardly influenced by any measure; during the decades when the crossing was protected only with Andrew’s cross, drivers had been used to continue as soon as the train passed. Regarding the character of the local rail traffic, the behaviour is nevertheless not dangerous here.

Comparative sample included three level crossings with warning lights without complementary barriers, where the observation was carried out in frame of previous projects. Out of 219 car drivers, 6,4 % ignored the warning completely and 0,9% could not stop because of speeding.

Comparing these two samples, we can say that the decisive variable, ignorance of the warning, seems to be improved by presence of the light barrier (6,4% : 2,2%) at this type of level crossing.

2.4.2 Observation of behaviour after the installation of light barrier in Otice

At the level crossings with warning lights and complementary barrier in Otice, following categories of behaviour were observed before and after putting the light barrier into operation: during the first two phases of the warning it was recognized whether the road user stopped in the first phase (red lights on, barrier still up), or came and stopped when the barriers were already reclined, or ignored the red light and went over the crossing in the first phase; another possibility was going through the reclined barriers, but such behaviour did not occur. During the third phase (barriers going up, red lights still on) was distinguished whether the road user waited properly till the end of the warning or entered the level crossing during the lifting of the barrier.

The recordings (two cameras were used, one for each direction) were made during undivided time sections including nights and days, working days and weekends. Both recordings were taken in summer, first in June, second one in August. The road users found at this level crossing were predominantly motor vehicle drivers and several cyclists; there were no pedestrians. During the phase “before”, 261 cases of interaction of road user and warning were recorded, “after” sample contained 157 cases.

At this crossing, comparison of behaviours before and after proved the influence of the light barrier especially during the last phase of the warning (barriers going up, red lights still on). During the first two phases, there were not significant differences (see tables 4 and 5).

Table 4: Otice, behaviour of road users during the first two phases of the warning

	Driver respected light warning during the initial phase	Driver respected light warning, came during the phase of reclined barriers	Driver did not respect the light warning during the initial phase	Total	Driver arrived during the final phase of the warning
Before	129 (55,1%)	94 (40,2%)	11 (4,7%)	234 (100%)	27
After	81 (56,3%)	59 (41,0%)	4 (2,7%)	144 (100%)	13

Table 5: Otice, behaviour of road users during the last phase of the warning

	Driver waited till the end of the warning	Driver continued with red lights still on	Total
Before	176 (70,4%)	74 (29,6%)	250 (100%)
After	139 (90,8%)	14 (9,2%)	153 (100%)

As the proportion of untimely entrances at the level crossing dropped by 20% in the period “after”, the results seem to indicate clearly that the presence of light barrier at level crossing with light warning and complementary mechanical barriers helps drivers to concentrate more on the basic light warning instead of movements of mechanical barrier.

2.5 Surveys of public acceptance

The surveys of public acceptance were carried out in Nová Včelnice and Kamenice nad Lipou, where the level crossings are located in town and the new measure have the impact on safety of local residents. The questionnaire was addressed only to respondents that lived in the area or used to pass the crossings equipped with light barrier regularly, so that they would know how the device worked.

The standardized questionnaire contained three questions:

- Are you satisfied with the present design of the railway crossing? (Optional answers see in Table 6)

- What do you think are advantages and disadvantages of the level crossing equipped with light barrier, compared to level crossing equipped with other form of protection? (Partial questions see in table 7)

- Do you think that light barrier at this level crossing helps to – at least to certain extent – prevent users from crossing on a red light? (Optional answers see in table 8)

The survey in Nová Včelnice was carried out in June 2012, including 125 respondents, and the same one in Kamenice na Lipou in May 2014, including 93 respondents. The results of the survey were almost the same in both localities, so that we present them in total.

Table 6: Satisfaction with present state of the level crossing

Yes, the crossing signaling device with the light barrier in the road is a good solution	197	91,2%
Yes, but I think that warning lights would be sufficient, the light barrier is unnecessary	2	0,9%
Yes, but extra mechanical barriers would be better	9	4,2%
No, a mechanical barrier instead of the light barrier would be better	4	1,9%
It is quite unnecessary, the previous solution, Andrew's cross with "Stop sign" was sufficient	0	0%
Other	4	1,9%
Total	216	100%

Table 7: Advantages and disadvantages of the level crossing equipped with the light barrier

	Agree	Disagree	No opinion	Total
The light barrier is clearly visible, even if sun lights	155 (71,1%)	7 (3,2%)	56 (25,7%)	218 (100%)
Even to an unconcentrated person, the light barrier gives a clear signal to stop	152 (69,7%)	3 (1,4%)	63 (28,9%)	218 (100%)
Unlike with mechanical barriers, no risk of getting trapped on a crossing	64 (9,4%)	1 (0,5%)	153 (70,2%)	218 (100%)
The light barrier does not prevent crossing on a red light as reliably as mechanical barrier	43 (19,7%)	20 (9,2%)	155 (71,1%)	218 (100%)
The light barrier saves time, it turns off faster than a mechanical one rises	90 (41,3%)	4 (1,8%)	124 (56,9%)	218 (100%)
The light barrier attracts too much attention, one may overlook something important	5 (2,3%)	55 (25,2%)	158 (72,5%)	218 (100%)

Table 8: How much the light barrier prevents road users from red light crossing?

Yes, definitely	120	57,7%
Yes, partially	34	16,3%
Yes, but rather only on drivers	32	15,4%
Yes, but rather only on pedestrians	1	0,5%
No	21	9,6%
Total	208	100%

Out of 218 interviewees, there were 20% pedestrians, 4% cyclists, and 76% car drivers. Most of them accepted the present state of the level crossing and did not wish any changes, only 4,2 % of respondents would have preferred mechanical barrier in addition to current design (see table 6).

The most widely appreciated advantage of the light barrier in comparison with other types of protection seems to be good visibility even by daylight, and its strikingness (see table 7); several interviewees noted that the light barrier was better visible than the basic warning lights. Respondents also mentioned time saving aspect. On the other hand, almost 20% of them stressed that the light barrier did not prevent red light crossing as reliably as mechanical barrier. Some respondents assumed that the device was less vulnerable than mechanical barrier, and, especially in Nová Včelnice (the very first installation in the CR), praised it as modern solution and even touristic attraction.

More than half (57,7%) of the respondents stated that the light barrier prevented road users from red light crossing, smaller proportion of them meant that only partially or only drivers (16,3% and 15,4% respectively); only 9,6% of interviewees presumed that light barrier was not prevention (see table 8), mostly with remark that this behaviour could not be prevented by any means.

It can be concluded that local users have rather positive attitude to the device. If the locality for installation is properly chosen regarding the parameters of level crossing, good public acceptance can be expected.

3 CONCLUSION: SUMMARY AND RECOMMENDATIONS

The interim results of SVEZA project show that the light barrier has the potential of not only huge geographical expansion, but also of use at level crossings with another category of protection.

One of the main achievements of the project was solution of technical – administrative problem of connection of the device to the level crossing signaling device. It turned out during the project that settling of electric connection of interface (convertor) between the body of light barrier and crossing signaling device is the key element limiting applicability of the device in conditions of the Czech Republic; the same circumstances may nevertheless occur also in other countries and SVEZA project brought the know-how.

Other research activities were aimed to reliability, service endurance, and effectiveness of the light barrier. Visual controls, measurements, observations, and surveys were carried out at three pilot sites, of which the first one has been operating already three years now, other two one year each. During the testing period, there haven’t occurred any accidents, not even at the level crossing in Nová Včelnice where the accidents used to happen.

Concerning reliability, there have not been any malfunctions reported yet. The device appears to be also rather resistant to heavy traffic and winter maintenance; there were only minor damages on the traffic studs cover glass at the eldest testing site, and one LED diode failed. All of these defects can be easily repaired in frame of regular maintenance and none of them endangers the functionality of the light barrier.

According to the results of observations, presence of the light barrier proved positive influence on drivers’ behaviour; compared to similar level crossings equipped with warning lights without mechanical barrier, the proportion of ignorance of the warning was significantly lower in Nová Včelnice. The observation also validated the assumption that the light barrier could be able to enhance the importance of basic warning lights for drivers at level crossings with warning lights and mechanical barriers – the proportion of untimely entering at the crossing in Otice decreased from 29% to 9% after installation of the light barrier.

Public acceptance investigated within surveys was very good. Local road users appreciated the safety benefits of the device, praising especially excellent visibility and strikingness, time saving and relative economy in comparison to mechanical barrier.

It can be concluded that the light barrier is able to serve as cheaper alternative to the mechanical barrier at one track level crossings. Apart from lower acquisition costs, it needs less demanding maintenance due to durability and resistance, as well as high reliability. The device proved to be also suitable complement for level crossings with warning lights and mechanical barriers; here, the light barrier enhances the significance of the basic warning lights.

Acknowledgements

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Comment

Paper about light barriers at level crossings in the CR was also presented by the research team of project SVEZA at the Global Level Crossing Symposium in the United States.

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