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28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

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ANALYSIS OF PEDESTRIAN AND CYCLIST BEHAVIOUR AT LEVEL CROSSINGS

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Abstract

Level crossings (LCs) are points of conflict between rail and road traffic. Therefore, from the aspect of safety they are potentially high-risk traffic points. Traffic participants at LCs are pedestrians, cyclists, motorcyclists, car drivers and locomotive drivers. The behaviour of traffic participants represents the main cause of traffic accidents at LCs. Most research examining road users' behaviour at LCs has focused on car drivers and there are few studies dedicated to pedestrians and cyclists, especially in Croatia. Cyclists are often treated like pedestrians but cyclists can travel much faster than pedestrians, which can cause unexpected behaviour. The paper gives an overview of the existing cycling features in the City of Zagreb and the statistics of accidents on LCs in the Republic of Croatia. Also, through a review of the major recent studies on the behaviour of pedestrians and cyclists at railroad crossings, the trends have been presented as well as the results of research. The review paper will serve as the basis for further research of design, traffic safety and the behaviour of pedestrians and cyclists, and their correlation at the LCs in the Republic of Croatia.

Key words: level crossings, pedestrians, cyclists, traffic safety

1 Introduction

Level crossings (LCs) are places of direct conflict between rail and road traffic. Since these are collision points of two traffic systems, they represent from the safety point of view traffic points of high risk at which there often comes to emergency situations, sometimes with the severest of consequences. Statistical data show that in more than 90% of emergency cases the main cause lies in the road motor vehicle drivers and pedestrians. In the Republic of Croatia there is a total of 1,514 LCs out of which 60 are level pedestrian crossings. The safety level depends on the category of the railway line and road, permitted speed, field conditions and local circumstances at the crossing point. Consequently, LCs can be secured by road traffic signs (minimally the sign STOP and St. Andrew's cross) and the visibility triangle or security device (automatic device – light-audio signals with or without half-barriers and mechanical device – barriers). Automatic or mechanical devices are used at 531 LCs, whereas the remaining 923 are secured by road traffic signs and the visibility triangle [1]. The issue of LCs is included in a large number of laws, regulations and other documents defining the security method as well as under whose jurisdiction lies the solving of certain segments of LC [2, 3]. On the other hand, although cycling has significantly increased over the recent several years, the cycling issues are included in the legal regulations at an extremely low extent [4]. Neither are the investments into infrastructure improvement sufficient, which affects negatively the safe flow of traffic and leads to emergency situations.

2 Analysis of cycling traffic

2.1 Summarized overview of carried out research of cycling traffic

A significant increase in cycling in the countries worldwide, particularly in the cities, has been evident and is the result of implementing long-year structural programs and measures as a special segment of comprehensive traffic policies with the aim of increasing bicycle traffic. The majority of these programs and measures are in correlation with the implementation of measures for the improvement of other travelling modes.

Review of literature [5] suggests the need to facilitate cycling through appropriate bicycle infrastructure, integration with public transport, traffic calming, training and education programs, bicycle access programs, and legal issues. Countries and cities with high levels of cycling and good safety rates tend to have extensive infrastructure, as well as pro-bicycle policies and programs, whereas those with low cycling rates and poor safety records generally have done much less. However, it is not clear which measures are the most effective and should be given priority in designing and implementing a pro-bicycle policy package. A significant increase in bicycle traffic is evident from the following. For example, Berlin almost quadrupled the number of bicycle trips between 1970 and 2001 and doubled the bicycle share of trips from 5% in 1990 to 10% in 2007. In spite of the sharp rise in cycling, serious injuries in Berlin fell by 38% from 1992 to 2006. In only six years, the bicycle share of trips within the City of Paris more than doubled from 1% in 2001 to 2.5% in 2007. The bicycle share of trips in Bogota quadrupled from 0.8% in 1995 to 3.2% in 2006. The total number of bicycle trips in London doubled between 2000 and 2008, while cyclist injuries fell by 12% over the same period. Amsterdam raised the bicycle share of trips from 25% in 1970 to 37% in 2005 while serious cyclist injuries fell by 40% between 1985 and 2005. From 1995 to 2003, the bicycle share of trips in Copenhagen rose from 25% to 38% among those aged 40 years and older [5]. Looking at these research results one cannot determine which measures/packages dealt with the issue of cycling traffic at level crossings, both from the aspect of relevant bicycle infrastructure, improvement of cyclists' traffic safety, etc. Therefore, it is necessary to carry out further systemic research of cycling traffic at LCs.

2.2 Features of bicycle traffic in the City of Zagreb

In the City of Zagreb for the last 15 years there have been ongoing measures to improve and encourage bicycle traffic in the overall travel. In the mid 1980s the bicycle traffic and bicycle-oriented surfaces were intended exclusively for recreational and sporting purposes (the first example was the bike path around the lake of Jarun) which is mostly the case today. In the period since 2010 additional 21 km of cycling paths have been made in the wider urban area and 138 km of sport-recreation cycling paths in the Nature Park Medvednica, which is a total of approximately 370 km. Also, the City of Zagreb undertook a number of other traffic technical and regulatory interventions with the aim of improving the conditions for bicycle traffic (e.g. removal of urban and architectural barriers, marking of cycling areas with red filled (infill) lanes in the full profile, construction of bicycle path or lane during reconstruction and major road repairs). First official data regarding the volume of bicycle traffic were recorded in the year 1999 for the purpose of a traffic study of the City of Zagreb [6]. The research covered in this study shows that only 0.7% of the daily trips are realized by bicycle. However, it is interesting to note that 51% of households said that they had at least one bicycle, which represents a respectable potential for greater use of bicycles as means of travel. After the above mentioned traffic study, several measurements and surveys were conducted which provided an approximate image for certain characteristics of the intensity of bicycle traffic. In the study performed by ISIP-MG [7], measurement of traffic at 16 locations was carried out, mostly on the city's busiest traffic corridors. Based upon these limited measurements,

it can be assessed that there is a certain amount of increase in bicycle traffic. Furthermore, by carrying out comprehensive research for the needs of the Project CIVITAS ELAN ZAGREB at certain locations the measurement of cycling traffic was carried out [8]. Figure 1 shows the results of measurements for 2008 and 2012. By comparing the measurement results one can conclude that at the observed locations significant increase in bicycle traffic was recorded, in the amount of 17.18% to even as much as 72.25%, although the cycling infrastructure is still insufficiently developed and not at an acceptable level.

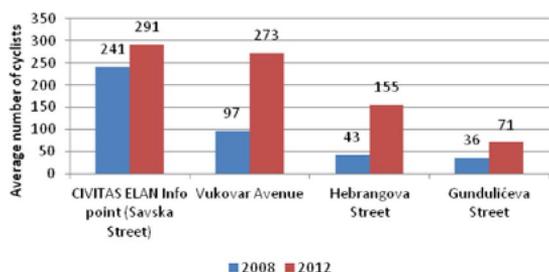


Figure 1 Average number of cyclists at four control locations [8]

Table 1. shows a significant reduction in the number of fatalities during 2012 in relation to the previous year 2011 by as much as 71.43%. The statistical reports [9] state as the most frequent causes of traffic accidents involving cyclists the following: riding across pedestrian crossing, failure to use cycling paths/lanes, riding on sidewalks, and no lights at night. It should be mentioned that during 2012 in traffic accidents involving cyclists, they were responsible for about 2/3 of traffic accidents of this type, which can be attributed to the low level of traffic culture, i.e. disregard of traffic rules. However, it is impossible to determine from the data what is the number and what are the types/consequences of accidents that occurred at LCs involving pedestrians, i.e. cyclists.

Table 1 Number and consequences of traffic accidents involving cyclists in the area of the City of Zagreb [9]

Number of traffic accidents involving cyclists	Year		Difference
	2012	2011	[%]
with fatalities	2	7	-71.43
with injured	309	297	4.04
with material damage	93	110	-15.45
Total	404	414	-2.42

Further development and improvement of bicycle traffic in the City of Zagreb will be focused upon interventions that can be defined through the following program components: improving conditions in the existing bicycle network, further development and expansion of bicycle paths or lanes, implementation of public bicycle service (e.g. nextbike), amending legislation regarding regulation of bicycle traffic, education and marketing activities to encourage people to use bicycles as a means for the realization of commuting [10]. Consequently, it is necessary to systematically monitor the movement of bicycle traffic and the safety level for the area of the City of Zagreb. Among other things, this would create a certain base of traffic data with the objective of more detailed analysis of non-motorized traffic in/at the area of LCs. Such analysis should result in a proposal of measures and guidelines for proper management and design of non-motorized traffic in/at the areas of LCs.

3 Analysis of safety situations at level crossings

In railway traffic an safety situation represents an undesired, unintentional or unexpected event or sequence of such events, which results in any kind of damage, regardless of the amount of damage. Emergency situations are divided into four basic categories: serious accidents, accidents, disturbances and avoided accidents [11]. Serious accident is an emergency situation in railway traffic in which at least one person has been killed, and/or five or more persons are physically injured, and/or the material damage is greater than five million kuna. An accident is an emergency situation in railway traffic with harmful consequences such as severe physical injuries of up to four persons and material damage that can be estimated at a value of up to five million kuna [1]. Traffic safety at LCs means safety of railway and road traffic. The safety condition at LCs in the Republic of Croatia is best shown by the statistical data about the number of traffic accidents and consequences. An analysis of accidents at LCs and their consequences in the period 2007-2008 still show a significant number of accidents, either fatal or greater number of injured persons, and with considerable material damage. Particularly worrisome trend of steady growth in the number of injured people tend to LCs with the highest level of security. Comparing the 2011 and 2012, it is evident that in the 2012 the number of serious accidents is significantly reduced (25%) and the number of fatalities as well (34.6%). In the 2012 on the LCs happened a total of 45 accidents, eight serious accidents and 37 accidents. It is disturbing the fact that seven of these accidents occurred at LCs secured with automatic devices with light-acoustic signaling and semi-barriers in which two people died and one person was seriously injured. On the LCs secured with light-acoustic signaling occurred 13 accidents in which one person was killed and eight were seriously injured, while the 25 accidents that occurred at crossings marked by road traffic signs "Stop" and "Andrew's Cross", five people were killed and six were seriously injured (Figure 2., Table 2. and 3.).

According to statistics published by the European Railway Agency (ERA), there are at least 123,000 LCs in the European Union (EU). Most of them (71%) are passive LCs without any active warning or protection devices, such as lights, bells or gates. Roughly 45% of LC accidents in the EU occur at passive LCs, and 65% of road users involved in accidents are drivers or occupants of passenger cars or heavy vehicles. In 2010, there were 359 LC accident fatalities in the EU. This represents 29% of fatalities in railway accidents but only about 1.2% of all road accident fatalities. Most of the direct causes are related to the behaviour of road users (95% [12]) such as distraction, while other causes of accidents were related to weather conditions or the condition of the driver (e.g. alcohol/drugs) [13]. An evaluation of accident data on 256 LC accidents was carried out as part of the SELCAT (Safer European Level Crossing Appraisal and Technology) project. About 91% of level crossing accidents in the EU were found to be caused by human failure, and over 80% were found to have been caused by the driver of the road vehicle not respecting the traffic rules [14].

Table 2 Overview of emergency situations at LCs [1]

Safety situation		SERIOUS ACCIDENTS						ACCIDENTS					
		2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
At LCs	secured with SS-devices	4	2	8	1	8	3	15	13	17	11	14	18
	secured with traffic signs	5	4	5	4	4	5	48	19	40	25	20	19
	pedestrian crossing	0	1	0	0	1	0	0	0	0	0	0	0
Total		9	7	13	5	13	8	63	32	57	36	34	37

Table 3 Analysis of consequences of emergency situations at LCs [1]

Safety situation		FATALITIES						SEVERELY INJURED					
		2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
At LCs	secured with SS-devices	7	2	9	1	10	3	1	4	6	5	4	9
	secured with traffic signs	5	6	6	6	4	5	11	11	11	5	4	6
	pedestrian crossing	0	1	0	0	1	0	0	0	0	0	0	0
Total		12	9	15	7	15	8	12	15	17	10	8	15



Figure 2 Emergency situations at LCs in Croatia [1]

4 Overview of studying the behaviour of participants in road traffic at level crossings

Most research examining road users' behaviour at LCs has focused on car drivers, and there are fewer studies dedicated to pedestrians and cyclists. One of the significant problems is trespassing. A number of studies have suggested that the main reason for trespassing is taking

a shortcut from point A to point B because the authorised route is assessed to be too far away. According to a study in Finland, most people were trespassing while going shopping, jogging, or on their way to school or work. Thirty-five percent of all respondents trespassed daily or almost daily. It is significant that 67% of all respondents answered that they trespassed at least once a week. Half of the respondents assessed that the trespassing is either completely or fairly safe. Overall, 59% of the respondents considered trespassing illegal, 15% considered it legal and 26% did not know. One of the measures to decrease trespassing is the installation of countermeasures. The data show that there were 78 bicycle trespassings before installation of countermeasures and zero trespassing after the installation of countermeasures [15]. Studies indicate that different road users might interact differently with the LC system. In particular, on-road studies indicate that the content of individuals' situation awareness or their sense of what is going on around them varies depending on their transportation mode, although some authors suggest that these differences result in cognitive incompatibilities between different road users [16]. Motorcyclists appear to be more focused on anticipating potential hazards than car drivers, whereas cyclists in dense traffic may focus more on seeking safe alternative travel routes such as bicycle lanes, service lanes and footpaths [17]. Beanland et al. designed a longitudinal survey to record interactions at LCs over a two-week period. The survey focused on understanding how individuals behaved in the presence of a train, which included examining the decision that they made (to stop or proceed before the train) and the specific factors that assisted their decision-making in that situation. The sample included 166 adults residing in metropolitan Melbourne (80%) and regional Victoria (20%), with a mix of car drivers, motorcyclists, cyclists and pedestrians. Visual information (e.g., flashing lights) emerged as one of the most influential factors for car drivers and motorcyclists, whereas pedestrians and to a lesser extent cyclists relied more on auditory information (e.g., bells) to alert them to the presence of a train. Pedestrians were also more likely than other road users to speed up and cross the tracks ahead of an approaching train. Overall, these results emphasise the importance of designing road systems to support cognition and behaviour across a range of road users, in order to ensure a safe system for all [18]. In addition, a relatively large survey of 1,862 cyclists in Queensland, Australia found that women are more likely to cycle off-road than men, and are less likely to commute by bicycle than men, and that, although factors related to traffic conditions, motorist aggression and safety are concerns for both women and men, women report a far greater number of these constraints [19]. Pedestrian treatments on risky behaviour at light rail transit LCs was researched by Siques. Five treatments were evaluated: pedestrian automatic gates, a prototype active pedestrian warning device, a prototype active "Look Both Ways" sign, barrier channelization at a skewed crossing, and a "Stop Here" pavement marking. Statistically, to reduce risky pedestrian behaviours, pedestrian automatic gates were reported as the most effective. However, pedestrians were found to be less likely to look both ways or stop before entering a crossing when a pedestrian automatic gate or pedestrian flashing light was installed. Interestingly, the "Look Both Ways" sign was found not to be effective in reducing the number of pedestrians entering the crossing immediately after train departures. Research on examples of innovative warning and control devices at LCs include four factors that enabled pedestrians to walk safely through LCs: pedestrian awareness of the crossing, existence of a pedestrian path across the trackway, pedestrian awareness of and ability to see an approaching train, and pedestrian understanding of the potential hazards at LCs [20]. Khattak and Luo [21] investigated pedestrian and cyclist behaviour at a dual-quadrant gated LC located in the residential area of the City of Fremont, Nebraska. The crossing has two sets of railroad tracks, two paved highway lanes, and is equipped with dual-quadrant gates. The gates have flashing lights, crossbuck sign and an audible bell. The crossing is equipped with a crosswalk on its west side for pedestrian use, which is sometimes used by cyclists as well. Most pedestrians and bicyclist use the crosswalk, but a few occasionally use the street to negotiate the crossing. Violations by pedestrians and cyclists were monitored using video surveillance in three instalments during the years 2008, 2009 and 2010. Violations were divided into four

groups: 1) passing under descending gates, 2) passing around fully lowered gates, 3) passing under ascending gates, and 4) passing around fully lowered gates between successive trains. During data collection a total of 1,074 non-motorized individuals were observed indulging in 807 violations. On average, 1.70 individuals were observed per crossing event and 1.27 violations per crossing event were noted. Analysis showed that there were no differences in the occurrence of gate-related violations by pedestrians and cyclists. Young children of around 8 years of age or younger were involved in 25% more gate-related violations than older crossing users. Violations increased with the presence of more individuals at the crossing during train crossing events, but the contribution from young children was greater than that from older crossing users. In Holland there were 48 fatal incidents in 1985 and the government policy was to decrease this amount of LC accidents by 50% by the year 2010. In 2006 on 2,724 public LCs of all types there were 4 accidents that took 9 lives and left 11 people injured, while no derailments due to LC accidents occurred. There were 93% of accidents caused by errors of some description by road users. Of these, there were 39% conscious errors. In 53% of accidents the road user did not see the train approaching until impact. Males were substantially more involved in incidents and accidents than females, while more than 30% of those involved belonged to the age group 20-29. The total involvement of age groups peaks between 10 – 59, school and working ages [22]. Reducing pedestrian and cyclist violations at LCs will improve traffic safety, but most technology-based countermeasures (e.g., automatic pedestrian gates, electronic signs) are expensive and difficult to maintain. Other options for that are enforcement and public outreach and proper education.

5 Conclusion

The existing level of adjustment of the traffic infrastructure to current and future growth of bicycle traffic is not sufficient, which can be seen from the presented characteristics of bicycle traffic in the City of Zagreb. The safety at LCs is a complex problem. Apart from technical and technological factors also human behaviour has to be taken into consideration and this is very difficult to predict, monitor and track. Whether referring to accident which resulted from the collision of a train and motor vehicle, cyclist or pedestrian, the consequences are larger by injuries. Research showed that the main cause of collision at LCs is the behaviour of road user participants. This can be largely assigned to risky behaviour of drivers i.e. their lack of attention when driving a vehicle, disregard of traffic regulations and stress. Risky behaviour of motorists, cyclists or pedestrians at LCs is extremely dangerous and mostly results in emergency situations. The road traffic participants are often not aware of potential danger at LCs, and adaptation and response time are often related to implicit impacts on perception and capability of decision making, e.g. stress, fatigue, personal problems, and physical and mental state. The review paper will serve as the basis for further research of design, traffic safety and behaviour of pedestrians and cyclists, and their correlation at LCs in the Republic of Croatia. Finally, apart from technical and technological design solving of the crossings, the systemic activities in terms of education of road motor vehicle drivers, cyclists and pedestrians is of extreme importance, with the aim of upgrading the level of their traffic discipline, culture and awareness about the causes and consequences of risk behaviour at LCs.

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