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23-25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

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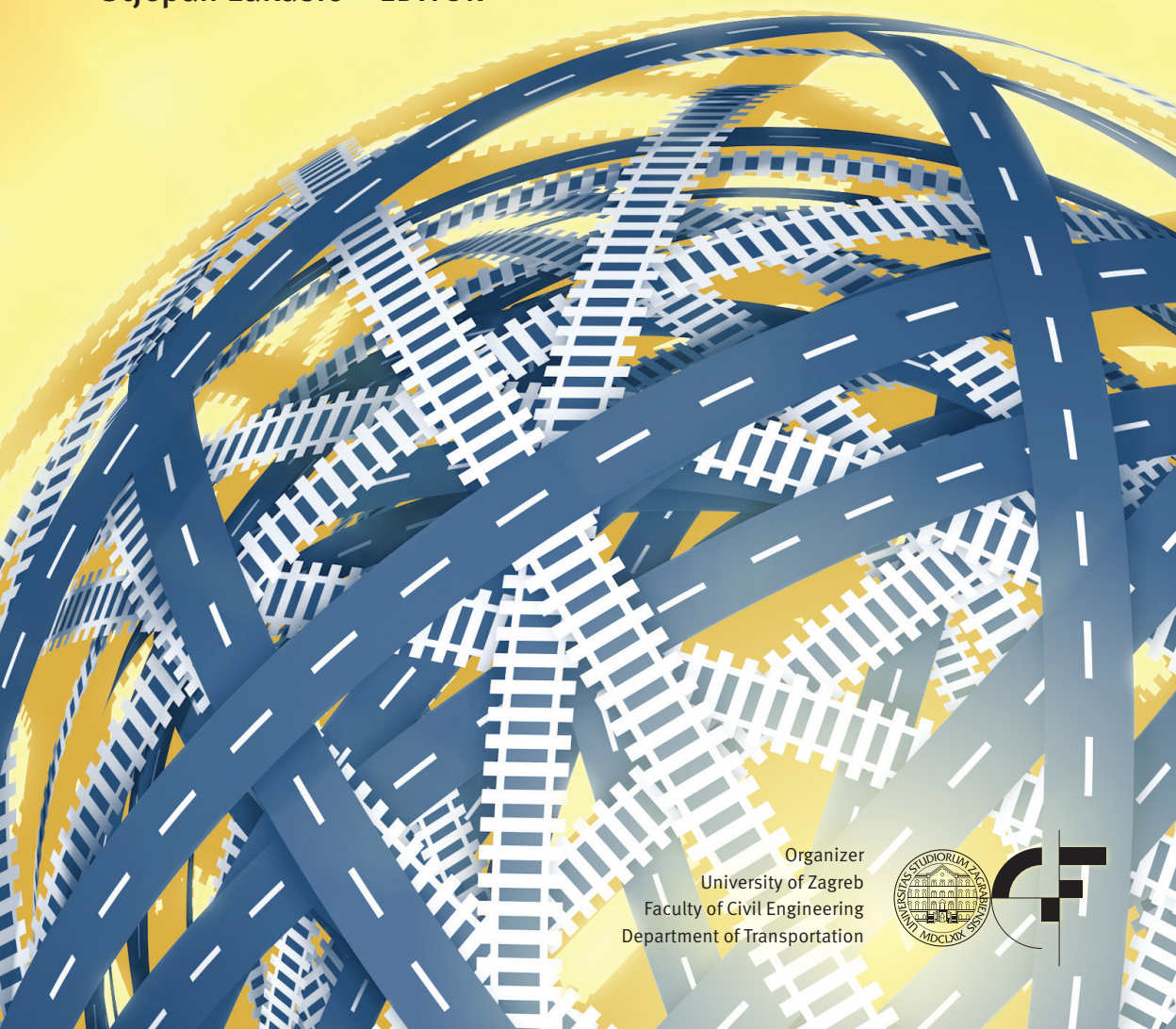

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SAFETY AT LEVEL CROSSINGS: COMPARATIVE ANALYSIS

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Abstract

From the safety point of view, level crossings (LCs) are critical points in the safe conduct of rail and road traffic. Due to the different characteristics of rail and road vehicles (size, speed, stopping distance, maneuvering capabilities etc.) level crossings are often places with frequent accidents which and in most cases result in human fatalities and big material damages, even though, all of them are secured with appropriate level of technical protection. Accident statistics have shown that the main cause for all accidents (more than 95%) is human factor of road users (drivers, cyclist and pedestrians) who didn't follow and obey traffic safety regulation at level crossings. This review paper presents current safety situation at level crossings in the Republic of Croatia and comparison with EU countries. Safety measures for preventing or diminishing level crossing accidents are presented and proposed.

Keywords: level crossings, safety, comparison analysis, safety measures

1 Introduction

Level crossings (LC) are places where roads cross railway lines or industrial tracks, i.e. from the aspect of construction, a place of crossing of the carriageway and the running surface of the rail [1]. Because of that, level crossings represent critical point of safety for both road and rail users. General perception in public is that the accidents at level crossings are primarily a railway sector problem, but statistical analysis of accidents show that the main cause of all accidents is human factor of road users (motor vehicle drivers, cyclist and pedestrians) [2,3]. According to [4] fatalities at level crossing accidents represent almost 30% of all fatalities in railway traffic, but only about 1% of fatalities in road traffic. Due to this fact, accidents at level crossings don't represent a significant issue for road sector authorities, but they are mayor obstacles for both traffic efficiency as well as rail safety [5].

In general, studies regarding level crossings safety can be divided into three categories: technical solutions, national and international safety programs and educational campaigns [6]. According to [7] the most important approach for increasing level crossings safety is 5E – Enabling, Education, Engineering, Enforcement and Evaluation, in which is of equal importance cooperation between road and railway sector, continuous education of road users, new technical solutions for level crossing protection systems and evaluation of effectiveness of implemented safety measures.

Since behavior of road users is the main cause for accidents at level crossings, most solutions are based on technical ways to prevent road users to intentionally or unintentionally break traffic rules. Some authors [8] suggest advanced scanning and road vehicle license plates recognition systems. Other authors [9, 10] would like to implement intelligent surveillance systems which will simultaneously give real time information to both train operator and road user. In Japan authors [11] are using obstacle laser detection systems during closed level crossing after which information is than transmitted in real time to train operators. In order to decrease road vehicles approaching speed, some authors [12, 13] suggest implementation of

reflective signs built in road pavement, rumble strips, in-car warning systems and LCD panels that will have information about consequences for illegal behavior.
Even the most technically advanced protection systems will not suffice if the road users don't obey or don't know the proper traffic rules. For that reason national programs and educational campaigns such as Operation Lifesaver in USA [14] and ILCAD – International Level Crossing Awareness Day [15] are trying to increase road user awareness on level crossing dangers by conducting educational lectures and workshops, round tables, creating multimedia games, posting educational posters and influencing social media. In 2000 Croatian railways started educational campaign "Vlak je uvijek brži" [16] in elementary schools, which included lectures, educational posters and pamphlets. This campaign is still active and it is expended on social networks as well.
Aim of this paper is to analyze all relevant statistical data regarding level crossing accidents in Republic of Croatia and compare it with the accident statistics of the all EU countries. The data was collected through comprehensive search of available literature and national safety reports. General classification of level crossings protection systems will be explained first, after which analysis of level crossing safety in Republic of Croatia will be shown. This data will be compared with statistics of all EU countries and appropriate measures will be suggested for improving level crossing safety.

2 Level crossings safety in the Republic of Croatia

Basic classification of protecting the level crossings is divided between passive and active protection. Passive protected level crossings are all those crossings which are equipped with any sign of warning, devices or any other protection equipment that is constant and that does not change depending on any traffic situation and where road users [17]. In the Republic of Croatia level crossings passive protection is considered to be the use of road traffic signs "St. Andrews Cross" and "Stop" together with the regulated visibility triangle.
Level crossing active protection is considered to be any type of protection which changes its state (sound, light or mechanical) according to the approaching train. In the Republic of Croatian most common automatic level crossings protection is use of flashing lights and sound traffic signs and use of half-barriers with the sound and flashing lights. In some places there are still level crossings which are protected with full barriers that are controlled manually by dedicated gate keeper.
The total length of railway lines in Croatia is 2.605 km, out of which 2.351 km are single track lines and 254 are double track lines. There are 980 km of electrified lines (977 km with 25kV/50 Hz A.C. system and 3km with 3kV D.C. system) [18].
Every level crossing in Republic of Croatia is protected with a minimum passive protection and out of total 1.520 level crossings, 62,76% are protected with passive protection systems and remaining 37,24% with active protection systems as shown in Table 1. [19].

Table 1 Classification and number of level crossings in the Republic of Croatia [19]

Passive LC		**Active LC**				**Total**
Traffic signs + visibility triangle	Pedestrian crossings	Pedestrian crossings with sound and flashing lights warning	Manual full barriers	Sound and flashing lights with half-barrier	Sound and flashing lights	
895	59	11	65	349	141	**1.520**
58,88%	3,88%	0,72%	4,27%	22,97%	9,28%	**100%**

Data analyzed for the last 5 years shows that in 2014 there were total of 37 level crossing accidents in Croatia, which is a 9,75% drop in comparison with the 5 year average, as shown in Table 2. [19].

By analyzing accidents according to type of LC's protection, it can be concluded that in the 5 year period 40% of all accidents happened on actively protected level crossings which is very concerning and shows poor traffic culture in the Republic of Croatia. Detailed analysis of all accidents according to protection level can be seen in Table 2, [19].

Table 2 Level crossing accidents in the Republic of Croatia by level protection type [19]

Type of LC / Number of accidents	Year				
	2010	2011	2012	2013	2014
Active LC	12	21	21	16	12
Passive LC	29	24	24	20	24
Pedestrian LC	0	1	0	0	1
TOTAL	41	46	45	36	37

Fatalities of level crossing accidents in the Republic of Croatia for the period 2010–2014 are shown in Table 3. In 2014 there were 7 fatalities which is a 27% drop comparing with the 5 year average of 9,6 fatalities, but overall that number oscillates from year to year in observed period.

Table 3 Level crossing fatalities by level protection type [19]

Type of LC / Number of fatalities	Year				
	2010	2011	2012	2013	2014
Active LC	1	10	3	7	1
Passive LC	6	4	5	4	5
Pedestrian LC	0	1	0	0	1
TOTAL FATALITES	7	15	8	11	7

Almost all fatalities are road traffic users because they didn't obey clearly visible road traffic signs and level crossings protection systems. As mentioned before, number of fatalities on level crossings is not of primary concern for the road sector due to a fact that the number of accidents and fatalities at level crossings represent just a small fraction of all road traffic accidents and fatalities in the Republic of Croatia, even though the main accident causes at level crossings are road traffic users. Table 4. shows the comparison between the overall number of accidents and fatalities in road sector and at level crossings for the last two years of available data [20].

Table 4 Comparison of accidents and fatalities of road traffic and level crossings in the Republic of Croatia [20]

Number of accidents / fatalities	Year			
	2013	2014	2013	2014
	Accidents		Fatalities	
Overall road traffic accidents	34.021	31.432	368	308
Level crossing accidents	36	37	11	7

Analyzing the Table 4. it is obvious why the level crossings accidents are not of primary concern for road sector because in the years 2013 and 2014 number of accidents at level crossings represent only 0,11% and 0,12% respectively, out of all the road traffic accident in republic of Croatia. Also the number of fatalities at level crossings represent only 2,98% and 2,27% respectively, for the years 2013 and 2014.

One of the key safety indicators is also the number of broken or damaged half barriers at actively protected level crossings when road vehicles run into them. Since the breakage of

the barriers happens while they are being lowered down or are completely in the final position, meaning at the time of approaching train, every such incident could lead to a potential accident with serious consequences. Table 5. shows the number of broken or damaged half-barriers in period from 2010-2014 [19]. Overall number of broken or damaged barriers is continually decreasing over the last 5 years, with 12,8% drop in the last year comparing with the 5 year average.

Table 5 Broken barriers in the Republic of Croatia [19]

Year	2010	2011	2012	2013	2014
Broken half-barriers	613	567	522	518	469

Number of broken or damaged half-barriers only partially shows the real situation due to a fact that only heavily damaged half-barriers are reported and also due to a large number of drivers who are intentionally driving around already lowered half-barriers.

3 Comparative analysis with EU countries

There are 114.120 level crossings in EU countries (excluding Malta and Cyprus) covering a total of 218.104 kilometers of railway tracks. [21]. A little more than half of all the level crossings have passive systems of protection (51%) and the rest have active protection systems [22], as it is shown in Fig.1.

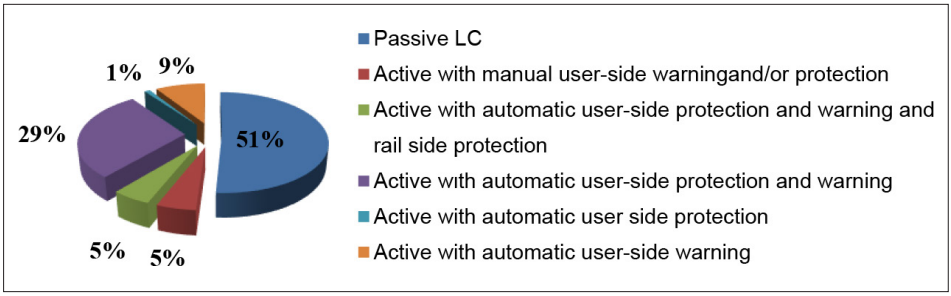

Figure 1 Breakdown of level crossings according to type [22].

Comparing just level of protection systems it can be observed that Croatia is a way behind the EU average when it comes to number of actively protected level crossings (37% in Croatia compared with EU average of 49%). Further analysis of all railway traffic accident statistics (Table 6.) shows poor level crossing safety standards in the Republic of Croatia in comparison with all EU countries.

It can be observed from Table 6. that the ratio of level crossing accident in all railway accidents is considerably higher in Croatia comparing with the all of the EU countries. As a 5 year average 37,9% of all railway related accidents in Croatia happened on level crossings while in EU it is considerably lower at 27,5%.

Also, one of the most important indicators of railway safety when it comes to level crossings is number of fatalities at level crossings as a ratio of all railway related fatalities, excluding suicides. Breakdown of all fatalities for Croatia and EU is shown in Table 7.

Unfortunately, it can be observed from Table 7. that the number of fatalities at level crossing accidents as a ratio of all railway related fatalities is considerably higher than for the EU countries. Average 5 year ratio for EU is 29,1% while in Croatia level crossings fatalities represents 44,5% of all railway related fatalities.

Table 6 Breakdown of railway accidents [22, 26]

Number of accidents / LC ratio	REPUBLIC OF CROATIA				
	Year				
	2010	2011	2012	2013	2014
LC accidents	41	44	45	36	37
Total railway accidents	118	99	105	110	105
LC ratio	**34,7%**	**44,4%**	**42,9%**	**32,7%**	**35,2%**

Number of accidents / LC ratio	EUROPEAN UNION				
	Year				
	2010	2011	2012	2013	2014
LC accidents	842	736	635	555	542
Total railway accidents	2.789	2.718	2.178	2.103	2.203
LC ratio	**30,2%**	**27,1%**	**29,2 %**	**26,4 %**	**24,6%**

Table 7 Breakdown of railway related fatalities [19, 23]

Number of fatalities / LC ratio	REPUBLIC OF CROATIA				
	Year				
	2010	2011	2012	2013	2014
LC fatalities	7	15	8	11	7
Total railway fatalities	27	26	18	19	19
LC ratio	**25,9%**	**57,7%**	**44,4 %**	**57,9 %**	**36,8 %**

Number of fatalities / LC ratio	EUROPEAN UNION				
	Year				
	2010	2011	2012	2013	2014
LC fatalities	385	332	396	315	294
Total railway fatalities	1.312	1.263	1.173	1.168	996
LC ratio	**29,3%**	**26,3%**	**33,8 %**	**26,9 %**	**29,5 %**

4 Safety measures for increasing level crossings safety

There is no one single measure for increasing safety at level crossings. The only efficient solution is to completely separate railway and road traffic in two levels by building overpasses or underpasses. But unfortunately high costs of such projects will prevent this kind of solution on all but the level crossings with the highest traffic volume or dangerous accident history. Therefore, it is necessary to find more immediate and cost effective solutions that can be implemented rather fast and it is appropriate for every level crossing, regardless of their protection level. However, even the most advanced protection systems will not suffice if the users don't obey or don't understand traffic rules regarding level crossings. In order to achieve that, there should be more emphasis on educating users on level crossing dangers. First step to achieve this goal is to widen curriculum in driving schools so that young drivers will be more prepared for level crossing dangers. Also, there should be a continuous national campaign throughout media and social networks with ads and posters explaining the dangers

and consequences of illegal behavior on level crossings. Furthermore, big poster panels with the same information could be installed in the close vicinity of level crossings with higher traffic volume and/or accident history. Since in Croatia there are 62,76% passive protected level crossings, one of the first technical measures should be regular maintenance of visibility triangle especially in times of increased vegetation growth (spring, summer), since this can severely diminished the visibility from road to railway tracks. Since the visibility triangle is calculated from the position of road traffic signs "Stop" and "St. Andrew's Cross", the position of these traffic signs on all passive protected level crossings should be moved to the maximum possible [24] allowed distance from the nearest railway track which is 3 meters. Reason for that is in increased visibility from road to railway track and thus better view on approaching train. Current situation of position of these traffic signs on passive protected level crossings in Croatia varies significantly from 3 meters up to 10 meters from the nearest railway track [25] so it is necessary to enforce this measure in order for the drivers to have better view of railway tracks and approaching train. This task should be responsibility of local road authorities in the area where the level crossing is located. On actively protected level crossings with half-barrier road vehicle drivers are intentionally disregarding traffic rules by driving around lowered half-barriers, which presents significant safety issue. Cost effective solution for this problem would be installation of median barriers for providing separation of directional traffic on the approaches to railway level. They are installed on the road centerline leading right next to lowered half-barrier so that it is impossible for drivers to go around the barriers once they are lowered down. The length of such separators should be at least 10 meters from the barriers, but it could be longer, depending on the local circumstances [26]. Since there are only 349 level crossings with half-barriers in the Republic of Croatia, this cost effective solution should be implemented nationwide on all of them.

5 Conclusion

Railway traffic is one of the safest transportation modes but it is concerning fact that accidents at level crossings are a significant safety issue worldwide as in Croatia. In 2014 there were 37 level crossing accidents in Croatia which is 9,75% drop comparing with the 5 year average (2010-2014). What is concerning that in the same period 40% of all LC accidents happened on level crossings with active protection. Number of fatalities on level crossing accidents in Croatia in 2014 is 27% lower than the 5 year average but overall it oscillates from year to year. Further analysis in the Republic of Croatia in 5 year period (2010-2014), shows that 37,9% of all railway related accidents (excluding suicides), as a 5 year average, happened on level crossings. That is a demeaning fact when comparing with EU average for the same period of 27,5% of level crossing accidents. Comparing level crossing fatalities as a ratio of all railway related fatalities in the same period (2010-2014) Croatia's 5 year average is very high at 44,5% fatalities at level crossings. Average for the same 5 year period for the whole EU is considerably lower at 29,5%. This comparison shows poor traffic culture in the Republic of Croatia and it is very concerning from safety point of view.

Since the main cause of all level crossings accidents is human behavior of road users (motor vehicle drivers, cyclist and pedestrians) [2,3], every implemented measure for increasing safety at level crossings should designed so they can maximally possible remove bad human decisions while driving or walking over level crossings. So, the only effective solution is building overpasses or underpasses, but high cost of such projects brings a need for more cost effective solutions, like proposed median barriers and increasing visibility triangle.

Unfortunately, technical solutions are only effective if the road users completely obey traffic rules regarding level crossings. Because of this fact and also accident history on level crossings in Republic of Croatia, it is equally important to systematically implement educational campaign for all level crossing users together with increased repression policies. Currently, the only educational campaign in the Republic of Croatia is conducted by "HŽ Infrastruktura"

in form of periodical lectures in elementary schools and handing out educational pamphlets to drivers on selected level crossings. This is a well thought campaign, but because of the budget constraints it is small in scale considering the current level crossing safety in Croatia, and it should be expanded to high schools and driving schools and also be a part of a national strategy for increasing safety at level crossings.

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