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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR



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THE EFFECT OF ROAD RESTRAINT SYSTEMS ON THE LEVEL OF ROAD SAFETY – POLISH EXPERIENCE

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Abstract

Roadside accidents happen when a vehicle runs off the road. The majority of these accidents are very severe because leaving the road is usually followed by hitting a solid obstacle (tree, pole, support, culvert front wall, barrier). Roadsides are some of the most important issues of road safety. They have been studied for years to identify roadside hazards and the effectiveness of road safety measures such as restraint systems. While restraint systems prevent crashes into obstacles or running off the road down steep slopes, they are obstacles themselves. If wrongly designed and located, restraints may pose a serious risk to the safety of road users. Examples of safety barrier models were analysed to understand how barriers change safety. It was found that the models differ and use different methodologies and data. In building a new analytical tool, the models' differentiating factors were combined to create a comprehensive model to match the Polish conditions. Fieldwork focussed on sections outside built-up areas, i.e. on national roads of the total length of app. 3,000 km. The data were inventoried separately for the left and right edge of the road and for the central reservation. Potential roadside hazards were identified (e.g. trees, slopes, utility poles, engineering structures) as well as the type of cross-section and existing types of safety barriers (concrete, steel, wire rope). Using the data collected, models of road safety measures were developed. By combining the effect of the roadside and safety measures, the models will help to build tools for road network management at the operational level (concrete locations on the road network) and select the right types of restraint systems and design the clearance zone.

Keywords: road restrain system, roadside, road safety, models

1 Introduction

Road accidents are still one of the causes of tragedy for many families. It is estimated that more than 1.2 million people die on roads all over the world and nearly 50 million people are injured. In the European Union (the safest region in the world), 25,000 die annually. And more than 1.1 million people are injured (including 250,000 seriously injured). In Poland (the EU's most dangerous country) about 3,000 people die annually and about 40 thousand are injured. A comparison of the level of safety of Polish roads with other countries indicates that the risk of being a fatal victim on Polish roads is many times higher than on roads in Germany or the United Kingdom [1]. The risk of being involved in an accident results from the malfunctioning of particular elements of the road transport system. Other causes include abnormal behaviour of road users, technical breakdown, bad weather and natural conditions [2], results of acts of vandalism or terrorism.

Road infrastructure and roadsides can be a factor causing road accidents when road user errors occur (e.g. elements that are not easily comprehended or clear, poorly organised traffic, curbed visibility, geometric parameters not adequate for the speeds) and have a strong in-

fluence on accident severity, especially where run-off-road accidents are concerned. Run-off-road accidents and their consequences can be reduced by improving the road and street network, completing and reconstructing the existing network, developing and implementing “self-explanatory roads”, developing and implementing “forgiving roads” and providing road signs and markings that are more understandable and road user friendly.

One of the devices supporting these actions is the use of road safety barriers. Before appropriate steps are taken, it is necessary to recognise the conditions in which hazards on the road occur and the effectiveness of the equipment used. Unfortunately, this kind of research is still lacking in Poland. To change that, a research project was launched focussing on road safety devices with particular emphasis on safety barriers. The results of the project can be useful for more than just Poland’s road network, and can in fact help to improve roadside safety across Europe because of the scale of the research.

2 Knowledge

So far, a significant number of studies have been conducted to determine the effect of traffic volume and road geometry on traffic accidents. These studies have shown that improving the geometry of the roadway can significantly reduce the number and consequences of accidents. A lot of the research looks at how the roadside changes safety. Traffic accident statistics in many countries show that about a quarter of all fatalities are caused by errant vehicles.

A run-off-road collision describes the primary road event in which a vehicle leaves the roadway as a result of loss of stability or sudden change of direction of travel (forced by speeding, loss of traction, etc.). Although occasionally after such collisions vehicles can return to the roadway, it very often leads to dangerous secondary events such as: roll-over, driving into a ditch, hitting an embankment or an object or roadside device e.g.: running into a road barrier, hitting a tree, a pole or a road sign [3]. The study of available literature shows that some researchers tried to establish the influence of selected road parameters (width of the roadway [4], type and width of the road shoulder [5]), road structures (bridges, culverts, road signs) [6], [7], obstacles along the road (trees, posts [8], [9]) and road equipment (road barriers and enclosures) [10], [11] on the risk of run-off-road collisions. The results of their research were used to model and simulate the effects of various combinations of geometric parameters and the road and traffic parameters on the frequency and effects of accidents. Based on the models, a set of preventive measures was developed and it was shown that the frequency of events can be significantly reduced by increasing lane and shoulder width, widening the central reservation, widening the roadway at bridge entrance, moving and removing dangerous road objects, decreasing the gradient of slopes and escarpments of ditches and introducing barriers and other safety systems [12]. More recent research focussed on roads that forgive driver error, for which the roadside obstacle-free zones turned out to be important [13], [14]. Using the results of field research, mathematical modelling and computer simulation, the recommended widths of the obstacle-free area, the distance from the roadway and the height of the road barriers were determined [15]. A tree located too close to the roadway, a bad structure of a pole or road sign, a poorly designed or installed safety barrier system are the subjects of study, research and preparation of standards, guidelines, or examples of good practice [16]. The main consequence of hazards on the roadside is not the probability of an accident, but its severity [17]. The severity of road accidents in Poland results primarily from improperly designed or used road infrastructure. This is the consequence of the absence or poorly formulated regulations and failure to apply road safety standards. One of the most important projects implemented in Europe was RISER (Roadside Infrastructure for Safer European Roads) [18]. The project was designed to determine the behaviour of drivers (in adjusting speed) to the conditions encountered. What was found was the correlation between the occurrence of the central reservation and the type of barrier and also the dependence of the vehicle’s road position on the obstacle type [19] indicates that the best current estimates of

the effects of median barriers are a 30 % increase in accident rate, a 20 % reduction in the chance of sustaining a fatal injury given an accident, and a 10 % reduction when sustaining a personal injury given an accident. Within the scope of research on the impact of road barriers and the roadside environment on road traffic safety other studies were conducted, including test results, which demonstrated that the development of a safe roadside and the correct use of vehicle restraint systems are key to improving the safety of road infrastructure users. It is also important for research to include actual speeds of vehicles [20]. It is that speed that is the primary determinant of accident severity of roadside-related accidents.

3 Selecting research test sites and database design

Understanding how safety barriers change road safety requires in-depth studies such as database exploration and design, conducting numerical tests (based on crash tests) and safety modelling (Fig. 1). More than seventy sections of national roads with a total length of about 3000 km across all of Poland’s regions are being monitored for road accidents, road parameters and traffic volumes. The data collected at these sites includes photographic documentation of accidents that involve running into a road safety device (Fig. 2).

The collected data are used to develop models of road safety measures and methods for managing road safety tools. Similarly to the TRL research [21], as part of observation of how road safety devices operate, various road sections were selected according to devices applied (old type, new type, steel, wire rope, concrete) and traffic and road parameters. An important criterion for the selection of sections was the assessment of individual risk [22] of running into safety barriers or poles. Data were divided into three groups: Road Database – containing information about sections, location, geometry, roadside; Traffic Database – containing data on the volume, type of traffic structure; Accident Database – containing data on accidents, victims, circumstances, types, causes, perpetrators, etc.

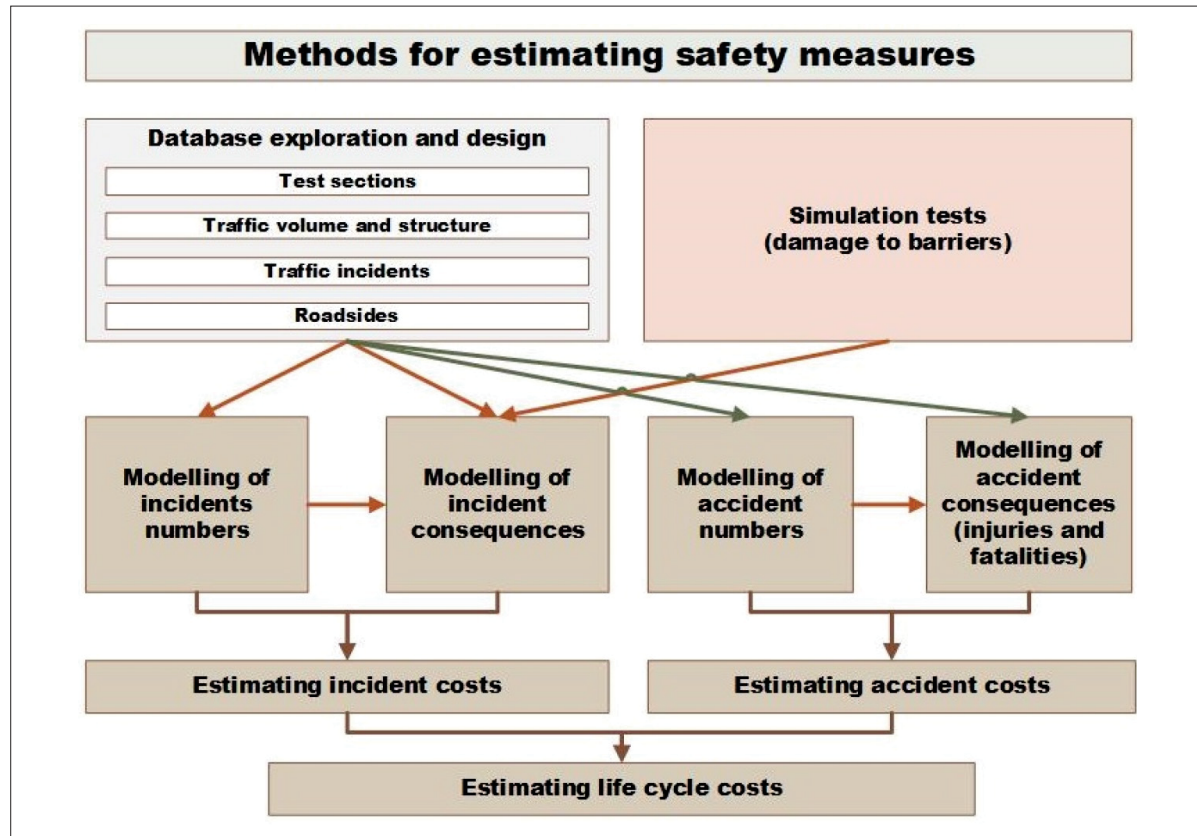


Figure 1 Diagram of analytical work on road restraint systems.

Between 2013 and 2015 there were 16,500 accidents related to the roadside (11 % of all accidents in that period). The accidents involved 20,700 people injured (16 %), including 6,400 seriously injured (16 %) and 2,100 people killed (24 %). Figure 3 shows the types of roadside-related accidents across the country. As the figures show, run-off-road accidents are clearly most severe when they involve hitting a tree.



Figure 2 Photographic documentation of road accidents (Source: General Directorate of National Roads and Motorways)

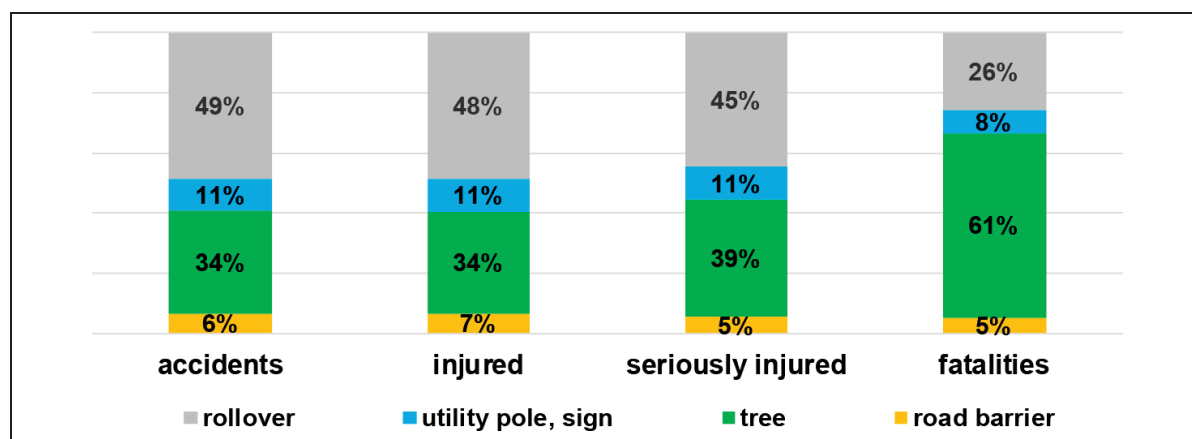


Figure 3 Types of accidents involving the roadside in Poland

4 Models of the effects of safety barriers on road safety

The database includes parameters assigned to reference lengths from 1 – 5 km, which are: length of section, annual average daily traffic flow, number of intersections and exits, share of sections with barriers, share of sections with trees, number of signs, posts and other road furniture. According to the recommendations (based on the analysis of other models) the following assumptions were developed:

- model to be used to calculate risk index and severity of events,
- risk index will depend on traffic volume,
- the analyses to be based on the existing data on accidents: hitting a barrier, running into a tree, running into a pole or sign,
- the results to distinguish between cross-sections (single and dual carriageway) and classes.

The results of the study are presented based on the DA victims density model for single-carriageway roads of GP class (main road with accelerated traffic) outside a built-up area. The accident density model is described with the following formula:

$$DA = \alpha \cdot Q^{\beta_1} \cdot e^{(B^{\beta_2} + S^{\beta_3} + T_1^{\beta_4} + T_2^{\beta_5} + T_3^{\beta_6} + C^{\beta_7} + P_1^{\beta_8} + P_2^{\beta_9} + P_3^{\beta_{10}})} \quad (1)$$

Where:

- DA – expected number of accidents per kilometres of road
- α – adjustment coefficient
- Q – annual average daily traffic (AADT)
- β_j (1,2,...,n) – calculation coefficients
- B, S, T¹, T², T³, C, P¹, P², P³ – factors related to the risk of an accident

Table 1 [Parameter estimates of the crash prediction model of Eq. (1)]

| Parameter | Coefficients | Value |
|---|--------------|-------|
| Adjustment | α | 0.01 |
| Traffic volume Q | β_1 | 0.79 |
| % of barriers B | β_2 | -2.03 |
| % of embankments S | β_3 | 1.25 |
| % of trees to 3.5m T ₁ | β_4 | 2.87 |
| % of trees above 3.5m T ₂ | β_5 | -0.58 |
| % of forests T ₃ | β_6 | -0.38 |
| Road class C | β_7 | -2.90 |
| % of shoulders above 1.5 m P ₁ | β_8 | -0.47 |
| % of shoulders to 1.5 m P ₂ | β_9 | -0.10 |
| % of soft shoulders P ₃ | β_{10} | 0.38 |

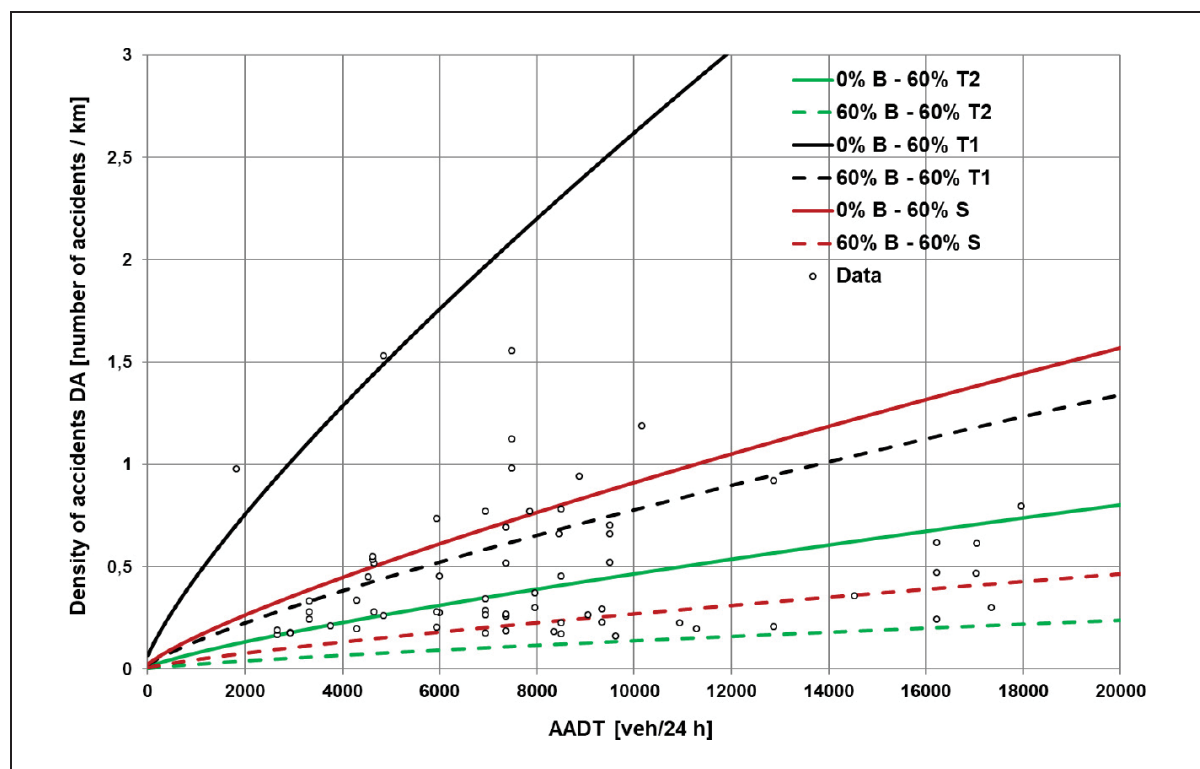


Figure 4 Density of accidents (DA) in relation to barriers and trees

In the case of the DA victims density model, the determination coefficient is 0.72. The factors with the strongest effect on the model had to do with barriers, number of trees along the carriageway (up to 3.5 and more than 3.5 m from the edge) number of barriers and road class. The study showed that accident density goes down as the number of barriers and hard shoulders goes up. Fig. 4 shows the effects of safety barriers, embankments and trees on accident density, DA. When all the other parameters are averaged and the effects of traffic, AADT, are included, DA shows a clear increase for more than a 60 % share of sections with roadside trees that are less than 3.5 m away from the road edge and no barriers are present. Where safety barriers are present, DA drops significantly for sections with roadside trees more than 3.5 m away from road edge and embankments. As the work continues, it will study a greater level of detail: the height and gradient of slopes, presence of obstacles, share of heavy goods vehicles, type of safety barriers, roadway width, different cross-sections (single and dual carriageways, 2+1 cross-section).

5 Summary

Over the last twenty five years more than 20,000 people were killed on Polish roads in run-off-road crashes (of which a clear majority involved hitting a tree). The main factors that influence the risk of being involved in such a crash are: historic developments, road class, length and element of carriageway, hazardous elements at the edge of carriageway (mainly trees), safety measures in place or lack of safety measures. To improve roadside safety we must: identify the hazards on the road network, conduct checks, conduct research (build models of the effects of selected factors on road safety, effectiveness evaluation), implement safety standards, develop guidance and principles for safe roadsides, ensure that there is collaboration between designers, road authorities and environmental organisations and institutions and exchange experience with other countries. More models should be developed that combine road hazards with the risk of accidents, with particular emphasis on the impact of road restraint systems. For years roadside environments have been one of the most neglected aspects of road safety efforts in Poland. Clarity is needed on the effects of roadsides on road safety. We must understand the hazards roadsides cause and implement effective solutions.

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