Current safety situation at level crossings in Croatia and the future research

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Abstract

Level crossings (LCs) represent a direct conflict between rail and road traffic. From the aspect of safety, LCs are traffic points of high risk. This is confirmed by the fact that they are often places where traffic incidents and accidents frequently occur, with consequences in human victims and great material damage. Those represent an actual problem of traffic safety which is characteristic of the traffic system of every country and in the Republic of Croatia as well. In Croatia every level crossing is protected in accordance with the stipulated legal regulations, and the protection level primarily depends on the category of the railway line (main, regional, and local) and the road (state, county, local, uncategorized), allowed speed on the line, terrain conditions, and local circumstances at the crossing location. On the Croatian Railways network in the total length of 2756 km, there are a total of 1542 LCs. Out of the total number of LCs 68.4% are protected only by road traffic signs and visibility triangle (signs informing about the approach to the crossing, STOP sign and Andrew's cross), and 31.6% of LCs are protected by devices (light-audio signals, half-barriers, barriers). The safety condition at level crossings in the Republic of Croatia is best reflected in the data on the number of traffic incidents and accidents (fatalities and material damage), as well as on the number of victims (killed or injured). This paper will introduce the current status of level crossings in Croatia, included types of LCs, statistical data of accidents, comparison with other countries, national safety programme for the protection of LCs, and research perspectives with aim of defining priority measures of improving safety at level crossings.

Keywords: level crossings, safety, Republic of Croatia.

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1 Introduction

The total length of the railway network in Croatia is 2722.41kms, which currently accommodates 1542 level crossings. In compliance with the legal regulations, all of them are protected in one of the foreseen ways (30% with protection devices, and 70% with road-traffic warning signs) [1].

Since level crossings are points of direct conflict between rail and road traffic, they represent collision points of two traffic systems, where often emergencies occur, sometimes with the severest consequences (material damage and fatalities). Therefore, safety of rail and road traffic at level crossings is extremely at risk, and the level crossings represent a serious safety problem.

The analyses carried out of the accident causes indicate that in spite of technical and technological improvements of protection systems, the number of accidents continues to be significant which refers to the primary responsibility of traffic participants (motorists of road vehicles and pedestrians) and only then of the equipment. In order to solve the safety problems at level crossings the research is necessary with the aim of improving the system from the technical and technological aspect, also requiring the analysis of the emergency causes [2].

A significant international project dealing with the problems of level crossings is SELCAT (**S**afer **E**uropean **L**evel **C**rossing **A**ppraisal and **T**echnology) as part of the FP 6 Program (area of "Sustainable Surface Transport Coordination Actions"), with the aim of harmonizing the approach to problem solving at the European level [3].

In Croatia the Program of solving the level crossings in the Republic of Croatia is topical, and it includes 1032 crossings. The planned deadline to solve these problems is 15 years, and the estimated value of the entire program amounts to about 122 million euro [4].

2 Overview of legislation at international and national levels

2.1 Overview of legislation at international level

As part of EU regulations that refers to the problems regarding rail infrastructure and traffic safety it is necessary to emphasize the following:

- Directive 2001/16/EC on the Interoperability of the Trans-European Conventional Rail System;
- Directive 96/48/EC on the Interoperability of the Trans-European High-Speed Rail System;
- Directive 2004/49/EZ on the Railway Safety;
- Directive 91/440/EEC on the Development of the Community's Railways;
- Directive 2001/12/EC amending Directive 91/440/EEC;
- Directive 2004/51/EZ amending Directive 91/440/EEZ
- Directive 2004/50/EZ about amendments of Directive 96/48/EZ and Directive 2002/16/EZ

Other significant relevant documents are:

- AGC – European Agreement on Main International Railway Lines;

- AGTC – European Agreement on Important International Combined Transport Lines and Related Installations;
- TER – Trans-European Railway (Project of improving the railway parameters in Eastern and Central Europe).

2.2 Overview of legislation at national level

Legal and sub-legal regulations at the national level that determine the traffic, technological and technical conditions, infrastructure classification, method of operation and protection of rail and road traffic, conditions for safe traffic flow include [5–9]: Law on railways, Law on rail traffic safety, Law on road traffic safety, Law on public roads, Decision on classification of railway lines, Regulations on criteria, procedure, method of defining and protection of rail-road crossings, Regulations on the method and conditions for safe rail traffic flow.

Based on the mentioned laws, and in accordance to the provisions of Article 98 of the Law on Rail Traffic Safety and Article 21 of Regulations on criteria, procedure, method of defining and protection of level crossings, the Program on solving level crossings in the Republic of Croatia has been brought and it refers to the period from 2006 to 2015. Apart from this Program, the National program of railway infrastructure for the period from 2008 to 2012 should be mentioned, which defines the plans of constructing new, and modernization and maintenance of the existing rail network, as well as the funding sources including also solutions for level crossings.

2.3 Program for solving level crossings in the Republic of Croatia

The Program for solving LCs is a national program which is one of the preconditions for systemic solving of the LC problems. Apart from the necessary planned technical and technological measures, the Program also provides the dynamics and priorities in solving regarding the types of solutions (elimination and merging of crossings, reconstruction of the visibility triangle, elimination without merging, supplementation of devices by half-barriers, installation of L+S instruments (light+sound), installation of L+S +HB (light+sound+half-barriers) devices and level separation).

Table 1: Realization of The Program for solving LCs.

Dynamics (year)	Technical solution							
	elimination and merging	reconstruction of the visibility triangle	elimination without merging	supplementation of devices by half-barriers	L+S	L+S + HB	Level separation	Total
2006	3	0	3	0	2	4	2	15
2007	1	0	3	0	6	14	1	25
09/2008	0	0	3	0	8	8	0	19
Total	4	0	9	0	16	26	3	59

Table 2: The Program for solving LCs (dynamics, solution).

Dynamics (year)	Technical solution							
	elimination and merging	reconstruction of the visibility triangle	elimination without merging	supplementation of devices by half-barriers	L+S	L+S + HB	Level separation	Total
2006.	28	4	29	6	30	24	24	126
2007.	10	16	3	20	14	40	40	109
2008.	27	11		3	28	32	32	108
2009.	79	17		12	19	23	23	159
2010.	27	11			50	19	19	116
2011.	64				38	8	8	116
2012.	18			2	51	6	6	83
2013.	33				32	5	5	75
2014.	36				28	3	3	69
2015	25				26	3	3	61
2016.-2020.						10	10	10
Total	347	59	32	43	316	166	69	1032

3 Basic characteristics of LCs on the Croatian railways network

3.1 Croatian railways network

The total length of all the railway lines in the Republic of Croatia is 2722.41km, out of which 2468.54km (90.7%) are single track lines and 253.87km (9.3%) are double track railway lines. There are 980.07km (36.0%) of electrified lines, out of which 824.37km (84.1%) with single phase AC 25kV/50Hz system and 137.70km (15.9%) with DC 3kV system. The railway lines in the Republic of Croatia have been classified into three categories [8]:

1) Railway lines significant for international traffic (M):
   a) Main (corridor) lines – they pass through pan-European corridors or their branches;
   b) Connection lines – they connect railway lines on pan-European corridors and their branches;
   c) Linking lines – they connect the international sea and river ports in the Republic of Croatia;
2) Railway lines significant for regional traffic (R);
3) Railway lines significant for local traffic (L).

In the process of integration of the Republic of Croatia into the European Union, the railway lines will be determined that will belong to the integral trans-

European railway network, and until then the network of the main (corridor) railway lines consists of the railway lines that pass through the Pan-European traffic corridors (X) and their branches (Vb and Vc).

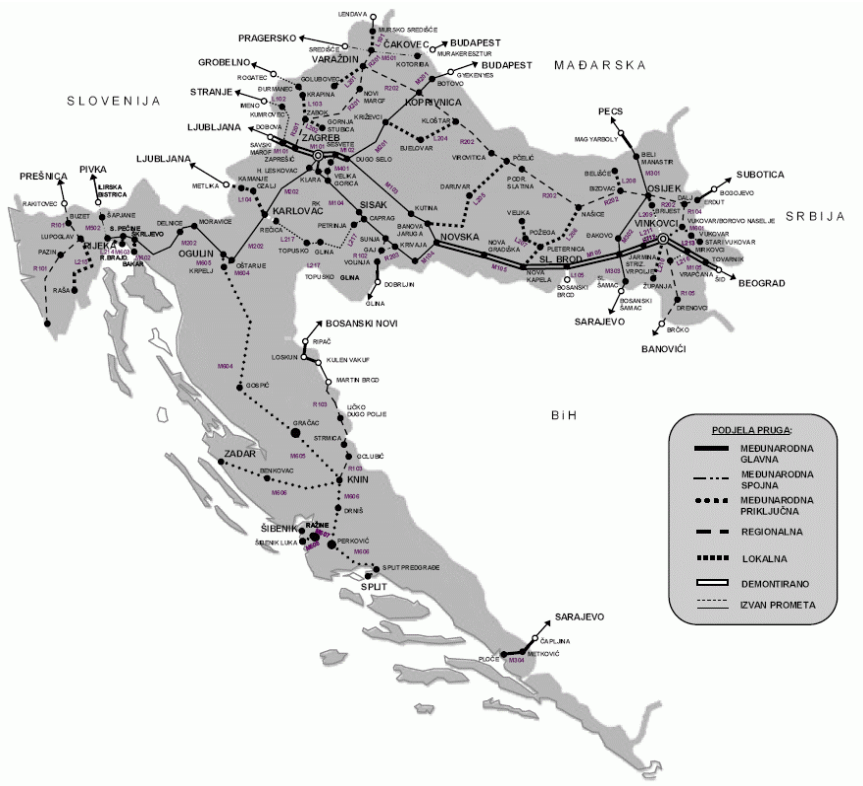

Figure 1: Network of Croatian Railways.

3.2 LC protection method

On the network of the Croatian railways there are no unprotected level crossings. Every level crossing, out of a total of 1542, has been protected in compliance with the stipulated legal regulations. The protection level depends on the rail line category (M, R, L) and road category (state, county, local, non-classified), permitted speed, terrain conditions, and local conditions at the point of intersection. Consequently, the level crossings may be protected by road traffic signs (minimally STOP sign and St. Andrew's cross) and visibility triangle, and there is a total of 1055 i.e. 68.41% such crossings; or by means of protection devices (automatic device – light-sound signals with or without half-barriers and mechanical device - barriers).

A significant technological indicator of safety is the density of level crossings in relation to the railway network length. The LC density is proportional to the

number of crossings and inversely proportional to the length of the railway network. In Croatia it is 0.52 LCs per kilometre of railway line (Germany 0.56, France 0.65, UK 0.46, Poland 0.94, the Czech Republic 0.89).

Table 3: Number of LCs on the network of the Croatian railways, regarding the protection method.

Year	Protection method		Total
	traffic sign + visibility triangle	automatic / mechanical	
2001	1171	442	1613
2002	1154	447	1601
2003	1128	448	1576
2004	1109	451	1560
2005	1096	458	1554
2006	1080	466	1546
2007	1055	487	1542

Table 4: Number of LCs on the network of Croatian railways, regarding the protection method and rail line category.

Year	Rail line category	Protection method		Total
		traffic sign + visibility triangle	automatic / mechanical	
2005	(M)	329	282	611
	(R)	296	114	410
	(L)	471	62	533
			Total	1554
2006	(M)	320	292	612
	(R)	297	114	411
	(L)	463	60	523
			Total	1546
2007	(M)	307	309	616
	(R)	289	114	403
	(L)	459	64	523
			Total	1542

4 Safety on LCs in Croatia

The traffic safety at level crossings means the safety of rail and road traffic. The safety condition at LCs in the Republic of Croatia is best reflected in the statistical data on the number of traffic accidents with consequences. The statistics and the overview of emergencies in the period from 2001 to 2007 are presented both in Tables [10–11].

Table 5: Share of traffic accidents at LCs in relation to the total number of accidents.

Year	Total number of traffic accidents	Number of traffic accidents on LCs	Share (%)
2001	81.911	578	0,71
2002	86.611	530	0,61
2003	92.102	517	0,56
2004	76.540	487	0,64
2005	58.132	454	0,78
2006	58.203	496	0,85
2007	61.020	514	0,84
Total	514.519	3.576	0,70

Table 6: Number of traffic incidents regarding the type of protection in the period from 2001 to 2007.

Year	Protection method LCs			Total
	Physically protected	Light signalization	Unprotected (only traffic sign)	
2001	243	109	226	578
2002	250	99	181	530
2003	290	107	120	517
2004	283	87	117	487
2005	274	80	100	454
2006	311	91	94	496
2007	303	96	115	514
Total	1954	669	953	3576

Table 7: Number of traffic incidents at LCs with victims.

Year	Protection method LCs			Total
	Physically protected	Light signalization	Unprotected (only traffic sign)	
2001	17	15	75	107
2002	23	16	52	91
2003	33	9	44	86
2004	22	10	36	68
2005	23	14	43	80
2006	28	19	37	84
2007	27	9	37	73

Table 8: Number of fatalities, seriously, lightly injured in traffic accidents at LCs.

Year	Consequences	Protection method LCs			Total
		Physically protected	Light signalization	Unprotected	
2001	fatalities	1	1	5	7
2002		2	4	8	14
2003		4	3	4	11
2004		3	5	4	12
2005		1	2	10	13
2006		1	4	11	16
2007		--	3	6	9
2001	seriously injured	7	6	30	43
2002		7	8	14	29
2003		10	2	13	25
2004		7	5	14	26
2005		7	7	19	33
2006		12	5	11	28
2007		11	1	11	23
2001	lightly injured	13	12	89	114
2002		23	13	57	93
2003		35	10	46	91
2004		21	6	57	84
2005		27	14	41	82
2006		32	12	29	73
2007		34	8	48	90

Table 9: Emergencies at level crossings and consequences.

Year	Number of emergencies at level crossings	Emergency consequences		
		Material damage	Victims	
		fractures of half-barriers / barriers	fatalities	seriously injured
2001	68	444	12	22
2002	69	457	12	31
2003	64	504	6	26
2004	68	566	16	13
2005	87	541	16	25
2006	78	639	17	19
2007	71	683	12	12
Total	505	3834	91	148

5 Evaluation of the safety condition at LCs in Croatia

The analysis of the research carried out and the statistical data during the seven-year period on the incidents at LCs and their consequences has led to the following conclusions:

- the share of LC accidents in the total number of traffic accidents in road traffic amounts to 0.693%, which is a much higher share than in the EU countries where it amounts to 0.01%;
- the share of fatalities in LC accidents out of the total number of fatalities in traffic accidents in road traffic amounts to 1.858%, which also represents a much higher share than in the EU countries where it is less than 1%;
- the data of 550 average annual collisions and fractures of barriers, as well as the frequency of crossing the railway line at LCs with the half-barrier / barrier lowered and the light-sound signalization turned on, proves inadequate behaviour of traffic participants which is in the majority of cases the cause of emergencies with the most serious consequences;
- in a significant number of LCs that are protected only by adequate traffic sign (STOP or St. Andrew's cross), there is no visibility triangle;
- the problem of unstandardized and unique monitoring of data, structure methodology and data processing at the authorized institutions (Croatian railways), Ministry of the Interior, road operators) which results from the absence of a unique base and joint information system;
- lack of uniformity of the legislation at the European level.

6 Conclusion and proposal for future research

LCs are points of conflict between rail and road traffic and potentially high-risk traffic points. Since a share of accidents at LCs in the total number of road traffic accidents ranges on the average at around 0.01%, and in rail traffic from 50-80%,

it may be concluded that the safety and the improvement measures of the system lie in the responsibility of the railways. However, the statistical data also show that in more than 90% of emergencies the main causes lie in the road vehicle drivers and pedestrians. Besides, there is a significant number of accidents at LCs protected by devices during their proper operation which is also an indicator of extremely low level of drivers' compliance with the traffic regulations. Therefore, the safety problem at LCs is a common problem both of rail and road sectors, and for its efficient solving there has to be cooperation between both sectors.

The measures for the improvement of the current system are the basis for further research and can be grouped in three basic categories:

- technological and technical aspect – adoption of new technologies and advanced technical solutions,
- human factor – education of traffic participants in order to improve the traffic discipline and the culture of drivers,
- legislation – monitoring and participation in harmonizing the European legislation and its implementation into the national legislation.

Only systemic and continuous implementation of measures and actions in compliance with the Program of solving LCs in the area of technical and technological solutions as well as in the area of educating the traffic participants may eventually result in the improvement of the current condition and in achieving higher safety of rail and road traffic at LCs.

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