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INVESTIGATION OF TRAFFIC SAFETY SITUATION AT THE LEVEL CROSSINGS IN LITHUANIA

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Abstract. Traffic safety assurance is the main task on roads as well as railways. At the level crossings both infrastructures cross each other. Therefore the problem of assuring the traffic safety at the level crossings remains permanently actual and is often researched. Requirements for passing the level crossing are clearly defined in the road traffic rules for the road users and in the railway traffic rules for railway carriers. However, despite all these aspects, a level crossing is the place which causes many problems for the users of both infrastructures. Though a number of deaths at level crossings amount to only 2% of the total number of road deaths, it makes 20–30% of the total deaths in railways. In this article the problems are described that occur during the use of the level crossings and are concerning the traffic safety assurance. The ways of increasing the traffic safety assurance are also discussed. This problem is actual because of the scientific research and discussions in various countries of the world. The article considers the traffic safety assurance in the level crossings of the Lithuanian roads and provides the context of the other European Union countries. The essential problems of the future are also provided and discussed. Inspections of the road sections were conducted before and behind the fifteen level crossings according to the description of procedures for inspection on road safety. The article consists of the following parts: analysis of problems at the level crossings, statistical analysis of accidents at level crossings in Lithuania and Europe, investigation results and conclusions.

Keywords: road, infrastructure, level crossing, accident, traffic safety, a description of procedures for inspection on road safety.

1. Introduction

Level crossings create serious potential conflict points for collisions between road vehicles and trains. A level crossing is the place where those two infrastructures intersect. Requirements for the design, maintenance and repair of level crossings are also clearly defined and regulated by the *Regulations for Installing and Using the Level Crossings*. Frequently, in order to finally solve traffic safety problems the level crossings must be eliminated by installing grade-separated crossings. Grade-separated crossings are the safest form. This solutions is very expensive, since it requires joining the efforts and the interests of the managers of both road and railway infrastructures, besides, it is complicated from a technical point of view and time-consuming. However, with the increasing road traffic volume and the growing speed of trains it will be impossible to constantly postpone this solution. Another aspect of the problem is traffic safety assurance at the existing level crossings. Many specialists agree that the problem must be solved in a complex way by implementing the engineering safety improvement measures, increasing penalties for the violations of traffic rules and by organizing educational public activities aiming that all the road users are aware of traffic rules when passing the level crossings.

Safety at level crossings is a worldwide issue which increasingly attracts the attention of relevant transport authorities, the rail industry and the public. More than 2000 accidents occurred at active and passive level crossings in the United States each year from 2006 to 2010 (Tey *et al.* 2011). Statistically, more than 400 people die each year in accidents involving road and vehicle at level crossings in the European Union (Fakhfakh *et al.* 2011) and 90% of these fatalities are linked to the errors committed by road vehicle drivers. In Australia, during 2001 and 2009 the report recorded a total of 355 rail related fatalities, at a rate of 41.8 per year. Not surprisingly, there are enormous economic and social costs associated with collisions at level crossings. For example, in Australia crashes at level crossings are estimated 32 million dollars each year, excluding costs associated with infrastructure

losses (Rakotonirainy *et al.* 2010). Therefore, road and highway safety professionals from several countries work with the same aim – to provide safer level crossings. Many countries carry out investigations searching for the most suitable ways to ensure safe traffic: Finland (in Finland the greater share of railway accidents occur at level crossings than in most other countries) (Silla, Kallberg 2012), France (Fakhfakd *et al.* 2011), Slovakia (Janota, Šebeňová 2011), Australia (collisions occurring at level crossings represent more than 40% of all rail related fatalities in Australia each year) (Rakotonirainy *et al.* 2010), (Tey *et al.* 2011), USA (where the Operation Lifesaver was initiated) (Mok, Savage 2005), (Savage 2006), (McCollister, Pflaum 2007), Great Britain (Evans 2011), (Nelson 2009), Estonia (which was the first to establish the Operation Lifesaver in Europe) (Koppel 2009), Israel (Gitelman *et al.* 2006).

The results of investigations, carried out in various countries, showed that road accidents, as mentioned above, are mostly affected by the human factor. USA investigations indicated that only 60% of road vehicle drivers stop at the "Stop" sign located before the railway crossings. 2/3 of vehicle drivers knew that they must stop at the "Stop" sign. In Australia, 85 fatal road accidents were investigated and it was determined that 86% of drivers knew how to properly pass the railway crossing. In Germany, 1/3 of vehicle drivers thought they are not obliged to stop at the railway crossing on the flashing red signals. A 10^{th} of them thought they were allowed to cross the closed barrier if there was no danger. Besides, it was also determined that a long waiting at the closed barrier makes the drivers angry, induce them to violate traffic rules and to pass railway crossing on the flashing red signal.

2. Problems and traffic safety situation at the level crossings

In Lithuania, pursuant to the *Regulations for Installing and Using the Level Crossings,* the level crossings are eliminated in case if a viaduct over the railway is built at a distance of 5 km and less from the crossing, if it is decided by the commission of technical inspection that the road approaches to the railway crossing are unattended or in poor condition, if the railway tracks undergo modernization and the speed is increased up to 160 km/h, if the condition of the crossing does not meet the requirements and does not ensure safe traffic of vehicles. The crossings of public use are maintained by the manager of public railway infrastructure. Within the limits of the crossing the manager of public railway infrastructure carries out the following works: installs the formwork of public crossing (road carriageway) which shall cover all railway tracks and continue for at least 0.5 m on each side of the outside track, repairs and maintains roads at a 10 m distance on each side of the outside track, installs, repairs and maintains the bed of public crossing, guard rails, marker posts, traffic-lights, illumination, barriers, other specific railway facilities located at a distance of less than 10 m from the outside track, as well as the clearance gate. Organization responsible for the operation of approaching roads installs and repairs the road carriageway up to the formwork of the crossing (at a distance of 0.5 m from the outside track), installs, repairs and maintains road signs situated at the approaches to the crossing. The manager of public railway infrastructure maintains and repairs the formwork of public crossing within the limits of the crossing, maintains and repairs railway tracks, maintains the road section at a 10 m distance on each side of the outside rail, repairs and maintains the bed of public crossing, based on approved drawings produces barriers and gates, maintains and repairs crossing posts, traffic-lights and automatic signalling systems, telephone and radio communications, electric supply equipment, external electric networks, illumination of the crossing.

Problems related to the crossings can be divided into two groups: elimination of the crossings (or installation of grade-separated crossings) and traffic safety assurance at the existing crossings.

Elimination of crossings. What concerns the removal of level crossings, i.e. their elimination or installation of grade-separated crossings this issue causes many problems in all countries. In countries with a large number of crossings, for example, USA the closing of crossings is solved effectively (Cotey 2009). It is emphasized that in order to solve this problem a team approach is necessary by cooperation with the local authorities (including road managers). Therefore, transport schemes are currently developed where the need to eliminate one or another particular crossing is determined, elimination alternatives are defined or grade-separated crossings are planned. One of the investigations presents details of models and procedures which provide screening tools for preliminary consideration of grade separation at rail-highway crossings. The main factors evaluated were vehicle delays and safety problems at the at-grade crossings. The screening tools developed consist of a model for the estimation of the expected number of accidents at a crossing, an approximate formula for estimating the economic loss due to vehicle delays, and a qualification criterion (Gitelman *et al.* 2006). It was determined that the costs of vehicle delays at the Israeli level crossings are much higher than the accident costs. In Lithuania, when planning modernization of the railway line Vilnius–Kaunas up to 160 km/h speed, the question of crossings raised, since according to the regulations no level crossings are allowed where the speed of trains is 160 km/h. Due to the fact that there are a lot of interested parties, the question was not successfully solved in the planning stage of the railway modernization, therefore it was suggested to study the crossings as the separate local projects and to solve the question in a complex way, since it is related not only to railway infrastructure but also to the general plans of municipalities and development

plans of the *Lithuanian Road Administration*. The mentioned projects require coordination between the *Ministry of Transport and Communications*, municipal institutions, *Transport Investment Directorate*, *Lithuanian Road Administration*, *State Railway Inspection* and the *JSC Lithuanian Railways* in order to create a financing system for this type of projects. Before that the operating speed at the crossings will be limited to 120 km/h. Knowing that the line has many crossings such reconstruction will do no good. Taking into consideration a density of crossings there will be no possibility to realize a design speed. Thus, the large-investment project will become ineffective for a long time until the questions of crossings' elimination are solved.

Traffic safety assurance at the existing crossings. It should be mentioned once again that many accidents at level crossings are caused by violations of traffic rules. In Lithuania, all the accidents at level crossings occurred due to the same reason. The most popular traffic safety improvement measures are as follows (Gailienė *et al.* 2011).

- Public education (wider education, courses, explanations) which in Lithuania is still poor. Good example is the Operation Lifesaver (International Organisation Continuing a Public Education Programme, OL) which was launched in 1972 in USA and appeared to be a very successful project implemented by volunteers and having a small budget. Further, the initiative spread to Canada, Mexico, UK, Argentina. The first OL subsidiary in Europe, called Operation Lifesaver Estonia (OLE), was founded in 2004 by Estonian Railways and two private persons (Koppel 2009). In all countries where the OL is active the safety level at level crossings has improved significantly, therefore this initiative is considered a very successful and representative of how to accomplish large work without a large budget.
- Improvement of visibility at crossings. In Lithuania, almost half of crossings do not meet visibility requirements.
- Installation of video cameras. There are crossings in Lithuania where the cameras have been installed, however, there is a lack of measures to enforce the drivers. Installation of cameras is expensive. For example, video cameras with an automatic number plate detection function, which would detect all the violations of the road users and transfer data to road police, would allow penalizing the drivers. However, they require additional investments.
- Prescription and increase of administrative penalties. This measure has not been considered in Lithuania.
- Modernization of railway barriers. This is one of the most effective measures, however, in Lithuania this possibility has not been considered.
- Installation of various measures which would attract driver's attention: a larger number and more vivid road signs, deceleration lanes.

Density of level crossings in Lithuania is not large compared to other countries. Compared to other 27 member-states of EU and Norway, it was determined that in Lithuania a level crossing is located every 4.17 km of railway track. The largest density of level crossings is in

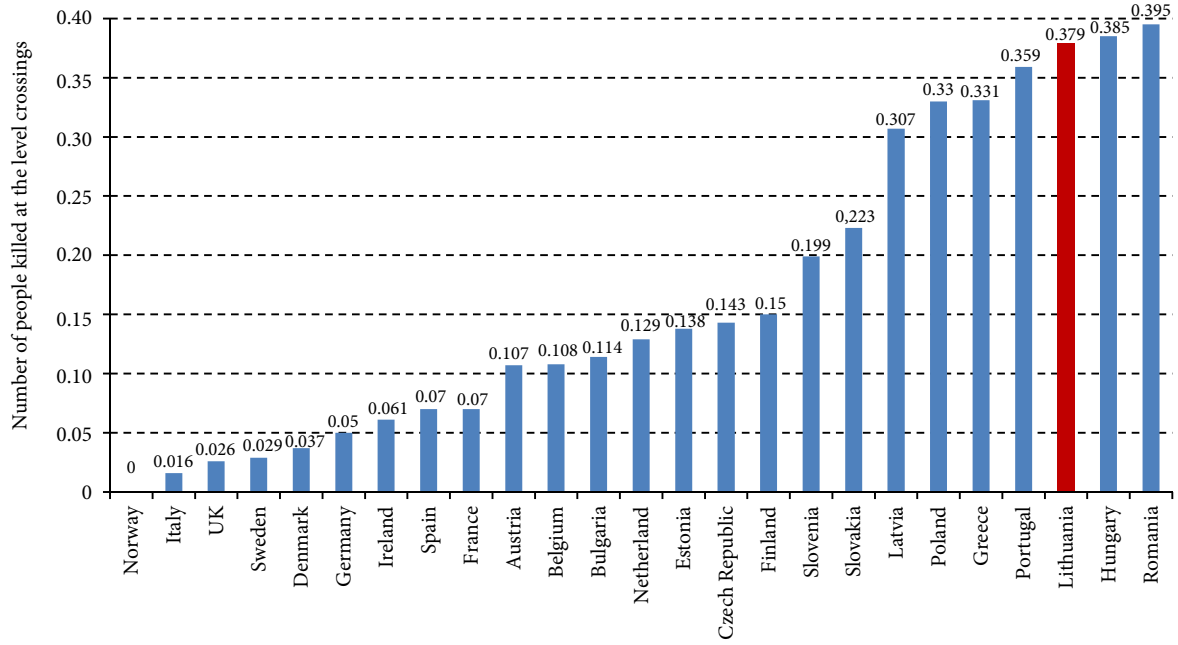


Fig. 1. A number of people killed at the crossings of EU and Norway per train km (a criterion of a number of people killed at the crossings per the distance travelled by trains is the ratio between a number of people killed and the distance travelled by trains per year (in million km) (data from ERADIS)

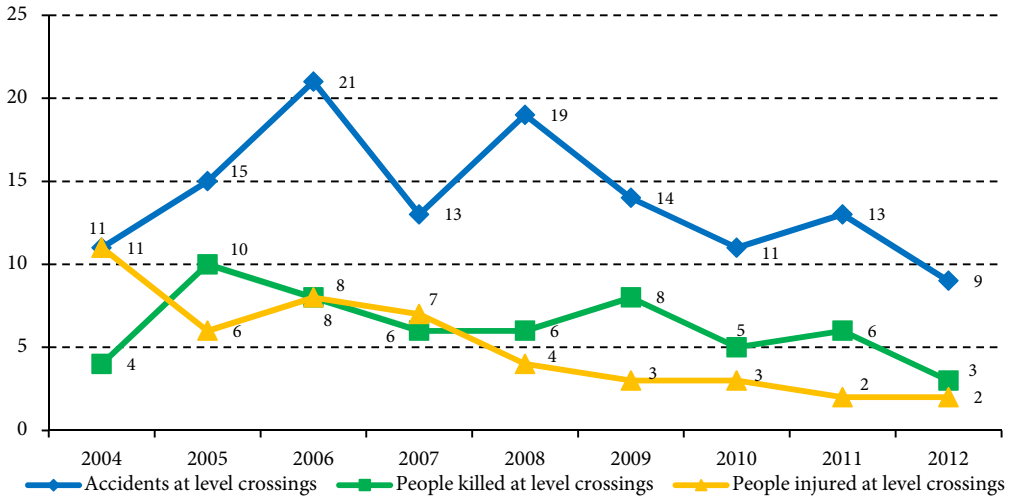


Fig. 2. Safety indicators at level crossings of Lithuania in 2004–2012

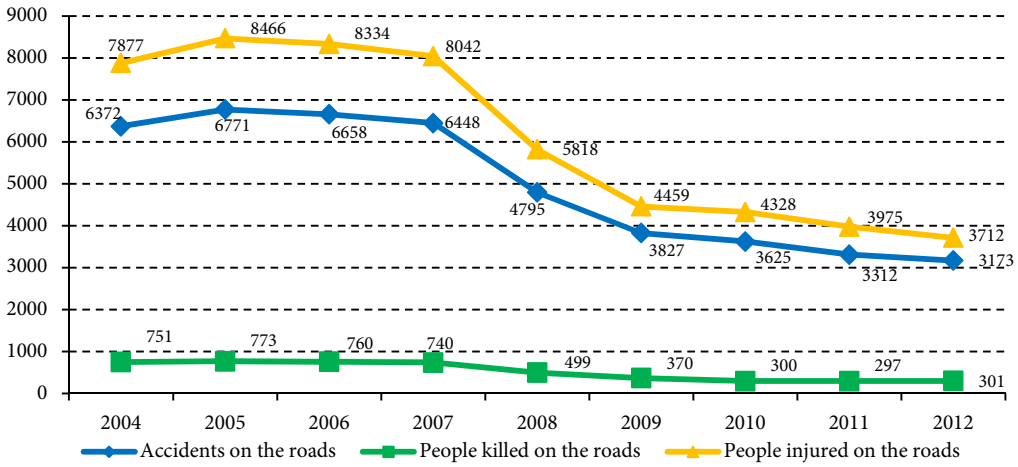


Fig. 3. Safety indicators on roads of Lithuania in 2004–2012 (data from "Statistics of valid traffic accidents in Lithuania 2006–2009" and "Statistics of valid traffic accidents in Lithuania 2007–2012")

Norway – every 1.02 km, the lowest density in Latvia – every 7.38 km. In the studied countries the crossing is located every 3.07 km of railway track on the average. On the other hand, a number of people killed at the level crossings in Lithuania substantially exceed the EU average. A number of people killed at the crossings of EU and Norway is shown in Fig. 1 (data from ERADIS – European Railway Agency Database of Interoperability and Safety).

The average number of people killed in EU and Norway per train kilometre is 0.166, and in Lithuania – 0.379. Poorer situation than in Lithuania is in Hungary and Romania. Fig. 2 gives a dynamics of accidents, people killed and injured at level crossings of Lithuania in the period 2004–2012.

Fig. 3 gives a dynamics of accidents, people killed and injured on the roads of Lithuania.

It should be mentioned that according to the statistics the occurrence of road accidents is mainly depending on road users' actions (Lama *et al.* 2006). A conclusion could be that a number of road accidents has been constantly decreasing, whereas, at crossings it remains at the same level for a number of years. The numbers vary accidentally without clear tendencies and without possibilities to make forecast and assessment. It is concluded that if the measures were found to increase safety level on roads, it is also possible to find measures which would force the drivers to observe traffic rules at crossings. Therefore, the aim of investigation is to determine violations of traffic rules on the road sections behind and before the crossing, to distinguish the most frequent violations and to suggest measures for stimulating the drivers to observe traffic rules.

3. Analysis of road sections behind and before the level crossing

The description of procedures for inspection on road safety sets three types of the road safety inspections according to the goals of the inspections. These are: the

periodical inspection, the night inspection and the target inspection. For the analysis of the level crossings the target inspection is usually conducted because the road section before as well as behind the level crossing has to be inspected. The inspection begins with the analysis of the plans, the pictures, the descriptions of accidents and other available material.

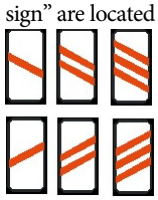
In order to achieve the aim of investigation, i.e. to carry out the inspection of the selected road sections behind and before the crossing, to assess a conformity of road elements to legal acts, to determine existing deficiencies of the road sections, the following tasks were set: to analyse information about the traffic of the road section (traffic volume of road, traffic composition, driving speed, etc.), to analyse information about the railway crossing (category, permissible driving speed, traffic volume of train, signalling equipment, etc.), to determine existing deficiencies of the road section (road signing and marking, road pavement, visibility, etc.), to determine existing deficiencies of the level crossing (the deck, signalling equipment, water discharge channels, etc.). For the analysis 15 crossings were selected intersecting with the roads of national significance: 2 of category I, 2 of category II, 2 of category III, 8 of category IV. A purposive inspection was carried out to inspect the road section behind and before the crossing. The inspection of the road sections before and after the level crossing was conducted in the following order. The inspection team went to the location of the level crossing and went forward and backward the particular road section on foot. The road section between the 1st road sign of the level crossing before the level crossing and the last road sign of the level crossing after the level crossing was inspected. The pictures of the deficiencies were taken and the descriptions of deficiencies as well as the means to fix them were provided in the inspection list.

During the inspection 73 deficiencies of the level crossings were determined. The main deficiencies are given in Table 1.

It was determined during the inspection that more than 1/2 (40) of all deficiencies are related to the road signing. Those deficiencies have a large effect on traffic safety; however, they are easily and speedily eliminated. Deficiencies of the level crossing infrastructure also have a large effect on traffic safety, though they are more complicated than those related to signing. Some level crossings need a small repair of their deck and water discharge equipment in some cases the overhaul is necessary.

When using level crossings one of the most important aspects is that the formworks of the crossings and the road pavements are free of potholes and as even as possible, i.e. pavement condition must ensure safe passage of the crossing at a max permissible speed. When a vehicle passes through the potholed formwork of the crossing or the formwork is too narrow to correspond to the width of the road, or there are potholes on the approaches to the crossing, or other formwork defects (e.g. exposed reinforcement at reinforced concrete crossing), it often happens that a vehicle loses its stability or may be even damaged. This may result in an accident and the vehicle may stay standing on the railway tracks or at the crossing (Gailienė *et al.* 2011).

Table 1. Deficiencies determined during the inspection

Description	Number of deficiencies
Insufficient visibility at the crossing (for vehicle driver and (or) for train machinist)	14
Road pavement defects	7
Deficiencies in road signing:	
Warning signs No. 140–145 „Advance warning sign" are located in the settlement 	6
Limited visibility of a road sign	4
Misuse of a road sign, misleading information	5
The absence of a road sign in a required place	5
The damaged (removed) road sign	9
Road signs installed without following installation distances and requirements	4
No marker posts before protective guard rails	7
Total	61

Another group of problems is assurance of visibility at the crossings. The inspection results showed that only one crossing met the current visibility requirements. Another investigation showed that 51% of crossings do not meet visibility requirement defined by the legal acts, whereas, observation of this requirement could help to avoid eight accidents (62%) that occurred on the level crossings in 2009. Based on visibility requirements at the crossings, the intersection angle between road and railway shall be equal to 90° (up to 60° is allowed). Analysis of the current situation indicated that at 5 crossings from 15 the intersection angle was 90°, at 7 crossings from 60° to 90°, at 3 – less than 60°.

Having carried out the analysis of traffic volume of motor vehicles and trains at the crossings and having compared this data to the current categories, it was determined that not all of the crossings correspond to their category. Based on traffic volume data, none of the crossings shall be given a lower category; however 5 crossings are suggested to get a higher category. The change into a higher category requires large investments for installing new engineering measures to ensure traffic safety.

State Railway Inspectorate (SRI) of Lithuania, which carries out the safety control of Lithuanian railways and records during their inspections the most frequent violations, has emphasised the following violations of current requirements for the level crossings: forest planting is planted in a way that the vehicle driver, being at a 50 m distance from the crossing and nearer, is not able to see the approaching train at a 500 m distance; road sections before the crossings are not provided with traffic signs required by the traffic rules; when the road leading to the crossing is not paved (gravel road), there is no pavement at a distance of at least 10 m from the outside track on each side of the crossing (according to the current requirements the pavement shall be laid).

Therefore, if the above investigation is compared to the SRI inspection results, a conclusion could be drawn that the results are very similar.

Since the problem of visibility is especially large, one of the measures to improve traffic safety at the crossings of poor visibility is to install speed bumps before such crossings. Speed bump is an engineering measure recommended to be used where it is necessary to maintain and reduce the permissible speed, to improve traffic conditions for pedestrians and cyclists and a social climate for local residents, to restrict comfort for the passing vehicles. Speed reduction bumps, erected before the level crossings of insufficient visibility, could be used together with a priority "STOP" sign to make the vehicles stop at this sign. Before a speed bump the warning sign "Uneven road" shall be installed. In order to determine the effect of speed bumps before the level crossings, investigation was carried out in Finland. Speed bumps were erected before and behind the level crossing. The study road section was equipped with speed measuring sensors installed at a distance of 70, 40 and 10 m before and behind the crossing which helped to identify the average speed of vehicles before and after the bumps were installed. A speed limit on the study road sections was 50 km/h. The average speed at a 10 m distance from the crossing decreased from 28 km/h and 23 km/h (before installing the bumps) to 15 km/h and 17 km/h (after installation of the bumps). This type of speed reduction guarantees that in case of necessity the drivers will be able to stop before the crossing (Seise *et al.* 2010).

4. Conclusions

The traffic safety condition at the level crossings in Lithuania is worse than in the other EU countries. The average number of people killed in EU and Norway level crossings per train km is 0.166, and in Lithuania – 0.379.

Investigation results, which coincide with the conclusions of other researchers, show that the largest problems at the level crossings are related to poor visibility and improper signing of approaching roads. In order to eliminate poor visibility the use of speed bumps is suggested based on Finnish experience which showed a possibility to successfully reduce the average vehicle speed before the level crossing. This measure would not only help to solve the problem of poor visibility but would also discipline the drivers, force them to reduce speed and to pass the crossing without exceeding the speed limit.

Another important deficiency determined at the crossings during investigation is the nonconformity of the categories of level crossings. Since the category of crossing is determined by the certain safety assurance measures, it is advisable to check the varied volumes of road and (or) railway traffic and to revise the categories of level crossings.

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