ASSESSMENT OF ROAD RESTRAINT SYSTEMS IN POLISH CONDITIONS

OCENA SYSTEMÓW POWSTRZYMUJĄCYCH POJAZD PRZED WYPADNIĘCIEM Z DROGI W WARUNKACH POLSKICH

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Abstract: Key to understanding the needs and tools of road infrastructure management is identifying the hazards and their sources involved in having no or faulty road restraint systems. Clarity is also needed on why the systems are wrongly designed, constructed, built and operated. To ensure that the problem is adequately understood, research and site observations were conducted and mathematical models were built to describe the level of roadside risk. To aid studies of road safety barrier and other road safety equipment functionality, it is vital to carry out field crash tests and crash test simulations. The main goal of the work is to develop a method for selecting optimal road restraint systems.

Keywords: road restraint systems; road safety; roadside

Streszczenie: Identyfikacja zagrożeń i źródeł zagrożeń wynikających z braku lub niewłaściwego stosowania systemów powstrzymujących pojazd przed wypadnięciem z drogi oraz identyfikacja błędnych rozwiązań projektowych, konstrukcyjnych, wykonawczych i eksploatacyjnych tych systemów jest kluczowa dla określenia potrzeb i budowy narzędzi do zarządzania infrastrukturą drogową. Tak poszerzone rozpoznanie problemu wymagało przeprowadzenia badań i obserwacji terenowych oraz budowy modeli matematycznych opisujących poziom ryzyka dla otoczenia dróg. Bardzo istotnym elementem pozwalającym na badanie funkcjonalności barier drogowych i innych urządzeń bezpieczeństwa ruchu są poligonowe testy zderzeniowe oraz badania symulacyjne testów zderzeniowych. Głównym celem prowadzonych badań jest opracowanie metody wyboru optymalnych systemów zabezpieczających pojazdy przed wypadnięciem z drogi.

Słowa kluczowe: systemy powstrzymujące pojazd; bezpieczeństwo ruchu drogowego; otoczenie dróg

1. Introduction

Roadside-related crashes occur when vehicles run off the road. The majority of the crashes have severe outcomes, especially when an object is hit (tree, pole, supports, front wall of a culvert, barrier). These accidents represent app. 19% of all of Poland's road deaths. Roadside crashes involve (based on SEWIK, a police database): hitting a tree (the main hazard), hitting a barrier, hitting a sign or utility pole, vehicle roll-over on the roadside, vehicle roll-over on a slope and vehicle roll-over into a ditch. In-depth research is required to understand how roadside factors affect road safety. Key to this is analysing and evaluating the need for road restraint systems and the selection of specific solutions. This is an area studied under the RID Programme (Development of Road Innovation) in the Road Safety Equipment project called RoSE. It will aim to develop a method for selecting optimal road restraint systems based on equipment selection criteria, site tests and crash and simulation tests. Sections of national roads are used to build models to describe the effects of selected road and traffic factors, including roadside factors, on road safety.

2. Knowledge

A review of the literature on the effects of roadside on road safety shows that it tends to focus on understanding the effects of selected road parameters (road width, type and width of shoulder, roadside trees and signs), the effect of road structures (bridges, culverts, road signs), roadside obstacles (trees, utility poles) and road safety equipment (safety barriers and guardrails) on the risk of accidents involving errant vehicles [1], [2], [3]. The results of the work were used to model and simulate the effects of different road geometry and traffic parameters on the frequency and consequences of the accidents. Models were used to develop a set of preventative measures and it was demonstrated that accident frequency can be significantly reduced by widening traffic lanes and shoulders, widening central reservations, widening roads on approaches to bridges, moving or removing hazardous roadside objects, reducing slope and ditch gradients, using road safety equipment including safety barriers and other restraint systems [4], [5].

More recent studies focussed on "forgiving" roads with obstacle-free roadside zones. The results of on-site tests, mathematical modelling and computer simulations were used to define recommended widths of obstacle-free zones and the distance from the road and height of safety barriers [6]. Studies often aim to understand the hazards of roadside trees, poor utility pole or road sign design and safety barriers that have been poorly designed or built. The results of this work have been used to develop guidelines and good practices [7], [8]. Poland has had very little research on the effects of hazards and sources of hazards on the likelihood of errant vehicles or the effectiveness of road safety equipment [9], [10].

Experimental studies on road safety were first conducted in the US in the early 1920s. Today's experimental crash tests are prepared and conducted under strict procedures set out in the standards [11], [12], [13]. With high costs of field tests,

new research methods were investigated. First used in the 1960s for military purposes, numerical simulations were used as analytical tools. They were first used for civilian applications in the late 1980s with computer crash simulations This was supported by the commercial version of the programme LS-DYNA [14]. Experimental tests, modelling, simulation, validation and experimental verification of crash tests are all covered extensively in numerous research articles and reports from Polish and international research centres [15], [16]. [17], [18], [19], [20], [21].

3. RoSE project

The main goal of the ROSE project (Road Safety Equipment) is to conduct comprehensive tests and analyses of various vehicle restraint systems deployed on roads and engineering structures. The work is to include preliminary tests of road safety equipment already in operation, additional site tests for selected crash tests, extended numerical tests and comprehensive analyses to help formulate road safety equipment suggestions and recommendations. The main project product is a new method for selecting optimal systems to prevent vehicles from running off the road. It will take account of the type and severity of hazards, road class, size and structure of traffic and driving conditions (vehicle speeds) on the road. The project features the use and development of the most modern methods for simulating numerical crash tests. The project's diagram is shown in Fig. 3.1. Because road safety equipment rules and selection criteria are not consistent with the standards and the guidelines leave certain aspects out [22], new rules and selection criteria must be developed.
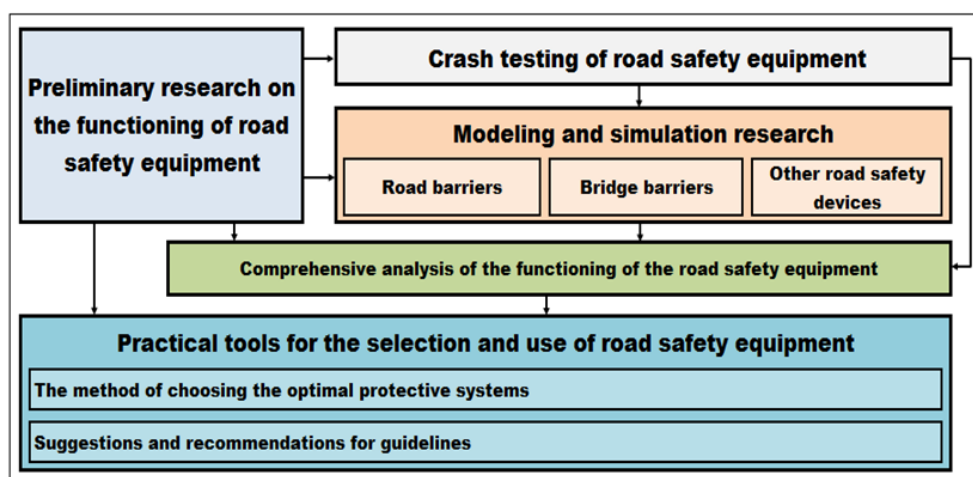

Fig. 3.1 Diagram of the RoSE project

As well as adopting the main goal, the project includes specific objectives which are as follows:
1. Identify hazards which are the result of a lack of road safety equipment or its poor application and identify wrong design, construction, build and operation

of road safety equipment.

2. Identify the effect of types of road and bridge safety barriers and other road safety equipment, their design features, additional elements, type of road and barrier location on the road and road and traffic conditions and the effects of wrong safety barrier design, construction, build and operation on their functionality and road safety.

3. Develop a classification of road safety equipment depending on the type of equipment, its function and road and traffic conditions by conducting comprehensive and multi-layer analyses of tests and observations and site and numerical tests.

4. Review of site tests

Before selecting crash tests for the purposes of the RoSE project, there was an extensive review of the literature and experts were consulted at length. A detailed review was conducted of previous safety barrier fieldwork to create a crash test database. An analysis of generally available reports and reports obtained by the authors helped to identify a set of problems which were investigated poorly or not at all. This was the basis for carrying out six site tests (fig. 4.1). They were:

1. TB32 crash test, for a road wire rope barrier for a section of a barrier installed on a curve with a radius of 400 metres. In addition, a second crash was conducted in the same place. Justification: Little is known about barrier behaviour on horizontal curves, in particular when the barrier is hit on the inner (convex) edge of road on a horizontal curve. Of particular importance for identifying the potential width of the obstacle-free zone behind the barrier.

2. TB32 crash test for a road steel barrier for a section of a barrier installed on a curve with a radius of 400 metres. In addition, a second crash was conducted in the same place. Justification: see above.

3. TB11 crash test for a road steel bridge parapet (low) mounted on a concrete plate with a 14 cm high kerb. In addition, a second crash was conducted in the same place. Justification: Need to better understand vehicle behaviour upon hitting the kerb and parapet with special emphasis on the ASI parameter. Lack of sufficient baseline materials for numerical tests.

4. TB51 crash test for a road steel bridge parapet (low) mounted on a concrete plate with a 14 cm high kerb. Justification: see above.

5. TB32 crash test for the connection between a road wire rope barrier and a steel barrier. Justification: Need to better understand system behaviour and the effect on the vehicle for a frequently used connection in Poland.

6. TB51 crash test for a steel barrier and lighting column placed within the barrier's working width. A steel barrier H2-W4-A, column class HE100. Justification: A frequent occurrence in Poland to have objects placed within the barrier's working width (lighting columns, gantries, etc.). Poor understanding of how the system works and the consequences of a crash, in particular involving an errant vehicle.

Fig. 4.1 Photographic documentation of test sites

5. Modelling the effects of roadside on road safety

To study the effects of roadside on road safety, a comprehensive database had to be built with data about road incidents, traffic volumes and elements of the road (Fig. 5.1). The first stage looked at national roads in the region of Pomorskie. While they only account for 4% of total roads, national roads carry more than 30% of Pomorskie's miles travelled. The first phase of the study was designed to build an inventory of roads and build roadside and accident databases. The next stage was to develop mathematical models to show the correlations between roadside and accidents. All analyses were based on data from the period 2013 – 2015.
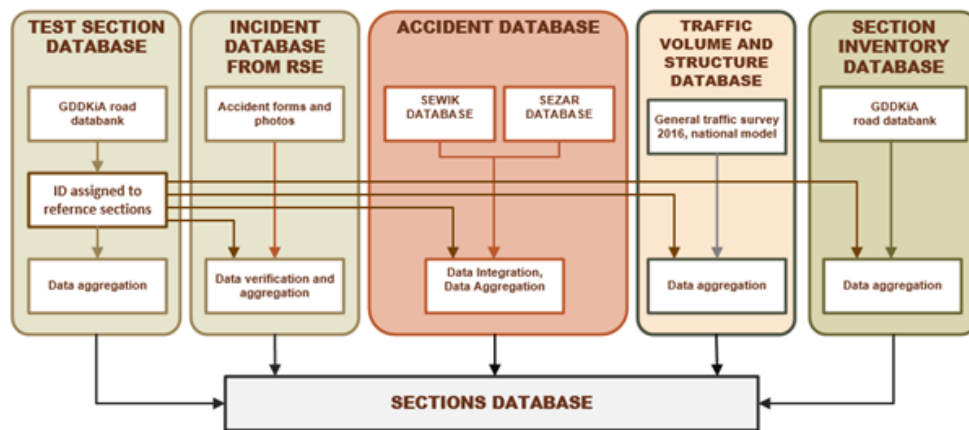

Fig. 5.1 Diagram of database for building road safety models

The inventory covered all sections of national roads in the region of Pomorskie at the total length of about 1000 km. Potential roadside hazards were identified (trees,

gradients and height of embankments, utility poles, engineering structures) and selected type of barriers (concrete, steel, ropes). The database had about eight thousand records – reference sections 1 – 5 km long. The records contained data about section length, annual average daily traffic flow, number of junctions, exits, and percentage share of sections with barriers, trees, number of signs, utility poles and other road objects. The basic problem when building the models was data availability and data quality. The first group of indispensable data comprised road accident data. The following were the main groups of problems affecting accident data:

1. Lack of a systemic approach to accident data collection. Each of Poland's road safety management levels has its own database with no links or consistency. All databases get their data from SEWIK. As a result, there is a lot of duplication and overlap when data are processed and some data are never used by some organisations.
2. Lack of data verification. Accident data are not verified systematically which makes any analysis and use of the data difficult. The police database gets accident locations wrong by quoting a wrong road number, wrong road category, inaccurate accident location and conflicting information regarding accident location.
3. Lack of access to additional data. Road safety analyses need additional data regarding road user behaviour such as speed, seatbelt usage, drunk driving or drug driving. Unfortunately, the regional level does not often collect such information.

Availability of data on road elements is another problem. Selected independent variables were not used to build the model, for example the presence and parameters of horizontal curves. Neither was the size of trees and the spacing between them considered. In addition, there should be more classes to specify the distance between trees and the edge of the road. Road width and the technical condition of the road and shoulders were not included either. The reason for this was that the data were not available at that stage of the analysis. To improve the quality of the conclusions and gain more knowledge on how roadside parameters affect safety, the authors are working on extending the available road elements database. Safety measure models will be updated and extended to include the above parameters.

The analyses and studies helped to build models of selected road safety measures. The following is an example of a road accident victim density model including the effects of the roadside (1):

$$GOF(Y) = \alpha \cdot Q^{\beta_1} \cdot e^{(B^{\beta_2} + S^{\beta_3} + T1^{\beta_4} + T2^{\beta_5} + T3^{\beta_6} + C^{\beta_7} + P1^{\beta_8} + P2^{\beta_9} + P3^{\beta_{10}})} \tag{1}$$

Where (1): $GOF(Y)$ - expected number of accident casualties per kilometre of road , α - adjustment coefficient, Q - annual average daily traffic , β^j $(1,2,...,n)$ - calculation coefficients, B - % of barriers, S - % of embankments, T_1 - % of sections

with trees, T_2 - % of sections with trees, T_3 - % of woodland sections, C – road class, P_1 - % of sections with hard shoulder above 1.5 m, P_2 - % sections with hard shoulder below 1.5 m, P_3 - % sections with soft shoulder.

Victim density was mostly affected by parameters such as the provision of safety barriers, the number of roadside trees (up to 3.5 and above 3.5 m from the edge) and road class. Studies show that victim density declines as the percentage of section with barriers and hard shoulders increases. Another conclusion from the study is that the length of sections with roadside trees and the corresponding protection do not in fact have much influence on victim numbers (Fig. 5.2 – the effect of trees if up to 3.5 m from the edge and barriers, with the other parameters averaged). Nearly identical GOF values were obtained for a 20% and a 60% coverage of roadside trees and barriers More analyses must be conducted in other Polish regions with more parameters in the models. So far, however, it is clear that safety barriers between the road and trees have a positive effect.
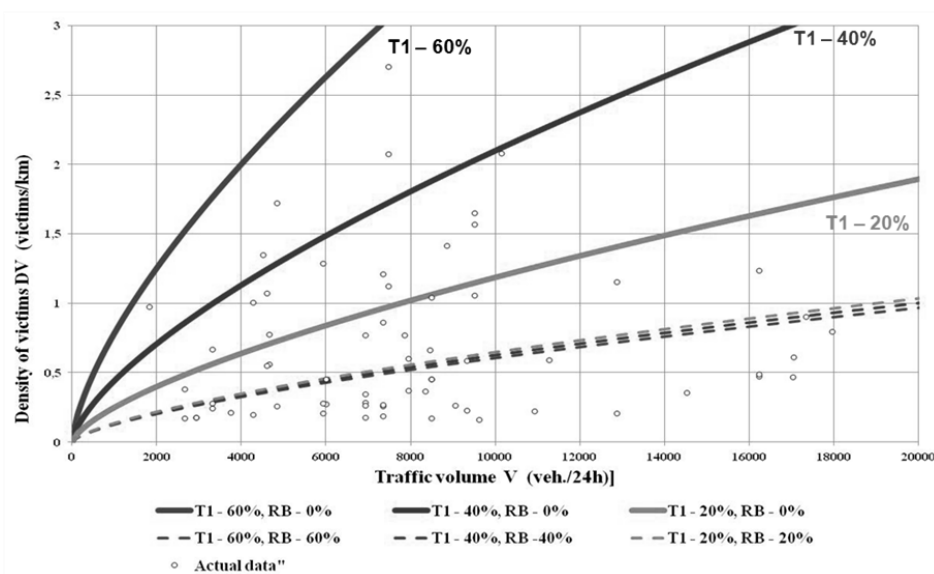

Fig. 5.2 Effects of sections with trees and safety barriers on road accident victim density

6. Summary

The work conducted under the project contributes new knowledge to road design, road traffic engineering and road maintenance. It also enhances methods for advanced numerical simulations of crash tests based on data from experiments. With no or inappropriate road safety equipment, it is important to improve models for estimating road accidents and their consequences. Models are very helpful with planning and designing road infrastructure.

Because road safety equipment and how it is used under different road and traffic conditions has an effect on its functionality and safety, it is important to study these areas and use the results to formulate modern methods for the design, construction and operation of road infrastructure giving sufficient emphasis to the role of the equipment in ensuring the safety of road infrastructure.

The results of the research will be used to develop a set of recommendations for formulating new guidelines for designers, manufacturers and constructors of road safety equipment and for formulating instructions for maintenance firms. Thanks to the guidelines road infrastructure safety will improve and the most common mistakes can be eliminated.

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