Road Infrastructure Safety Management in Poland

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Road Infrastructure Safety Management in Poland

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Abstract. The objective of road safety infrastructure management is to ensure that when roads are planned, designed, built and used road risks can be identified, assessed and mitigated. Road transport safety is significantly less developed than that of rail, water and air transport. The average individual risk of being a fatality in relation to the distance covered is thirty times higher in road transport that in the other modes. This is mainly because the different modes have a different approach to safety management and to the use of risk management methods and tools. In recent years Poland has had one of the European Union's highest road death numbers. In 2016 there were 3026 fatalities on Polish roads with 40,766 injuries. Protecting road users from the risk of injury and death should be given top priority. While Poland's national and regional road safety programmes address this problem and are instrumental in systematically reducing the number of casualties, the effects are far from the expectations. Modern approaches to safety focus on three integrated elements: infrastructure measures, safety management and safety culture. Due to its complexity, the process of road safety management requires modern tools to help with identifying road user risks, assess and evaluate the safety of road infrastructure and select effective measures to improve road safety. One possible tool for tackling this problem is the risk-based method for road infrastructure safety management. European Union Directive 2008/96/EC regulates and proposes a list of tools for managing road infrastructure safety. Road safety tools look at two criteria: the life cycle of a road structure and the process of risk management. Risk can be minimized through the application of the proposed interventions during design process as reasonable. The proposed methods of risk management bring together two stages: risk assessment and risk response occurring within the analyzed road structure (road network, road stretch, road section, junction, etc.). The objective of the methods is to help road authorities to take rational decisions in the area of road safety and road infrastructure safety and understand the consequences occurring in the particular phases of road life cycle. To help with assessing the impact of a road project on the safety of related roads, a method was developed for long-term forecasts of accidents and accident cost estimation as well as a risk classification to identify risks that are not acceptable risks. With regard to road safety audits and road safety inspection, a set of principles was developed to identify risks and the basic classification of mistakes and omissions. This work has added to the Polish experience of preparing and implementing such tools within the competent road authorities.

1. Introduction

Poland continues to be one of the European Union's worst performing countries for road deaths. In 2015 there were 2,938 people killed on Polish roads with 39,800 people injured. While the priorities set out in national and regional road safety programmes [1] help to systematically reduce Poland's road deaths, the results are far from what is expected. Road safety can be improved by implementing principles of

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road safety infrastructure management (RIS) on the network of European roads as adopted in the Directive [2]. RIS management involves the use of procedures throughout the life cycle of a road. The purpose of the procedures is to identify road hazards systematically, assess the possible consequences for road users, use measures to eliminate the hazards or mitigate the consequences. The consequences are measured with the number of accidents, injured and killed in road accidents and the costs of road accidents. The document recommends that member states should use tried and tested tools for road safety management such as:

- road safety impact assessment (RIA),
- road safety audit (RSA),
- safety management on existing road networks:
- road safety ranking (RSM),
- road safety inspection (RSI).

The Directive points out the need for research programmes in an effort to improve safety on the roads of the European Union. In point 7 it reads: "Research is vital to improving safety on the roads within the European Union. Developing and demonstrating components, measures and methods (including telematics) and disseminating results play an important part in increasing the safety of road infrastructure" [3]. Similar claims are made in road safety management research [4 - 6]. The authors stress the importance of research and its application in road safety programmes and strategies. Research is critical to reducing accidents and casualties.

To meet the needs of road authorities (national, regional and local), the Gdansk University of Technology (Department of Highway Engineering) in cooperation with the Krakow University of Technology (Department of Road Construction and Road Traffic Engineering) have developed several basic tools for managing the safety of Poland's road infrastructure [7 - 12].

2. Methodology basis

The purpose of the method is to help road authorities to take rational decisions about road safety, road infrastructure safety and the consequences that occur in the various stages of the life cycle of a road structure [13, 14]. Work on building the particular elements of Poland's road infrastructure safety management adopted the following assumptions:

- the management system and its elements will cover all stages of a road structure's life cycle (planning, design, construction, operation and closure),
- road safety infrastructure management is based on risk management,
- a variety of methods to identify hazards and sources of hazards will be used.

Risk and hazard are two intertwined terms in highway engineering risk management. In risk measure analysis Jamroz [11] describes risk as the hazard of a consequence occurring at a specific point in time. This is why risk is usually defined as the anticipated consequence which may be caused by a potential source of hazard. Hence, a hazard that may lead to a specific consequence will materialise if certain unfavourable conditions occur (e.g. driving into opposing traffic and causing a head-on collision caused by speeding). The risk will be a consequence suffered by the driver (e.g. a fatality) and the sources of the hazard may include: road infrastructure, weather, traffic, etc. [13 - 15]. Depending on the assumptions, three types of risk are usually distinguished: social, individual and group risk [13, 15].

Social risk refers to how groups of society behave generally in road traffic in a specific area. This is a consequence (number of accidents, victims and damage suffered in road accidents) within a specific time interval in a specific area which may occur as a result of dangerous events caused by a road traffic system. Depending on the measure that will represent the specific area, risk may be:

- overall – all consequences suffered as a result of road incidents (number of accidents, victims, accident costs).
- normalised – total consequences relative to section length, area, population, number of vehicles, etc.

Social risk is the product of three variables (exposure to risk, probability of a dangerous event, consequence of a dangerous event), and individual risk is the product of probability and consequence. The measure of social risk for road sections is usually defined as the number of accidents and victims per kilometre of road in a year (some papers use periods of three years). It describes the mean probability of being injured in a road accident on a road section and is applied to all road users. The level of risk has a strong correlation to increasing traffic on a specific road section [16 - 19]. Individual risk is defined as the mean level of the probability of a consequence to be suffered by a single member of a specific community while using a road network (per unit of kilometres travelled) in a specific area within a specific time. Individual risk for road sections is measured with the number of accidents (AR), injuries (IR), fatalities (FR) per vehicle kilometres travelled (VKT) in a year. The level of individual risk tells each driver or road user that they should adapt their behaviour to the level of hazard on a given road section.

3. Method of impact assessment

Assessing the impact of a planned road on road safety involves a strategic analysis of how the variants of a road will affect road safety on a network of public roads within the planned road's impact area [5]. The Road Impact Assessment (RIA) is conducted to rank the variants of the planned road by their impact on road safety within the network of roads that are within the planned road's impact zone. The results of the analysis should be included in a multi-criteria analysis (together with other criteria: technical, economic and environmental criteria) when assessing the variants of the road under analysis. The road safety impact assessment should also be used to reject from further design stages those variants that do not meet basic road safety standards. The research problem was to develop a method for forecasting road safety measures such as accident density AD, injury density ID and killed density KD also known as measures of societal risk. Measures of societal risk are calculated using the following relations (example for accident density AD) (1):

$$AD_{i,j,v,k} = \beta_{1,A,1} \cdot Q_{i,j,v}^{\beta_{2,A,k}} \cdot \exp\left(\beta_{3,A,k} \cdot Q_{i,j,v} + \beta_{4,A,k} \cdot PHV_{i,j,v}\right) \cdot f_{TP} \cdot f_{RL} \cdot f_{AE} \cdot f_{DI} \quad (1)$$

where:

- $Q_{i,j,v,}$ – average annual daily traffic on the analysed road section j, for the year of the forecast i, variant v (thou. veh./ 24h),
- $PHV_{i,j,v}$ – share of heavy vehicles (trucks and buses) on the analysed road section j in forecast year i, for variant v (%),
- $\beta_{1,} \ldots \beta_{n,}$ – equation coefficients,
- k – number of carriageways, k=1 one carriageway, k=2 two carriageways,
- f_{TP} – rate of the effect of the year of forecast which takes account of the level of socio-economic development of a country and systemic actions designed to improve road safety,
- f_{RL} – rate of the effect of road location (curvature, waviness, region of the country),
- f_{AE} – rate of the effect of the type of roadside (urban, industrial, rural, wooded) cut across by the analysed road section,
- f_{DI}– rate of the effect of junction or interchange density DI.

Figure 1 shows selected road safety measures depending on ADDT intensity. The values for road class A and S are clearly lower.

The authors recommend using the PTV Visum software as one of the elements of the tool Safety PL – Support Tool for Road Safety Impact Assessment. The choice of the PTV Visum software has been dictated by the fact that it is the most commonly used tool for work related to forecasts and analyses of traffic on newly designed roads in Poland. This approach will help to use the results of traffic forecasts for the entire impact area of the planned road, in the prepared models predicting accidents and casualties without the necessity to transfer them to other tools that support the calculation of road safety assessment. The essential element preceding the calculation of road safety measures is preparation of

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data on homogeneous sections in the impact area. For this purpose, the PTV Visum programme will prepare attributes for all variables in the prepared prediction models of accidents and victims. The modules are shown in figure 2.

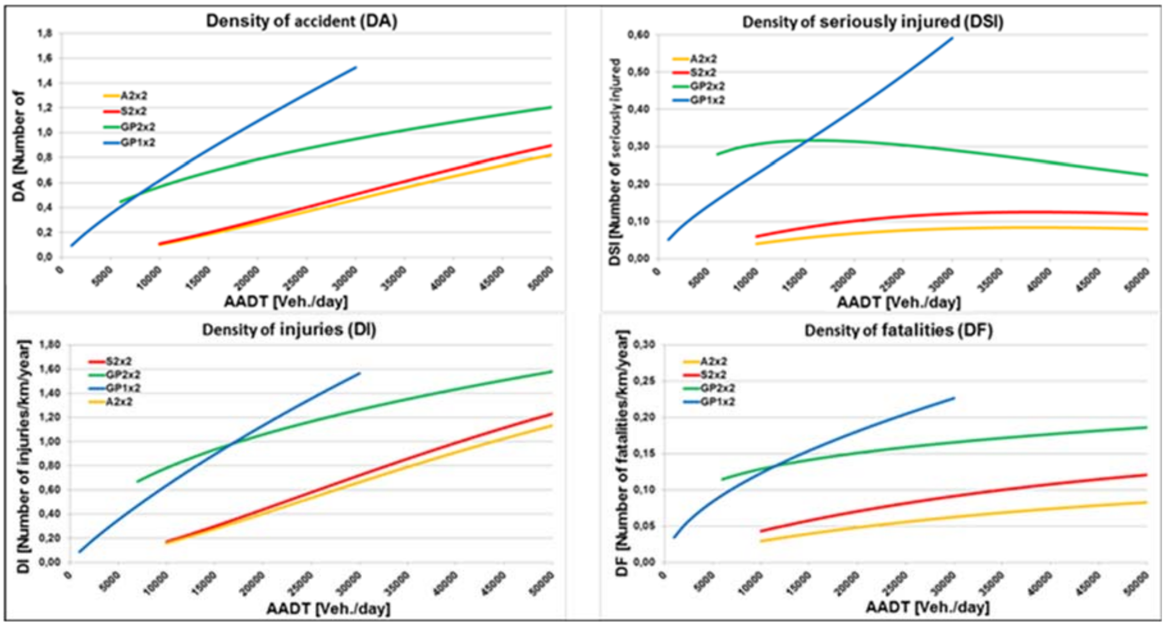

Figure 1. Road safety measures depending on ADDT intensity

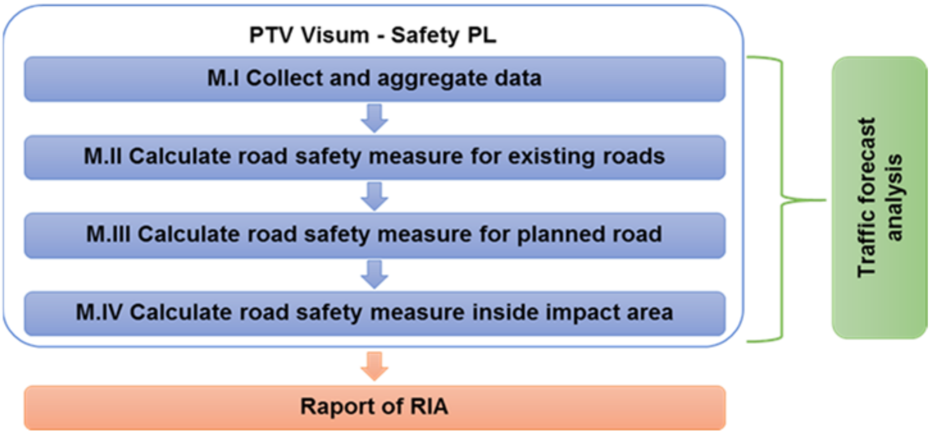

Figure 2. Safety PL modules

4. Road safety audit

With more than ten years of audit implementation experience in Poland [7] two groups of problems can be identified. They are related to:

- the process of road design and use of safety standards,
- the prevalence, correctness and effectiveness of the auditing procedures.

In the first group of problems, road safety audit shows that statistically the same errors keep appearing quite often when it comes to designing the cross-section and vertical alignment, layout, junctions and interchanges:

- the use of 1x4 and 1x6 cross-sections with no central reservation,
- structures (utility poles, barriers) are placed on narrow pavements (1.5-2.0 m),

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- cyclists and pedestrians are not effectively segregated in the street cross-section,
- steep slopes are used in hazardous places,
- sight distance is not sufficient on horizontal and vertical curves,
- the distances between junctions are too small; junctions are classified in the design as exits
- poor surface drainage of the carriageway,
- selection of the wrong junction type,
- interchanges not matching traffic parameters.

The second group of problems arise due to difficulties with ensuring:
- professional staff and independence of auditors' comments,
- objectivity in assessing a design's proposals for their safety and reasonable recommendations.

At present, there are three documents that are related directly to audit procedures:
- Regulation 42 of the Director General for National Roads and Motorways of 3 September 2009 concerning the road safety impact assessment and road safety audits of road infrastructure projects
- Act of 13 April 2012 revising the public roads act and some other acts introducing the road safety audit – an independent, detailed and technical assessment of a public road being designed, built, improved or used for the safety of road users
- Ordinance of the Minister of Transport, Construction and Maritime Economy of 14 September 2012 concerning training and certificates for road safety auditors.

5. Managing the safety of an existing road network

The main objective of road safety ranking (RSM) is to select sections that carry the highest individual risk, i.e. the likelihood of being involved in fatal crash of a road user and sections that carry the highest societal risk and the biggest potential for reducing accident costs as a result of road authority actions [8]. The intermediate goals of RSM are to:
- systematically assess safety on existing road networks,
- identify and rank high risk sections,
- identify and rank sections with the highest density of accident costs and sections with the highest potential to reduce accident costs,
- create a basis for selecting sections that need work of the highest effectiveness.

In the traffic safety ranking five classes are proposed depending on the potential for reducing accident costs on road sections (A, B, C, D, E) [14]. While hazardous sections must be ranked on national roads only, in 2015 a new ranking was developed for the National Road Safety Council covering regional roads. Figure 3 shows an example of the ranking looking at societal risk (density of accident costs) for run-off-road accidents. For the particular technical classes of national roads, the risk of an accident was assigned at three levels of acceptance:
- unacceptable risk level on a road section means a strong likelihood of severe personal or economic consequences – the road section cannot operate safely until that risk is reduced or the sources of the hazard are removed.
- tolerated risk level on a road section means a medium or low likelihood of personal or economic consequences – the road section may operate temporarily or under certain conditions (such as the use of ad hoc solutions to improve safety such as speed limits, a more intensified road traffic enforcement).
- acceptable risk level means low or very low likelihood of personal or economic consequences – the road section can operate with no additional measures.

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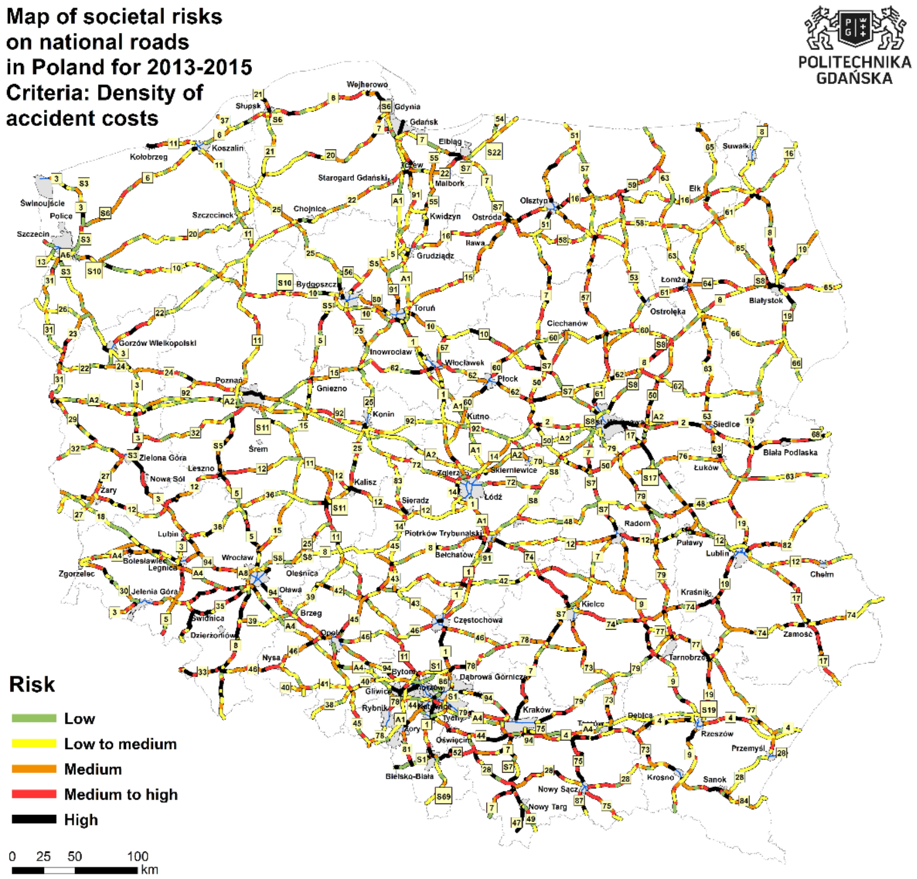

Figure 3. Map of sections of national roads, societal risk, accident density

6. Road safety inspection

Road safety inspection is part of road safety management based on risk management [8] and part of measures and preventative steps taken by road authorities. The purpose of road inspection is to identify hazards and sources of hazards on the road network and as a consequence, implement effective treatment to improve road user safety and road network standards. Road network inspections are divided into three types: general (regular drives on inspected roads), detailed (on-site visits with observations of road user behaviour and checks of e.g. sight distance) and special (at night-time, in road works zones). The results of inspection can be used to update technical requirements or design guidelines and to help with selecting the right treatment.

Once identified, the defects should be assessed and assigned to three hazard classes: class A – low, class B – medium, class C – high. There are risk classes assigned to defect classes: high – unacceptable – class C hazard, medium – conditionally acceptable (acceptable provided that specific treatment is applied) – class B hazards, low – acceptable, class A hazards. The responses to the risks identified vary depending on the risk classes: immediate response, response spread over time – using immediate temporary solutions and responses to take place over time. The decisions should be taken based on inspector assessment (using their knowledge and experience) and objective measures of hazards. The main criteria for classifying defects identified in an inspection are as follows:

- speed limit – set in the general regulations or local speed limits and real speed (if it exceeds the speed limit significantly this may be the consequence of a wrong cross-section)
- type of area (urban built-up, built-up – small towns, built-up on city outskirts, non-built-up),

- type of cross-section (cross-section 1x2 + wide hard shoulders outside urban areas are a potential class C, similarly 1x4 cross-sections in built-up areas, 2x2 or 2x3 potentially mean much higher speeds than allowed – class C in the case of unsignalised at-grade pedestrian crossings),

Experience from previous road safety inspections on Polish roads and the authors' own site work was used to define the characteristics of the hazard classes:

- class A: the effect of defects on safety is low or none – acceptable level of risk, if removed, the road standard improves; if this would involve significant expenditure, no improvements will be made (except when this is part of a comprehensive section treatment),
- class B: the effect on safety is medium – tolerated level of risk, if removed, the road standard and safety would improve substantially; if this would involve significant expenditure, temporary treatments would be required to reduce the risk of accidents,
- class C: the effect on safety is significant – unacceptable level of risk, the defects must be removed to improve safety, safety treatments must be made as soon as possible.

The same defects are ranked differently under different conditions. This can be exemplified with unprotected objects close to the roadway (such as trees, lampposts) which can be ranked as class A, B and C hazards:

- built-up area with no restrictions to visibility (A),
- built-up area – restricting visibility (B),
- non-built-up area (90 km/h), distance 0-3 m (C); 3.1-5 m (B); above 5.0 m – (A),
- non-built-up area (70 km/h), distance 0-1.5 m (C); 1.6 – 3 m (B), above 3.1 – 5 m (A),
- there may be additional differences when the location is on a horizontal curve.

Road safety inspections should lead to specific treatments designed to remove and modify hazards or to protect against them. The improvements would mainly be designed to:

- transform the road and street network to build hierarchy thanks to additions and changes to the existing network,
- develop concepts and implement in practice "self-explanatory roads" which feature: an easily recognisable function and use, traffic segregation by users and speed, speed limits adjusted to local limits and easy to understand for motorists,
- develop concepts and implement in practice "forgiving roads", with no dangerous side obstacles and equipped with passive safety measures,
- remove errors in road infrastructure that cause accident concentration sites the so called "black spots" and sections with the highest risk of fatality,
- implement measures designed to reduce head-on crashes by separating traffic flows and enabling safe overtaking manoeuvres,
- develop pedestrian and cyclist facilities and introduce relevant maintenance standards to ensure that walking and cycling has no barriers and is safe,
- introduce new safer solutions in the infrastructure as regards junctions and road cross-sections,
- ensure a more comprehensible and traffic user friendly signage,
- implement infrastructural treatments to improve road user safety when visibility is restricted,
- implement ITS measures for road traffic enforcement and control.

7. Conclusion

The authors' preliminary analyses show that the effectiveness of road infrastructure safety management tools, i.e. how effective they are in reducing accident casualties, is estimated as follows: road safety impact assessment: 10 – 25%, road safety audit (three stages combined): 5 – 20%, infrastructure inspection (systematic): 1 – 20%. The effectiveness increases on roads which did not have any road safety management procedures before. A well organised road safety system, equipped with the right structures and procedures can help to reduce the risk of injury or death of road users. If properly applied,

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road safety inspection as one of road safety management tools, can help to reduce accident casualties. Because the method presented here applies to national roads only, new methods for road safety management on local authority roads should be developed and implemented. In addition, new tools should be built to ensure that road traffic hazards are objectively ranked and road safety treatments are evaluated for their effectiveness. If implemented, new and innovative elements of automating road safety inspection procedures (data collection, defect classification, choice of the most effective remedial measures) will help to make it more efficient and consequently improve the safety of road users.

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