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INCREASING LEVEL CROSSING SAFETY IN URBAN AREAS - CASE STUDY CITY OF ZAGREB

Martin Starčević, Danijela Barić, Ivan Broz
University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia

Abstract

Level crossings (LC's) are one of the most dangerous points in railway traffic with frequent accidents that result in significant material damages and almost always fatalities. When level crossings are located within highly populated urban areas, they represent an even higher risk for accidents because of increased traffic volume for both the road and rail sectors. There are currently 34 level crossings in the City of Zagreb, some of which are on the roads with the highest traffic volume in the Republic of Croatia. Accident analyses on level crossings show poor traffic culture, especially pedestrians, which are intentionally disregarding traffic rules and showing poor judgment. This paper will show the existing condition and possible improvements of identified shortcomings of observed level crossings in the City of Zagreb and it will also present the existing level crossing regulations, classification, and safety on the railway network in the Republic of Croatia.

Keywords: level crossings, safety, urban areas

1 Introduction

The city of Zagreb is the capital of the Republic of Croatia and it is the largest city in the country with a population of 790.017 inhabitants [1]. As such, the Zagreb railway junction is the largest in the country and represents a central core in the railway network of the Republic of Croatia. Zagreb railway junction consists of 14 main and other international lines as shown in Figure 1.
Currently, there are 34 level crossings in the City of Zagreb within Zagreb railway junction and some of them are on the roads with the highest road traffic (vehicles as well as pedestrians) volume in the Republic of Croatia, as well as on the railway tracks with highest train movements in the country. Because of such a high traffic volume of both the road and rail sector level crossings in the City of Zagreb, level crossings are places with increased risk for traffic safety in general.

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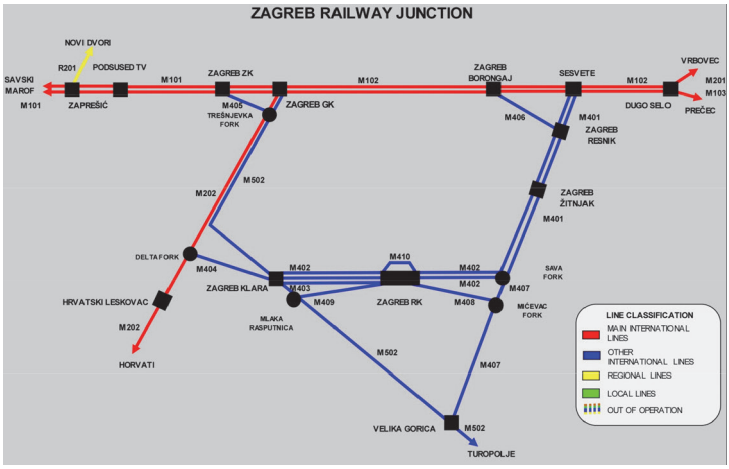

Figure 1 Zagreb Railway junction [2]

Since LC's are places where roads and/or pedestrian paths cross railway tracks, accidents at these places often result in serious damages and fatalities which diminish railway safety reputation, even though almost all of the accidents are caused by motor vehicle drivers or pedestrian violations [3]. Accidents at level crossings result in a higher mortality rate than any other types of road traffic accidents because of the disparity in mass between the train and the road user (motor vehicle, cyclist, or pedestrian). Furthermore, fatalities at level crossings accidents represent on average 30 % of all railway-related fatalities but only 1-2 % of fatalities of road traffic accidents [4]. As such, LC's represent a significant safety challenge due to complex socio-technical systems that involve interactions between many different types of road users and railway operators and infrastructure [5].

For that reason, level crossings need to be properly marked and protected with appropriate protection systems which can be divided into passive and active protection systems [6]. In passive protection systems, road users are solely responsible for observing traffic situations because traffic signs used for passive level crossings (traffic signs "Stop" and " St. Andrews Cross) do not change their state regardless of the approaching train. In contrary to passive systems, active protection changes its state to warn road users of approaching trains. This can be in the form of flashing lights and sound and/or full of half barriers [7]. Figure 2. shows the classification of protection systems in the Republic of Croatia.

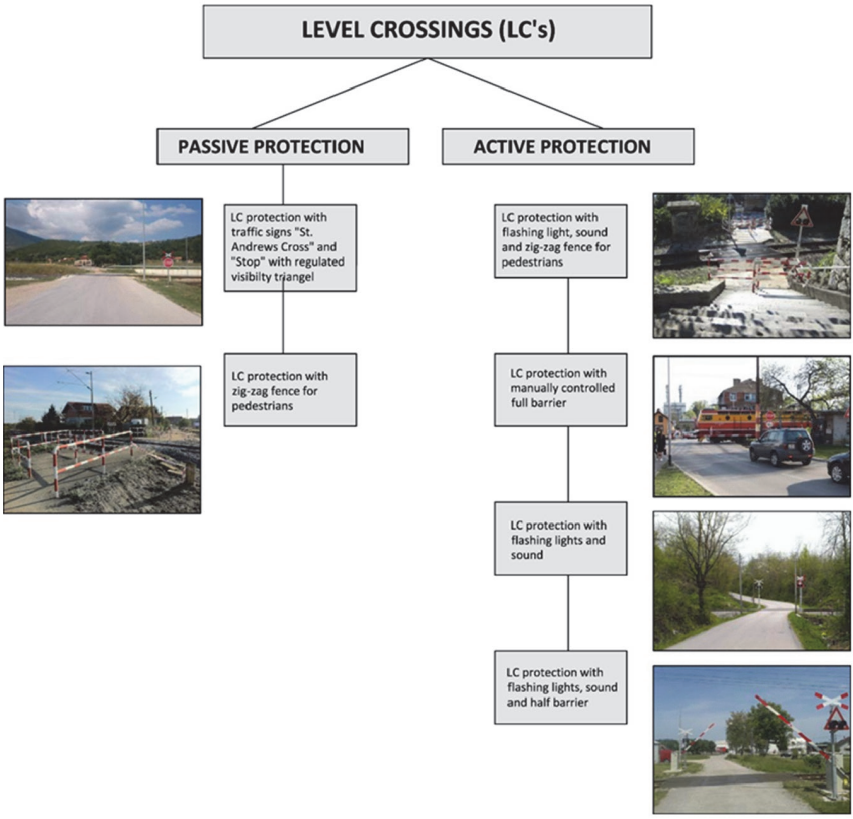

Figure 2 Classification of level crossing protection systems [7]

Despite technical protection systems, the number of accidents at LCs remains high, and studies point to user behavior as a key factor. Analysis of 256 LC accidents as part of the Safer European Level Crossing Appraisal and Technology (SELCAT) project showed that human failure caused 91 % of LC accidents in the EU; over 80 % occurred when a vehicle driver failed to respect the traffic rules [8]. A substantial proportion of LC's accidents occur when safety equipment at that crossing is functioning properly [9] further implicating risky road user behavior as the main problem. Thus, understanding what factors and situations lead road users to engage in risky behavior at LC's is key to predicting safety problems and designing effective countermeasures. In general, studies regarding level crossings safety can be divided into three categories: technical solutions, national and international safety programs, and educational campaigns [10]. To achieve maximum safety for all LC users, final safety measures should be designed equally within these three categories.

This paper aims to analyze all relevant statistical data regarding LC's safety and existing conditions within the Zagreb area and to show possible improvements of identified shortcomings of observed level crossings. The data was collected through a comprehensive search of available literature and national safety reports, as well as a field study by the authors.

2 Level crossing safety statistics for the Republic of Croatia

The total constructed length of the railway network in Croatia is 2.617 km, out of which 2.343 km are single-track and 274 km are double-track lines [2]. Out of 1.512 level crossings on the railway network in Croatia, 61,3 % have passive protection systems, and the remaining 38,7 % active systems [11]. When comparing to the EU average percentage of active protection systems (49 %) it can be noted that Croatia is behind the EU when it comes to active protection for LC's. [12].

Unfortunately, active protection systems for LC's are not a guarantee for decreased accidents and fatalities. Analyzing level crossing fatalities from 2007 to 2019 in the Republic of Croatia it can be observed that the overall number of fatalities is decreasing (Figure 3.), but what is concerning is that on average almost half of all the fatalities happened on level crossings that had active protection systems.

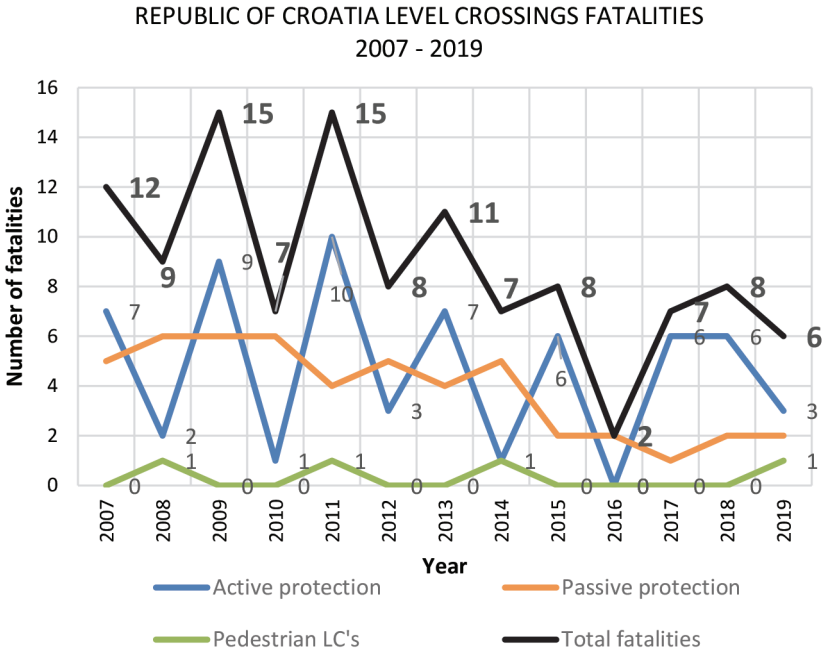

Figure 3 Level crossing fatalities in the Republic of Croatia [11][13]

Data shown in Figure 3. is a testament to a very poor traffic culture in Croatia, especially when all these active protection systems were properly working at the time of the accidents.

Another proof of poor safety culture in Croatia is the number of broken or damaged half barriers 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, every such incident could lead to a potential accident with serious consequences because of the approaching train. Figure 4. is showing the number of broken/damaged barriers from 2007 to 2019.

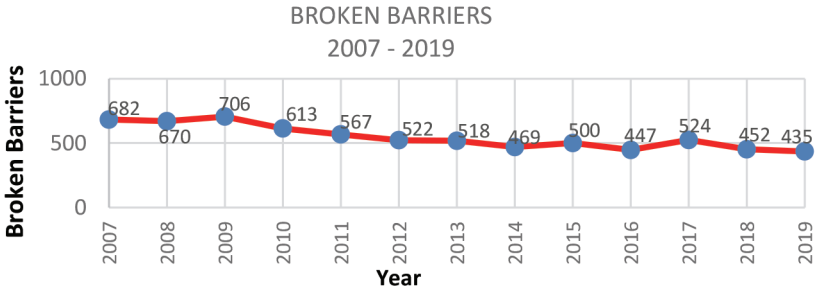

Figure 4 Broken/damaged barriers in the Republic of Croatia [11][13]

The overall number of broken or damaged barriers is continually decreasing over the observed period, but it is still significantly high, especial when there are only 454 level crossings with barriers in Croatia. The number of broken or damaged barriers only partially shows the real situation because only heavily damaged barriers are reported and there is no data about drivers who are intentionally driving around lowered barriers.

3 Level crossing in the city of Zagreb

There are currently 34 level crossings in the City of Zagreb, as shown in Figure 5.

Figure 5 Level crossings in the Zagreb area

Out of 34 level crossings, only seven of them have passive protection systems and the rest of them have active protection systems. Eight LC's have flashing light/sound systems, 17 have flashing light/sound and half-barrier and five LC's have a full barrier with the dedicated level crossing keeper [13].
In the period between 2010 and 2019, there have been a total of 34 accidents with 11 fatalities and 14 persons seriously injured on 15 level crossings, as shown in Table 1.

Table 1 Level crossing accidents in the City of Zagreb [13]

LINE	KM	LC's NAME	PROTECTION SYSTEM	ACCIDENTS (2010-2019)	FATALITIES (2010-2019)	SERIOUSLY INJURED (2010-2019)
M101 DG-Savski Marof-Zagreb Gk	426+357	R. Austrije	Full barrier + keeper	3	2	1
M101 DG-Savski Marof-Zagreb Gk	427+014	Vodovodna	Full barrier + keeper	1	0	1
M101 DG-Savski Marof-Zagreb Gk	428+853	Sokolska	Full barrier + keeper	2	0	1
M102 Zagreb Gk - Dugo Selo	430+112	Staj.Trnava	Light/sound +half-barrier	7	7	2
M102 Zagreb Gk - Dugo Selo	430+661	Osječka	Light/sound +half-barrier	1	0	1
M102 Zagreb Gk - Dugo Selo	432+393	Retkovec I	Light/sound +half-barrier	2	0	0
M102 Zagreb Gk - Dugo Selo	434+688	Sljeme	Light/sound	1	0	0
M102 Zagreb Gk - Dugo Selo	435+465	Jelkovečka	Light/sound	5	1	4
M102 Zagreb Gk - Dugo Selo	436+329	Selnica	Light/sound +half-barrier	1	0	0
M102 Zagreb Gk - Dugo Selo	440+295	Staklana	Light/sound +half-barrier	2	0	0
M202 Zagreb Gk - Rijeka	432+273	K.Mlinarić	Light/sound	3	0	3
M202 Zagreb Gk - Rijeka	436+981	Žižići	Light/sound	1	0	0
M202 Zagreb Gk - Rijeka	442+312	Horvati	Light/sound	3	0	1
M502 Zagreb Gk - Sisak - Novska	416+242	Buzin	Passive protection	1	1	0
M502 Zagreb Gk - Sisak - Novska	418+744	Utinjska	Light/sound +half-barrier	1	0	0

It can be observed that these accidents happened on 15 out of 34 level crossings that currently exist in Zagreb and only one accident/fatality on a level crossing with only passive protection system. Unfortunately, the rest of the accidents and fatalities happened on LC's with active protection systems that worked properly. Two LC's with the highest number of fatalities are LC R. Austrije and LC Trnava (Figure 6.) which are predominantly pedestrian crossings, even though they are seldom used by motor vehicles. Both LC's are located in highly urban areas on double-track railway lines with high traffic volume and very long barrier closure. Because of such a long closure of the barriers (almost 44 % of the time within a 6-hour observed period), almost all of the pedestrians are using these LC's illegally by going under or around lowered barriers [14].

Figure 6 Level crossings R. Austrije and Trnava (Zagreb)

All the fatalities on these two LC's were pedestrians or cyclists going under or around lowered barriers. Another problem for pedestrians is a fact that these LC's are on double-track railway lines and they neglect the fact that once one train pass there is a real possibility of another train from opposite directions. Also, since most of the trains in the Zagreb urban area are low noise electric trains, it's hard to hear the approaching trains with all the rest traffic noise in urban areas.

4 Possible safety improvements on critical LC's

The best way to prevent accidents at level crossings is by building either overpasses or underpasses or completely close certain level crossings. Unfortunately, in most cases, it is just not financially or technologically justified for such large investments to be made, especially in large urban areas, such as the City of Zagreb. Since the vast majority of all illegal users on observed LC's are pedestrians and cyclists, measures for increasing safety on LC's should be concentrated on them.

Because of long LC's closure in urban areas, it is understandable for pedestrians and cyclists to be impatient, and therefore it is the main reason for illegal crossings. But, regardless of the barrier closure duration, it can be expected that pedestrians and cyclists will always try to cross illegally, especially if they can't visually see the approaching train. This is especially true in the case where railway tracks are in a straight line before the level crossing (such as LC Trnava, LC Vodovodna, LC R. Austrije direction from west, to name a few...).

The only way to prevent pedestrians and cyclists to cross illegally is to physically preclude them to enter the LC area. One way to accomplish that is to implement vertical bars underneath the barriers so that is impossible for anyone to go underneath the lowered barrier. Unfortunately, for that solution to work, it is necessary to install protection fences along the entire length of the railway track on both sides of the line. This solution will also prevent most trespassing of railway tracks outside of legal railway crossings. Another possible solution is to install warning billboards in front of each LC that will warn all users of the dangers of crossing illegally, especially on double-track lines where there is always a possibility of another train approaching from the opposite direction (all the LC's on lines M101 and M102).

Of course, even the best technical solutions will not suffice if the users don't obey them, so it is of utmost importance to have continuous educational campaigns about the dangers of level crossings. Unfortunately, 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 safety brochures to drivers and pedestrians on selected level crossings [15]. This campaign, even though is well designed, is small in scale and doesn't cover all potential level crossing users and it should be extended to high schools and driving schools, as well as more active on available social networks which have a significant influence on the younger population. Also, it should be a part of the regular education curriculum in elementary schools so that the kids (future LC's users as drivers or pedestrians) learn from an early age about the dangers and proper use o level crossings.

5 Conclusion

Level crossings (LC's) are one of the most dangerous points in railway traffic, especially when they are located within a highly populated urban area where traffic volume is increased not only with motor vehicles but with pedestrians and cyclists. The City of Zagreb is the largest urban area in the Republic of Croatia with 34 level crossings within city limits. In the period between 2010 and 2019, there have been 34 accidents with 11 fatalities and 14 persons seriously injured on LC's in the City of Zagreb. Unfortunately, the majority of the fatalities were pedestrians and cyclists who didn't (intentionally or unintentionally) obey traffic rules when traveling over level crossings. Since most of these level crossings are located on railway lines with high traffic frequency, and thus level crossing closures are longer than average, this fact can not be justification for the illegal behavior of level crossing users. Since building overpasses or underpasses in such a highly developed urban area is not financially or technologically feasible, other measures need to be implemented to increase safety at level crossings. Since there is not one single measure that can accomplish full safety, a combination of a different set of measures is preferable. This can be accomplished with a set of technical solutions that can minimize or completely remove bad human decisions (such as vertical bars under barriers, protective fences) with a continuous educational campaign including school visits, media appearances, and warning billboards on every critical level crossing.

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