Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 45 (2020) 562–571

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 2nd International Congress on Transport Infrastructure and Systems in a changing world (TIS ROMA 2019), 23rd-24th September 2019, Rome, Italy

Safety at LCs in Italy: evidence from the Safer-LC Project

Stefano Carrese[a], Marco Petrelli[a,*], Alessandra Renna[a]

[a] *Department of Engineering, Roma Tre University, Rome, Italy*

Abstract

In railways one of the most critical point is represented by the intersections with road, especially at level crossings, where the interaction between road users (cyclists, pedestrians, motorcyclists, drivers, etc.) and train users might generate conflicts and risk situations. Level crossing accidents represent 24% of all significant railway accidents when railway suicides are excluded according to the European Union Agency for Railways statistics. There is a complex interaction among the components that makes this kind of intersection dangerous, depending on the road users' behaviour, the unsafe layout of the infrastructure and the response of the various type of users with regard to the different conditions (traffic, weather, design, etc.).

Starting from these considerations, the SAFER-LC Project has the objective of upgrading safety and minimising risks at and around level crossings by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management and new design of level-crossing infrastructure.

This paper presents the results of the first phase of this project with special attention about the results of the Italian level crossings conditions. With regard to the first phase of the project, the paper proposes a comparative analysis between Italy and seven European countries (Greece, Finland, France, Italy, Norway, Spain and Turkey), carrying out an in-depth Level Crossing accident analysis with data and reports from the railway operators and the national accident investigation bodies. The analysis focuses the attention on specific variables such as details on collision, victim, road and railway environment, level crossing characteristics and circumstances. The analysis highlights the existence of some critical issues for safety with important differences in terms of characteristics and intensity in each country and especially for the Italian case.

Keywords: Level Crossing, In-depth Safety Analysis, Accident

* Corresponding author. Tel.: +39-06-57333383; fax: +39-06-57333441.
E-mail address: marco.petrelli@uniroma3.it

10.1016/j.trpro.2020.03.056

1. Introduction

Despite having technical systems in place to make the intersection between the road and railway tracks safer, accidents at level crossings (LCs) continue to occur and the consequences of these are amongst the most serious of all road traffic accidents (Davey et al, 2005). Moreover, according to International Union of Railways (UIC, 2016) the risk of collision at LCs has increased along with the growing volume of global freight and passenger traffic, both road and rail. As stated by United Nations Economic Commission for Europe (UNECE, 2010), in low and middle-income countries, the levels of motorization are rapidly rising and in high-income countries, there is an increasing use of bicycles as inhabitants become more environmentally conscious, also highlighting the need to take into account the interests of vulnerable road users.

A LC is where a railway line is crossed by a road or right of way without the use of a tunnel or bridge (Office of Road and Rail web, ORR). LCs represent a critical safety point for the train and road user. This intersection is characterized by a complex interaction between the components that make up often unpredictable, particularly road user behaviour. The coordination between different organisations responsible for managing risks at these points adds a further layer of complexity. In general, railway operators are mainly involved in level crossing accidents rather than road managers but having protection measures in place is necessary not only for the safe running of trains but, above all, to safeguard road traffic and other categories of vulnerable users such as pedestrians and cyclists or motorcyclist. According to the European Union Agency for Railways (ERA), the ultimate safety goal for infrastructure managers should be the elimination of LCs but the right mix of non-technical or operational measures jointly implemented by road and rail authorities is needed to reduce the risks in the short term (ERA, 2016).

The distinction between passive and active LCs and the specific equipment adopted is important to explain different behavioural demands. Closed barriers represent a strong and almost unmistakable signal to road users that they should stop in front of the crossing. The main challenge for road users at active LCs is the extrinsic imposition of waiting time that comes into conflict with the individual's mobility goals and potentially provokes violations (Seehafer, 1997). Approaching to a passive LC, road users need to evaluate the appropriate distance to stop and grant the right of way to an approaching train. Thus, there are fundamental differences in the action that need to be activated and executed facing passive LCs compared to LCs that are equipped with barriers (Grippenkoven and Dreßler, 2018).

Starting from the experience of the SAFER-LC project (SAFER Level Crossing by integrating and optimizing road-rail infrastructure management and design), this study proposes a comparison between Italy and other six European countries (Greece, Finland, France, Norway, Spain and Turkey), carrying out an in-depth LC accident analysis with data and reports from the railway operators and the national accident investigation bodies.

This paper is divided into 5 sections including also the introduction. The second section is relative to a general overview of the SAFER-LC project. The third section presents a statistical description of safety at LCs in Europe distinguishing the type of LCs and the accidents occurred at LCs. In the fourth section, the in-depth analysis is introduced, showing the methodology developed, the results of the Italian in-depth analysis and the comparison among the 7 countries. The last section contains the conclusions of the study.

2. Overview of the SAFER-LC Project

The SAFER-LC project, funded under H2020-MG.3.4. 2016, aims to improve safety in road and rail transport by minimising the risk of LC accidents. The objective of the project is obtained by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management of LC safety and by developing alternatives for the future design of level-crossing infrastructure.

The SAFER-LC Consortium is led by UIC and composed of 17 partners from 10 different countries (France, Finland, Norway, Spain, Greece, Germany, Italy, Belgium Hungary and Turkey) representing railway operators, railway infrastructure owners, road operators, research centres, academia and industry suppliers and bringing a range of complementary skills required for this multidisciplinary research project. Specifically, the Consortium consists of 1 rail association (UIC), 1 road association (International Road Transport Union, IRU), infrastructure managers and railway operators (French National Railways, SNCF and Greece Railway Company, TRAINOSE), 6 rail research institutes (CEREMA, Spanish Railways Foundation, IFSTTAR, Technical Research Centre of Finland, Intermodal Transportation and Logistics Research Association, German Aerospace Center), 3 universities (Norwegian University

of Science and Technology, University of Roma Tre, University of Technology of Belfort-Montbéliard), 2 small and medium-sized enterprises and providers (Commsignia, Geoloc System).
A series of pilot tests across Europe have been rolled out to demonstrate how the developed solutions can be integrated, validate their feasibility and evaluate their performance. The solutions and tools that are developed and proposed in the SAFER-LC project will permit road and rail stakeholders to find more effective ways to: (1) detect potentially dangerous situations causing collisions at LCs, (2) prevent incidents through innovative user-centred design and (3) mitigate the consequences of disruptions due to accidents or other critical events at the rail or road side. The project focuses both on technical solutions such as smart detection services and advanced infrastructure-to-vehicle communication systems and on human processes to adapt infrastructure designs to road user needs and to enhance coordination and cooperation between different stakeholders from different land transportation modes.
The main output of the project is a toolbox which will be accessible through a user-friendly interface which will integrate all the project results and solutions to help both rail and road stakeholders to improve safety at LCs.

3. Safety at LC in Europe

Despite the safety purpose is directed towards the removal of LCs a high number of these infrastructures has been observed in Europe in the current scenario. In 2014, there were 114,580 LCs in the 28 EU Member States (ERA, 2016). Many differences could be found between European countries however. For example, France, Germany and Poland had the highest number of LCs in Europe (more than 9,000) and Ireland, Portugal, Slovenia, Bulgaria, Latvia, Estonia and Luxemburg had the lowest number of LCs (fewer than 1,000) as it is shown in Fig.1.
On average, there are five LCs per 10 km of line in the EU. The highest densities of LCs per km of line can be found from Sweden, Hungary, Austria and the Czech Republic where there are more than 75 LCs per 100 kilometres of railway line. The lowest densities of LCs can be found from Bulgaria and Spain where there are less than 25 LCs per 100 line kilometres. As a critical part of a railway infrastructure, LCs have been gradually removing. In fact, the number of LCs has decreased with a speed of about 4% per year over the past five years across Europe (ERA, 2016). In some countries, the reduction is even higher. At European level, with the current rate of reduction half of these passive LCs will remain after 2030.

3.1. Types of LCs in Europe

In 2014, passive (unprotected) LCs represented 47% of all LCs. These LCs are usually equipped with a St Andrew cross traffic sign but do not provide any active warning to the road users (ERA, 2016). Active LCs (protected) represented 53% of all crossing types. In Europe in 2014, LCs with automatic user-side protection and warning (barriers with lights) were the most common type of active crossings (57%), followed by the LCs with the automatic user-side warning (typically flashing lights and sound) (18%). Only 9% of active LCs is equipped with automatic user-side protection and warning and rail-side protection and LCs with manual user-side protection and warning has the same share.

3.2. Accidents at LCs in Europe

LCs constitute a significant safety concern. In recent years, on average, every day, one person has been killed and close to one seriously injured at LCs around Europe (ERA, 2016). In Europe, the number of fatalities in all types of railway accidents has decreased, except for those related to LC accidents. This can be partly explained by the continuous increase in road traffic across Europe, which may increase the likelihood of a LC accident (ERA, 2016). According to ERA (2016), there was a stagnation in the number of LC accidents, with 506 accidents recorded on railways of the EU countries in 2014, compared to 510 accidents in 2013. However, since 2009, a slightly decreasing trend has been observed. The number of LC accidents has reduced a 3% per annum. LC accidents represent 24% of all significant railway accidents and 27% of all fatalities on the railway (suicides excluded). Although there is no data for all countries, the information available indicates that the majority of accidents at LCs occur on passive LCs.
According to ERA data, Germany and Poland were the countries with more LCs accidents in EU-28 from 2010 to 2017 and, for example, in 2017 registered 73 and 57, respectively, accidents at LCs. In the same year, other countries

by the number of LC are France (41) and Czech Republic (36). In Italy 12 accidents occurred at LCs. The main statistics about the number of accidents occurred at LCs in some selected European countries are shown in Table 1.

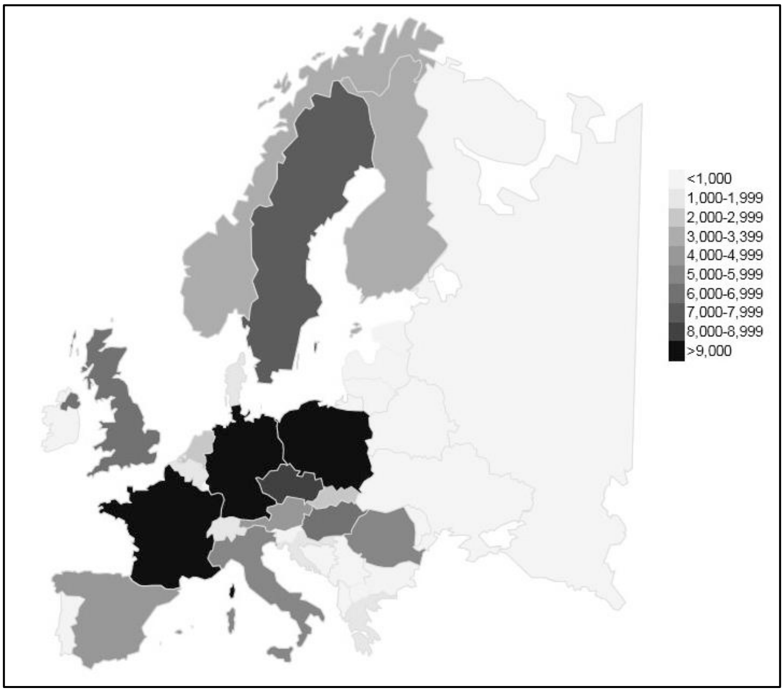

Fig. 1. Total number of LCs in Europe, 2014 (ERA 2016) –
Source: SAFER-LC project, Deliverable D1.1 – Analysis of LC safety in Europe and beyond

Table 1. Accidents at LC accidents in some European countries (ERA statistics)

Country	2010	2011	2012	2013	2014	2015	2016	2017
Poland	86	86	77	75	65	74	76	57
Germany	73	56	79	59	67	61	50	73
Czech Republic	57	34	47	36	46	36	34	36
France	36	40	38	42	51	41	48	41
Greece	16	8	6	5	10	11	1	6
Italy	15	18	13	14	16	19	15	12
Spain	11	8	8	11	10	8	10	12
Finland	9	5	11	4	4	10	6	7
Netherlands	9	14	19	21	13	3	7	11
United Kingdom	7	11	10	12	11	11	10	10
Norway	3	2	2	3	2	3	0	2

In terms of severity of accidents in relation to year 2017, Germany, Poland and France were the countries with more LCs fatalities in EU-28 (44, 42 and 42, respectively). Other countries by the number of LC fatalities are Czech Republic (20) and Spain (14). In Italy 8 fatalities occurred at LCs in that year. The main statistics about the fatalities in LC accidents between some selected European countries are shown in Table 2.

Table 2. Fatalities in LC accidents in some European countries (ERA statistics)

Country	2010	2011	2012	2013	2014	2015	2016	2017
Poland	55	62	61	52	43	53	48	42
Germany	45	28	45	32	41	35	28	44
Czech Republic	34	17	19	15	24	21	23	20
France	27	32	33	30	25	27	31	42
Greece	12	5	8	4	5	8	1	4
Italy	11	15	13	10	7	8	7	8
Spain	10	8	5	7	8	6	8	14
Finland	8	2	6	2	2	6	7	9
Netherlands	8	11	13	187	7	13	4	6
United Kingdom	4	6	7	9	9	2	5	9
Norway	3	1	1	2	1	1	0	3

4. In-depth analysis investigation

This section contains a) the methodology developed to conduct the in-depth analysis, b) the results of the Italian in-depth analysis and c) their comparison with the results of the in-depth investigations in other 6 European countries from the contents of the SAFER-LC project.

The in-depth analysis is characterized by a scope wider than a general statistical accidents analysis where the number of available data is fewer. In fact, in-depth investigations differ from accident analyses based on data obtained by different sources at the national level due to the fact that the aim is to understand accident causes and the level of detail and the number of information is higher. Through this type of analysis, it is possible to structure a detailed database that puts in relation more data that could provide current accident characteristics in terms of statistical analysis.

After an appropriate selection of the variables to take into account, an in-depth analysis permits to define critical areas and the context of the study. However, the definition of the variables is developed with respect to the purpose of the investigation using a variety of technical data from several in-depth databases such as the vehicle design, the design of the infrastructure, traffic management and human factors.

The aim of this type of analysis is to explain the events occurred in terms of impacts and causes. In fact, the large number of variables makes possible to investigate the mechanisms behind the occurrence of events. In-depth investigations are a good tool to examine crash scenarios and configurations allowing to derive general safety measures if a statistical significance is observed. In fact, if the number of cases, the period of time and the variables are limited, a limited knowledge and validity can be expected for a statistical analysis.

In general, this kind of analysis with the comparison between the results of different databases, is always hard at the international level due to the different definitions of variables, different investigation criteria and different ranges of data representativeness. Other important characteristic is that in-depth investigations are time- and cost-consuming, but highly effective in terms of the investigation of individual crashes as well as the investigation of a large number of accidents with the aim of answering specific questions and gaining insight (In-DeV Project, 2016).

4.1. Methodology applied

In this specific case, the in-depth analysis has been structured into 5 phases: 1) a first phase was relative to an accurate selection and definition of the variables that could influence and characterize the scope of the study (accidents at LCs); 2) in the second phase a collection of data and information have been required; 3) the third phase was based on the development of a standard form containing the selected variables; 4) the fourth phase contains a detailed analysis to define the specific critical areas and the variables more influential; 5) the last phase of the analysis contains a

comparison between the countries involved in the SAFER-LC project that could provide preliminary information about safety measure to reduce the events.
Specifically, the analysis has been organized using a standard form containing 9 specific variable categories and 35 variables: a) collision related information (outcome, type of involved vehicle, month, weekday, hour and year); b) victim related information (type of victim, type of road user, outcome, gender, age, intentionality, involvement in secondary tasks and intoxication); c) road environment (road traffic volume, type of road, road speed limits, number of lanes per direction, type of road surface, existence of level crossing sign before LC, inclination and crossing angle); d) railway environment (train volume, train speed limits, condition of wait platforms and number of tracks); e) LC characteristics (type of LC, location of LC and sight distances); f) circumstances (weather and lighting conditions); g) type of train; h) effect (delays and costs); i) main factors affecting the accident. The data collection form used is based on a form built in the framework of the RESTRAIL project to collect in-depth data on train-pedestrian collisions (Silla et al., 2012).

4.2. Italian in-depth analysis

In Italy, 12 accidents have been deeply inspected using data from the investigations reports of DIGIFEMA (Direzione Generale per le Investigazioni Ferroviarie e Marittime) and other information from specific additional evaluations to estimate some variables such as daily train traffic volume and road traffic volume. The railway accident investigation teams study the railway accidents (including LCs accidents) with regard to the repetitiveness and the seriousness of the events, the impacts on the railway safety and the different stakeholders involved. The investigation team prepares a report that includes a description of how the accident happened, the factors leading up to it and its consequences, as well as the investigation team's proposed improvements to traffic safety.
The investigated data used for this in-depth accident analysis are relevant also in comparison with the LC Italian inventory, they covered a period between 2011 and 2015 and the data used are reported on Table 3 and Table 4 in terms of the most relevant variables, distinguishing between rural and urban environment.

Table 3. In-depth accident data for the most relevant variables in urban environment (source: DIGIFEMA investigations reports)

CATEGORY	VARIABLE	Accident 1	Accident 2	Accident 4	Accident 5	Accident 6	Accident 9	Accident 12
Collision	Outcome	Fatality	Fatality	Fatality	Fatality	Light injury	Serious injury	Unknown
	Type of road vehicle	No vehicle involved	No vehicle involved	No vehicle involved	Passenger car	Bus	Passenger car	Bus
	Year	2011	2011	2011	2012	2012	2013	2015
Victim	Type of victim	Pedestrian	Pedestrian	Cyclists	Other	Other	Car passenger	
	Type of road user	Local inhabitant	Local inhabitant	Local inhabitant	Local inhabitant	Local inhabitant	Unknown	Local inhabitant
	Outcome	Fatality	Fatality	Fatality	Fatality	Light injury	Serious injury	
	Gender	Male	Male	Male	Unknown	Male	Male	
Road environment	Road traffic volume	2001-3000	2001-3000	2001-3000	>10000	5001-10000	5001-10000	2001-3000
	Road speed limit	50 km/h	50 km/h	50 km/h	50 km/h	50 km/h	50 km/h	50 km/h
	Type of road surface	Asphalt	Asphalt	Asphalt	Asphalt	Asphalt	Asphalt	Asphalt
	Existence of level crossing sign before LC	Yes	Yes	Yes	Yes	No	Yes	No
	Crossing angle	70-110 degrees	70-110 degrees	70-110 degrees	70-110 degrees	> 110 degrees	> 110 degrees	70-110 degrees

Railway environment	Train traffic volume	51	51	51	34	17	32	10
	Train speed limit	● 95 km/h Milano-Lecco ● 80 km/h Monza-Molteno	● 95 km/h Milano-Lecco ● 80 km/h Monza-Molteno	● 95 km/h Milano-Lecco ● 80 km/h Monza-Molteno	● 110 km/h	150 km/h	140 km/h	110 km/h
	Condition of wait platforms	Average	Average	Average	Poor	Poor	Average	Not known
	Number of tracks	2	2	2	2	2	2	1
LC characteristics	Type of LC	Automatic user side protection	Automatic user side protection	Automatic user side protection	Automatic user side protection and warning and rail side protection	Automatic user side protection and warning and rail side protection	Automatic user side protection and warning and rail side protection	Automatic user side protection and warning and rail side protection
	Sight distances	poor visibility	poor visibility	poor visibility	good visibility	poor visibility	good visibility	poor visibility

Table 4. In-depth accident data for the most relevant variables in rural environment (source: DIGIFEMA investigations reports)

CATEGORY	**VARIABLE**	**Accident 3**	**Accident 7**	**Accident 8**	**Accident 10**	**Accident 11**
Collision	Outcome	Serious injury	Fatality	Fatality	Fatality	Fatality
	Type of road vehicle	Truck	Truck	Passenger car	Other	Other
	Year	2011	2012	2012	2013	2014
Victim	Type of victim	Other	Other	Car passenger	Other	Motorcyclists
	Type of road user	Unknown	Unknown	Local inhabitant	Local inhabitant	Local inhabitant
	Outcome	Unknown	Fatality	Fatality	Fatality	Fatality
	Gender	Unknown	Unknown	Male	Unknown	Unknown
Road environment	Road traffic volume	5001-10000	1001-2000	10-100	5001-10000	5001-10000
	Road speed limit	50 km/h	80 km/h	< 30 km/h	50 km/h	80 km/h
	Type of road surface	Asphalt	Asphalt	Gravel / unpaved road	Asphalt	Asphalt
	Existence of level crossing sign before LC	Yes	Yes	No	Yes	Yes
	Crossing angle	> 110 degrees	70-110 degrees	70-110 degrees	70-110 degrees	> 110 degrees
Railway environment	Train traffic volume	10	40	11	40	18
	Train speed limit	120 km/h	150 km/h	140 km/h	105 km/h	135 km/h
	Condition of wait platforms	Average	Average	Poor	Not known	Not known
	Number of tracks	1	2	1	1	1
LC characteristics	Type of LC	Automatic user side protection and warning and rail side protection	Automatic user side protection and warning and rail side protection	Passive level crossing	Automatic user side protection and warning and rail side protection	Automatic user side protection and warning and rail side protection
	Sight distances	poor visibility	poor visibility	poor visibility	poor visibility	good visibility

The number of accidents studied and the types of collisions recorded have no statistical significance concerning only 12 accidents but they provide relevant information on critical situations at Italian LCs. About the environment, the accidents occur in rural and urban areas with similar share: 7 occurred in urban environment and 5 in rural ones.

If the information about the gender was available, the victims in LCs accidents were typically men. This information is related, for urban areas, mainly to pedestrians and cyclists while in rural areas, to truck and bus drivers. It could indicate a male tendency to underestimate risk situation and a lower level of tolerance.

A large number of the accidents were related to an illegal crossing both for pedestrians, cyclists and cars due to the high waiting times (e.g. more than 10 minutes). For specific type of road vehicle (trucks and buses), there were some specific deficiency of the level crossing layout in terms of poor visibility (signals, LC presence, darkness and vegetations) and the lack of enough space to complete the turning movement. The condition of the wait platform was usually acceptable and the road were characterized by the presence of asphalt.
The road speed limits were according to the road environment and seems to be not influential in LCs accidents. Also train speed limits seem to be not so relevant in LCs accidents but they influence the seriousness of the events occurred. The share of LC accidents occurring at active LCs is 92% due to the fact that in Italy the majority of LCs are active and equipped with automatic user side protection and warning combined with rail side protection.
According to the information at disposal, other factors are not so important to explain the cause of the accidents. In particular, the entity of the road traffic volume in LCs with accidents is low and similar to all LCs. The LCs in Italy are typically located on roads with low traffic volumes where the traffic level changes mainly according to the area (rural or urban). Different conditions are related with the train traffic volume in LCs with accidents: this is not similar to all LCs in Italy but this, in Italy, varies geographically. The train traffic in the North of Italy is different from the South of Italy where the level of traffic is smaller. In both cases, the level of train traffic seems to be not correlated with accidents.

4.3. Comparison between Italy and other 6 European Countries

In this section a comparison between seven European countries (Greece, Finland, France, Italy, Norway, Spain and Turkey) has been carried out from the experience of the SAFER-LC project. The involved partners were responsible for collecting the data from relevant sources in each country such as accident investigation reports from railway operators and national accident investigation bodies. The in-depth LCs accident data was investigated and reported both by organisations independent from railways (Greece, Finland and Italy) and by railway stakeholders (France, Norway, Spain and Turkey). The accident data cover a period of almost 5 years and the extent of data period varied between 4–10 years for each country: France, Italy, Norway and Turkey provided the requested five years, the Spanish data covered 4 years, the Greek data concern a period of 6 years and the Finnish data of 10 years. The total number of reported accidents by country varied between 12 and 578 and the number of involved persons varied between 21 and 453.
The main results here presented have been selected from the contents of the Deliverable 1.2 (*Level crossing accidents and factors behind them*) of the SAFER-LC project, referring to the most representative variables. Most LCs accidents occurred during daytime when the road traffic volume is higher. The highest road traffic volumes in accident locations can be found in France with a significant share of accidents (24%) at LCs where road traffic volume is higher than 5,000 road vehicles per day. In Greece, in Finland and in Norway the road traffic volumes are typically smaller (100/200 vehicles per day) but the accidents mainly occurred at LCs where the road traffic volume is maximum (over 60%).
The victims in LC accidents are most often car drivers or pedestrians and typically men. In terms of age, in France 46% of fatal victims were 60 years or older and in Finland the corresponding share was 33%. Information about intoxication could be interesting but few countries collect this type of information. For example, in Finland 22% of fatal victims were intoxicated by alcohol, medicines and/or drugs (unknown cases were excluded).
In terms of road environment, the most important results are referred to road speed limits, type of road surface, LC characteristics, location of LC and sight distances as it is shown below. A high share of LC accidents occurred in areas where the road speed limit is rather low such as Tukey (100%), Greece (87%), Norway (83%) and France (78%) where road speed limit is 50 km/h or less.
The road had asphalt pavement in most LCs accidents in Greece (98%) and in Italy (92%) whereas the road passing the LC was typically unpaved in LCs accidents in Finland (54%) and in Norway (60%) as it expected in terms of prevalent environmental condition. Most LCs accidents occurred in urban environments in Greece (63%), in France (56%), in Italy (58%) and in Turkey (63%). In Norway 95% of LC accidents occurred in rural environment.
There were some variations by country on the type of LCs. The accidents occurred typically at passive LCs in Finland (68%), in Turkey (47%) and in Spain (40%). Most accidents occurred at LCs equipped with automatic user side

protection and warning in France (72%) and in Norway (45%). Most LCs accidents occurred at LCs equipped with automatic user side protection and warning combined with rail side protection in Greece (57%) and in Italy (67%).
The sight distances were in most cases according to instructions in Finland (82%) and in Norway (91%) whereas a rather high share of accidents occurred at LCs with poor visibility in Italy (75%) and in Turkey (69%).
The main factors affecting LC accidents were breakdown of the car at LC, car abandoned at LC, car violating the barriers, excessive speed, non-observation of road signage, overtaking the queueing traffic, distraction, limited visibility due to glare from the sun and loss of control (vehicles or bicycles).
According to the data collected and analysed, it is possible to underline that LCs accidents depend mainly on uncorrected behaviour of LCs users (violations and/or mistakes in crossing often due to the lack of a clear detection of LCs) in all countries analysed. However, in-depth analysis showed large differences among these countries for the different environmental and context conditions involving different factors and causes of LCs accidents.

5. Conclusions

The aim of the study was to propose a comparative analysis between Italy and other six European countries (Greece, Finland, France, Norway, Spain and Turkey), carrying out an in-depth LC accident analysis with data and reports from the railway operators and the national accident investigation bodies starting from the experience of the SAFER-LC project. This project, funded under H2020-MG.3.4. 2016, aims to improve safety in road and rail transport by minimising the risk of LC accidents. The objective of the project is obtained by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management of LC safety and by developing alternatives for the future design of level-crossing infrastructure. The project focuses both on technical solutions such as smart detection services and advanced infrastructure-to-vehicle communication systems and on human processes to adapt infrastructure designs to road user needs and to enhance coordination and cooperation between different stakeholders from different land transportation modes.
Despite the safety purpose is directed towards the removal of LCs, a high number of these infrastructures has been observed in Europe in the current scenario and, always at European level, with the current rate of reduction half of these LCs will remain after 2030. Passive (unprotected) LCs represented 47% of all LCs while active LCs (protected) represented 53% of all crossing types. In Europe, the number of fatalities in all types of railway accidents has decreased, except for those related to LCs accidents and these represent 24% of all significant railway accidents and 27% of all fatalities on the railway (suicides excluded).
The results of the Italian in-depth investigation, even if the number of accidents studied and the types of collisions recorded have no statistical significance concerning only 12 accidents, provide relevant information on critical situations at Italian LCs. Differently from many other European countries, the LCs accidents are mainly due to specific categories of LCs users (VRU or truck and buses drivers) and they were related to an illegal crossing due to the high waiting times or related to some specific deficiency of the level crossing layout.
Although the collected in-depth LC accident data does not generally cover all the occurred accidents at LC in each country and their number is generally low due to the fact that an in-depth analysis is time- and cost-consuming, this type of analysis has various added values. It is possible to collect a high number of information and technical data taking into account a wide variety of variables to understand accident causes. In fact, the large number of variables makes it possible to investigate the mechanisms behind the occurrence of events. The level of detail and the structure of the analysis allows to identify the factors that contribute to accidents with respect to a variety of parameters.
The proposed in-depth analysis provided a technical structure that could be implemented in other similar studies or analysis. Despite the low number of documented cases and the lack of information for some variables, this specific analysis permitted to define current accident characteristic due to its highly effectiveness in terms of the investigation of individual crashes. The analysis requested a particular attention on the phase of definition of the variables, with respect to the context and the purpose of the investigation and, on the organization of the standard form containing specific variable categories.
Taking into account the limitations of the in-depth analysis, recommendations regarding in-depth LC accident databases have been introduced. In fact, an appropriate database allows to assess the innovative measures to improve the safety of LCs. The variables which are especially interesting from human factors point of view are the victim details such as type of victim, his/her qualities, motives and/or behaviour provide valuable input data when assessing

the possible effects of LC safety measures. The coverage of victims' details could be improved by a close cooperation of different parties involved in accident investigation.

The more detailed information on victims of LC accidents supports the authorities and railway stakeholders in their decision making process to allocate the funds for the traffic safety work and to decide the targets (e.g. safety campaigns). Moreover, the detailed information of the surroundings of LCs and the types of LCs were the LC accidents occur, for example, allow the planning and identification of different safety measures to different types of LCs.

One major challenge is relative to the differences of data collection procedures and the amount and details of documented data between countries. Therefore, the recommendation is to increase the cooperation between the organisations conducting the in-depth LC accident investigations and the organisations which report the yearly accident numbers to the ERA database. Furthermore, it would be useful to have a European wide recommendation on LC accident data collection including proposal on most useful variables to be collected. A more detailed European wide LC accident data would enable more detailed analysis of LC accidents and would lead to useful conclusions.

References

Davey, J, Ibrahim, N, Wallace, A, 2005. Motorist behaviour at railway level crossings: An exploratory study of train driver experience. Article presented at Australasian Road Safety Research, Policing and Education Conference, Wellington, New Zealand.

European Union Agency for Railways, 2016. Railway Safety Performance in the European Union, Belgium.

Grippenkoven, J, Dreßler, A, 2018. SAFER-LC: Level Crossing Design Meets Traffic Psychology. In: Proceedings of the 3rd German Workshop on Rail Human Factors, pp. 8 -14. Braunschweig: ITS mobility. ISBN 978-3-937655-45-1.

In-DeV Project, 2016. Review of current study methods for VRU safety Part 1 – Main report.

International Union of Railways, 2016. "UIC eNews" Nr 496, May 2016.

Office of Road and Rail, 2017. Web: http://orr.gov.uk/rail/health-and-safety/infrastructuresafety/level-crossings.

SAFER-LC Project, 2017. Deliverable 1.2 - LC accidents and factors behind them.

Seehafer, W, 1997. Verkehrsgerechte Sicherung von Bahnübergängen. In: VDEI e.V. (Ed.), Eisenbahningenieurkalender '97, pp. 109-134.

Silla, A., Kallberg, V-P, Salenius, S, 2012. Detailed data on railway suicides and trespassing accidents in EU Member States. Confidential working paper of work package 1 of RESTRAIL project.

United Nations Economic Commission for Europe, 2010. Road Traffic and Road Signs and Signals Agreements and Conventions Status and Contracting Parties, http://www.unece.org/index.php?id=26749.