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Original scientific paper

Unified Approach to Risk Assessment at Railway Crossings

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Abstract – **This conference paper discusses a new analytical approach to the evaluation of traffic safety at the railway crossings. The new method is based on the use of ontological principles. The ontological tools present a comprehensive decision-making tool, will can be applied to any potential hazardous railway crossing on a road or rail network.**

Keywords – **railway crossing, Traffic safety, Ontology.**

I. Introduction

The primary focus of the research task is to create a systematic tool for evaluation of the level of safety at railway crossings in the Czech Republic. Within the framework, the author aims to implement the use of hierarchically structured data in the topic of traffic safety analysis. Knowing that there is currently no comprehensive tool that could summarize and considers all important criteria affecting the resulting level of safety, the author is taking the initiative to create such a unified analytical tool. These efforts are fully in line with the European transport policy outlined in the White Paper of the European Commission, the adoption of which the Czech Republic committed to. The main objective is the overall reduction of all types of traffic accidents. The priorities contained in this material are fully in line with the targets set by the Member States of the European Union and the United Nations, which aim to halve the number of people killed and seriously injured on the roads (by 2030, 50% less than the baseline). [3] [4]

This contribution outlines the issue of safety at railway crossings in a broader context and its necessity at a conceptual scientific level. At the same time, the intention of the research lies in application of the ontological approach to the safety issue. The ontology and the ontological (conceptual) modelling as a modern analytical tool are presented, as well as the reasons for choosing a particular ontological language for creation of the resulting ontological model. Furthermore, parameters primarily or secondarily influencing the safety of participants of operation at railway crossings are defined within the framework of specifically focused scientific analytical activity. The paper concludes by presenting the objectives of the research task, its outputs and at the same time discussing the potential limitations in terms of the possibilities of the ontological approach.

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II. Safety Issues at Railway Crossings

The topicality of the idea of systematically increasing safety at the railway crossings is also confirmed by the only slightly decreasing number of traffic accidents, the resulting societal losses and the fact that traffic accidents are usually fatal in terms of the consequences of the accident participants. The following Fig. 1 shows the evolution of the number of accidents at railway crossings together with the numbers of fatalities.

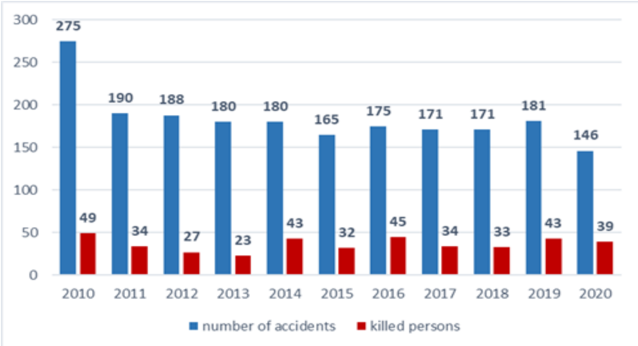

Fig. 1. – Traffic accidents at railway crossings and corresponding fatalities [5]

Therefore, it is essential to shift the general approach into a proactive one via modification of railway crossings and adjacent roads. This means to try to prevent accidents even at railway crossings which currently do not have a higher accident rate but which nevertheless appear to be risky in the terms of their traffic / construction layout or road markings. However, the amount of railway crossings presents a challenge for application of this approach, mainly due to the density of the road network in combination with the length of the railway network in the Czech Republic, which is approximately 10 000 km. Specifically, there are currently approximately 7 800 railway crossings on the railway network in the Czech Republic. Within this number, the individual levels of protection or the types of railway crossing safety equipment used vary greatly. [6]

Looking at the statistics of accidents at railway crossings published by the Railway Inspectorate for the year 2019, it is still evident that the number of both accidents and fatalities is not decreasing. There were 181 incidents, in which 43 persons died. At the same time, 93 persons were seriously injured. In 2020, a total of 146 emergencies were recorded. The statistics show a total of 39 fatalities and 95 persons seriously injured in 2020. Nevertheless, the accidents at railway crossings are usually fatal for the involved road users, primarily from due to the completely disproportionate parameters of the colliding vehicles (train/car). The continuing trend in the number of accidents and the severity of their consequences clearly calls for a further analysis of the current situation and the necessity of appropriate measures to improve the level of safety at the railway crossings. This approach clearly corresponds with the global accentuated idea of Vision Zero and objectives implemented in the Czech Republic in the National Road Safety Strategy. [4] [5]

III. CURRENT APPROACH TO RISK ASSESSMENT AT RAILWAY CROSSINGS

It is crucial to look at the issue of railway crossings comprehensively, both from the point of view of traffic safety defects of the road in question and at the same time from the perspective of the safety at the railway transport route. Currently, there is not a unified, comprehensive and adequate approach or tool to increase the level of safety of all traffic participants. Unfortunately, the safety issues of the road and the railway infrastructure are being dealt with separately by the administrators or managers. Primarily, this is done due to the different institutions which are responsible for the management of the infrastructures and the differences in funding. This methodologically inefficient approach makes it difficult to achieve an adequate, socially acceptable level of traffic safety at the railway crossings. Therefore, the aim of the research task is to unify the approach and create a tool for systematic evaluation of the safety. The focus is on railway crossings on Class II and III roads, as well as on local roads. This stems from the extensive research work already carried out within various research projects and also from the knowledge that railway crossings on Class I roads are often equipped with an adequate level of security, such as railway crossing light interlocking with additional barrier barriers.

IV. ONTOLOGICAL CONCEPT

During one of the initial parts of the research, an extensive search was carried out for currently available analytical tools that would be able to assess a number of different but mutually influencing parameters and would be therefore suitable for application to the research in question. Given that the issue of the safety at railway crossings is influenced by a number of interrelated parameters, the optimal solution seems to be their explicit definition and arrangement by creating an ontology. This will prevent any misinterpretation of the individual terms or relations between the parameters in the analysis of traffic safety at specific railway crossings. An ontology, by its very nature, clearly defines the terms and relationships between terms from a specific area of reality that it accurately describes. This shows that an ontology provides means of capturing and abstracting the real world, or parts of it, and allows minimizing or even completely eliminating the differences between the perception of a particular area of reality by the humans on the one hand and the information database systems on the other. This goal is achieved by standardizing and formalizing the meaning of concepts in the generalized part of the surrounding world. As a result, ontologies can subsequently be used in tasks based on the modelling, querying or inference. Since ontologies are used to represent reality, a suitable ontology modelling language is also needed. One of these languages is the OntoUML, which is based on the Unified Foundational Ontology (UFO), and was created as an extension of the Unified Modeling Language (UML) in the context of Giancarlo Guizzardi's doctoral thesis on "*Ontological Foundations for Structural Conceptual Models*". It was the UFO ontology, or the ontological language OntoUML, that was chosen as a suitable tool for modelling the particular reality under the investigation, i.e. railway crossings. [1] [2] [7] [8]

The synthesis of the UFO ontology and the selected graphical modelling language OntoUML will result in the design of a custom hierarchically structured model, which will be validated. For the purpose of the investigation, the obtained traffic engineering data is used. The specialised software OLED (OntoUML lightweight editor) serves as the modelling environment. The next step is creation of a database of railway crossings within the CEBASS web application environment ("Central Evidence of Safety Analyses of the Road Network"), which serves as an effective tool for the presentation of the results obtained. The advantage of this database is and ability to encompass a comprehensive dataset in one place. At the same time, the database works with the ontological principles of hierarchically structured data and contains a detailed parameterisation of the entire set of the analysed railway crossings, including their projection in the base map. [1] [2] [7] [8] [9]

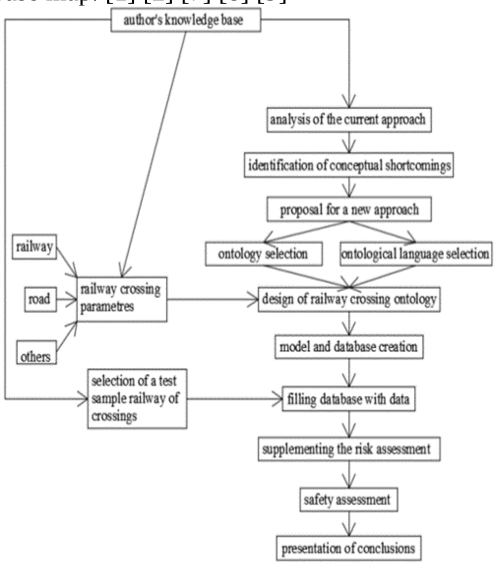

Fig. 2*.* – Individual phases of the research task.

The resulting risk assessment of individual railway crossings will be based on the proposed and validated ontology model. The model will be complemented by the knowledge base of the system designer in regards to the risk rating of individual parameters, or a combination of interrelated parameters, if they are in an inadequate state.

In parallel with the identification of the traffic safety defects, a database of specific typologically appropriate remediation measures is being created. This approach enables to the model to suggest appropriate measures even for future cases which may combine a different safety defects which are not currently apparent. Therefore, the use of ontological tools enables to create a comprehensive decision-making tool, that can be applied to any railway crossing on the road or rail network. For better clarity, Fig. 2 shows a flow chart with individual phases of the research task.

V. PARAMETERS CONSIDERED WITHIN THE ONTOLOGY

The overall level of safety of each railway crossing is determined by the combination of risks connected with identified safety defects. The concept of risk consists of a combination of two elements, namely the probability of occurrence of the potentially negative event and the severity of resulting consequences. However, some of the risks cannot be mitigated and therefore, it is also necessary to consider an acceptable level of risk. Any incident in the area of a railway crossing leads to disruption of both rail and road traffic, resulting in the reduction in their operational reliability. As the volume of traffic in both modes increases over the years, the probability of an incident increases as well. In the end, the individual characteristic parameters of the railway crossing and its close approximate determine the probability of an accident. The parameters have a greater or lesser effect onto the resulting level of safety, however, the effects are also affected by their qualitative state at any given moment. At the same time, it is important to realise that all parameters are interdependent within a single entity (railway crossing) and influence each other. Particularly risky is the situation where a railway crossing shows an inadequate quality status for several interacting parameters. In this case, the hazardousness of the crossing in question increases not in an additive but rather multiplicate or exponential way. If we understand the ontology as a certain knowledge base, which not only stores the data itself (in this case the parameterisation of railway crossings) but also defines the relationships between these data, it can be described as a rather suitable tool for describing the resulting level of safety.

On the basis of the detailed research and especially the expert knowledge, the following set of parameters that affect the level of traffic safety at railway crossings was defined. The parameters are currently divided into three groups – road segment, railway segment and group of parameters which cannot be clearly assigned into one of the two previous groups. These parameters, which are presented in Fig. 3, serve as a ground plan for the ontology creation and serve as a base for the ontology model. At the same time, it is necessary to comment on the parameter of weather conditions. In the list below, only the parameter of the possibility of glare from the sun is given. Other variables of the weather conditions parameter such as rain, snow, wind or ice on the road are not taken into account in the current database due to their variability. Their possible inclusion will be decided in the next phase of the research task.

Currently, first implementation and validation were performed on selected railway crossings located in the Central Bohemia Region. Different typologies of construction and operational design of the crossings are represented in this dataset. Different types of the safety defects are also identified across the sample. It is therefore a diverse set of railway crossings that provides a suitable basis for the development and subsequent validation of the ontology model as a decision tool. The figures below show examples of hazardous railway crossings identified within the test dataset. These examples show various parameters are interconnected and how the resulting level of safety is adversely affected. [10]

rail
intensity of rail transport
importance of the railway
number of tracks
line speed
level of signalling systems
layout of the railway
regulation S 4/3
type of railway signalling systems
road
road traffic intensity
road category
speed limit
layout of the road
vertical curvature of the road
condition of traffic signs
perceptibility of the railway crossing
variability of road width
condition of the crossing road
possibility of glare
railway crossing distance from the intersection
perceptibility of traffic signs
walking route across railway crossing
others
number of accidents
railway crossing angle
location urban/rural area
assessment of obstacles in the clearance zone

Fig. 3. – Categorisation and definition of the main parameters affecting the safety at railway crossings.

Fig. 4 shows a railway crossing where the statistical evaluation of traffic accidents identified a glare as the primary cause of the majority of observed traffic accidents. This in combination with other parameters (vertical and horizontal alignment of the road) lead to inadequate level of safety.

Fig. 4. - Example of adverse combination of parameters (glare, vertical curvature of the road, layout of the road).

The Fig. 5 shows another inadequate state of the parameter – obstacles in the clearance zone, namely the limitation of visual conditions due to the planting of an inappropriate crop (sunflower) in the crossing's visual clear zone. Given that this is a technically unprotected railway crossing, where road users are required to make sure that they can cross the crossing by sight before crossing it, the restriction of the line of sight to the railway line is found to present a significant risk.

Fig. 5. – Obstacle in the clearance zone of the driver.

The Fig. 6 shows a prime example of hazardous railway crossing. The crossing is located on a long straight stretch of the road with unmaintained vegetation alongside. These factors adversely affect the predictability and visibility of the crossing to the driver (parameter - perceptibility of the railway crossing). At the same time, the vegetation is also located along the railway line and limits the desired view of the railway line (obstacles in the clearance zone).

Fig. 6. – Example of adversely affected perceptibility of the railway crossing

VI. Future direction of research

The primary objective of the ontology-based decision tool is to provide a socially acceptable level of road safety at railway crossings. This encompass a reactive approach for railway crossings already showing accident events but also a pursuit of a proactive approach, for those railway crossings that do not currently show higher accident rates but presents a clear and significant risk for the road users. However, the essential part for its successful implementation is to have a systematic procedure which is able to identify and define traffic safety defects and the subsequent corrective measures.

The proposed evaluation tool, once successfully completed, will extend and complement the existing CEBASS web application developed and used at the Department of Forensic Experts in Transportation. The web application is already used by the Road and Motorway Directorate of the Czech Republic and the Regional Road Maintenance Administration of the Central Bohemian Region. At the same time, it is the intention of the author of the project to address the relevant state administration authorities that manage the road or railway transport routes in question and to offer them the possibility of cooperation as well as the conclusions resulting from the research.

VII. Possible limitations

The primary limitation is seen as a lack of deeper understanding of use of ontology onto this particular issue. The Unified Foundational Ontology is described mainly in Dr. Guizzardi's dissertation. However, there are only a few practical examples or examples of work dealing with UFOs. Especially this is the case for the UFO-B, UFO-C and UFO-S ontologies. For this reason, the current phases of the research is utilized the ontology UFO-A, which is already considered to be complete and is at present described in greater detail.

VIII. Conclusion

The presented contribution presents the initial design phases of a unified decision-making tool for a comprehensive assessment of the level of traffic safety at railway crossings. The tool operates and takes advantage of an ontological approach (UFO-A). The main advantage of ontological approach is the possibility to apply the resulting analytical tool to any railway crossing on a road or rail network. Furthermore, the proposed approach addresses the current issue non-cooperative and fractured approach from the road and rail managers. The principles, parameters definition and the results of initial test were presented. These were accompanied by practical examples of identified railway crossings from the Central Bohemia Region.

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References

[1] Ontological Foundations for Structural Conceptual Models, Giancarlo Guizzardi, The Netherlands, ISBN 90-75176-81-3, 2005
[2] UML and the unified application development process, Arlow Jim, Neustadt Ila, ISBN 978-80-7226-947-1, 2003
[3] White Paper of the European Commission – creating a competitive and resource efficient transport system, European Commission, Brussels, 2011
[4] Road Safety Observatory [online]. Copyright © Available from: https://www.czrso.cz/nsbsp/2021-Strategie-BESIP-2021-2030.pdf
[5] Railway inspection [online]. Copyright © 2006 QCM, pp. Available from: http://www.dicr.cz/rok-2020-na-draze-nejmene-mimoradnych-za-poslednich-17-let
[6] Basic characteristics of the railway network www.spravazeleznic.cz [online]. Copyright © 2020 Railway Administration, state organizations Available from: https://www.spravazeleznic.cz/o-nas/vse-o-sprave-zeleznic/zeleznice-cr/zeleznicni-sit-v-cr
[7] OntoUML Community Portal. OntoUML Community Portal [online]. Copyright © 2017 Available from: https://ontouml.org/
[8] OntoUML | CCMi [online]. Copyright © 2016 Available from: https://ccmi.fit.cvut.cz/metodiky/ontouml/
[9] CEBASS Available from: https://cebass.fd.cvut.cz/
[10] ČSN 73 6380 Railway crossings