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APPLICATION OF ONTOLOGY/CONCEPTUAL MODELLING IN THE CONTEXT OF RISK IDENTIFICATION AT LEVEL 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. The ontology can be considered as a knowledge base that not only stores the data itself, but also defines the relationships between these data, and can therefore be described as a clearly suitable tool for describing risks at level crossings.

Keywords: Level crossing, traffic safety, ontology, data utilisation.

1. Introduction

Safety analysis, or risk analysis, is a topic that resonates across many different disciplines. Transport safety analysis is no exception. If we look at a particular area of transport as an interrelated and influencing system, it is necessary to address the question of whether the system is working properly and indicates an adequate level of safety not only for the system as a whole but also in relation to its users. The issue of safety analysis is closely related to the issue of collecting, processing, evaluating and interpreting data that affect the safety level of a particular system. Given the considerable amount of measurable data that the modern world makes possible through technology nowadays, it is important to work effectively with this data. The approach of how to store the data is also an important factor. Currently, simple tools such as MS EXCEL are used for these purposes. However, it is questionable whether this approach is effective in relation to subsequent analyses, creates a realistic view of the analyzed system and satisfies the needs of subsequent complex analyses over these data. At the same time, it is important to ensure the highest possible standardisation of procedures in these analyses in the context of minimising the potential impact of analysts' subjective assessments on the risk analysis outputs. The aim of this systems approach to safety analysis is to increase the informative value of the data at all stages of the analysis and risk classification of a particular system.

2. Conceptual modelling, ontology

Conceptual modelling allows you to create a model of a real part of the world. The basis of this modelling is an ontology that guarantees the correct interpretation of all terms. A conceptual model is created by synthesizing a theoretical knowledge base and an appropriate tool. In this context, the theory is represented by an ontology and a graphical modelling language is used as a tool. The ontology, unanimously defines terms and relationships between terms in the specific reality domain described for which the ontology is created. In general, an ontology is a tool for capturing the real world, or parts of it, in the form of standardizing and formalizing the meaning of concepts in the described part of the world. For this reason, ontologies can be beneficially used in modelling, questioning or derivation tasks [1–3].

2.1. Conceptual modelling

Conceptual modelling can also be defined as conceptual modelling. Conceptual modelling allows modelling of real world elements. A conceptual model is realized by combining a theoretical knowledge base and a suitable tool. The theory is represented by an ontology, which uniquely defines terms and relationships between terms from the specific reality domain described for which it is created, and a graphical modelling language is used as the modelling tool. An example of this is the Unified Modelling Language (UML). Conceptual modelling is based on modelling the real world domain by using Entities and Relationships between these parameters. The term Entity can be used to imagine a real world object capable of independent existence and is uniquely distinguishable from other Entities. The notion of Relationship specifies the relations between Entities and at the same time describes certain properties. An important term is the notion of Attribute, which indicates a property of Entities or Relationships. The Figure 1 shows graphically the relationship between the ontology that gives a clear meaning to the conceptual model, the conceptual model that can be described by the UML modelling language and this specific modelling language. In general, it can be assumed that conceptual modelling represents the initial phase of the analy-

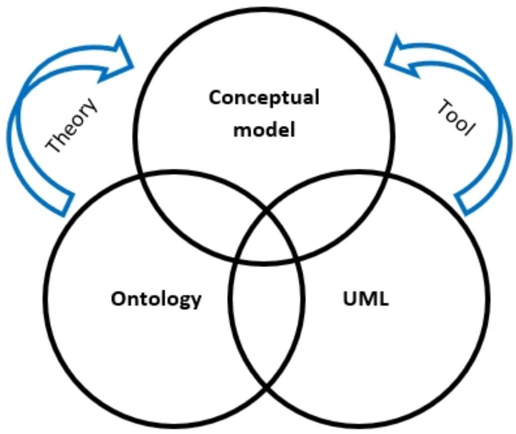

Figure 1. The relation between conceptual model, ontology and UML modelling language.

sis. The next phases are the proposal of the logical model and the implementation within the physical model [1, 4–6].

2.2. Unified Foundational Ontology

The foundations of Unified Foundational Ontology (UFO) were specified by Giancarlo Guizzardi in his PhD thesis. UFO is currently being further developed by the NEMO research group of which Giancarlo Guizzardi is a part. It is a universal upper-level ontology that can be used for application to any part of the real world. The UFO ontology is further divided into the following three interrelated units:

(1.) UFO-A deals with individual aspects of reality, which are considered to be individual objects, so-called endurants. UFO-A has been used to analyse structural constructs of conceptual modelling, such as object types and taxonomic relations, associations and relations between associations, roles, properties, data types and weak entities, and participation relations between objects.

(2.) UFO-B is a part of the ontology, which extends the original UFO-A ontology by dynamic process and events called perdurants, which are varying depending on time.

(3.) UFO-C extends the UFO-B ontology and deals with social aspects. By this term we can imagine aspects that are e.g. faith, actions or social roles [1, 3, 7].

2.2.1. OntoUML

OntoUML is an ontology language for ontological conceptual modeling. OntoUML is an extension of the UML language and is based on the UFO ontology. The foundations of UFO and OntoUML are based on Giancarlo Guizzardi's PhD thesis "Ontological foundations for structural conceptual models" [1]. In his thesis, Guizzardi proposed a new fundamental ontology for conceptual modeling (UFO) and used it to evaluate and redesign the UML for the purpose of conceptual modeling and domain ontology engineering (see the Figure 2) [2].

3. Motivation for Applying at Level Crossings

The following section discusses the evaluation of the accident rate at level crossings in the Czech Republic. The input dataset represents accidents that occurred at level crossings between 2010 and 2020. For this period, the Railway Inspectorate of the Czech Republic recorded a total of 2 182 accidents in which 1 116 persons were injured and 430 were killed. The Figure 3 shows the evolution of the number of accidents and their consequences at level crossings over the 12-year period. Considering the evolution of the number of accidents, no decreasing trend can be identified between 2011 and 2021. The number of injured persons also shows a decreasing trend, which can be classified as a rather fluctuating trend over the period analysed. The most important indicator, namely the number of persons killed, does not follow a decreasing trend either, except for the last year analysed, 2021 [8, 9].

The Figure 4 shows the evolution of the number of accidents at level crossings by type of signalling system. It can be deducted from the number of incidents that level crossings protected only by a traffic sign have an almost similar absolute accident rate as level crossings equipped with a level crossing signalling system with light signals without barriers. However, taking into account the ratio between the number of level crossings protected only by a traffic sign (3 486 pcs) and the number of level crossings equipped with a signalling system with light signalling without barriers (2 363 pcs), it can be reasonably stated that the relative accident rate is higher and therefore the safety level is lower for level crossings equipped with a signalling system with light signalling without barriers [8, 9].

The mentioned negative statistical evaluation of the level of safety at level crossings equipped with level crossing signalling system with light signals without barriers is clearly confirmed by the statistics summarised in the Figure 5. The figure shows the evolution of the number of persons killed in accidents at level crossings according to the type of signalling system. In the period under review, a total of 210 persons were killed at level crossings protected by level crossing signalling system with light signals without barriers, which is three times higher than the number of persons killed at level crossings protected only by traffic sign [8, 9].

To summarise this section, based on statistical data on the number of incidents at level crossings and their consequences, an unsatisfying development trend can be stated. In general, there is no significant year-on-year decreasing trend in the number of accidents or the number of persons injured or killed. Also alarming is the negative assessment of the safety level of level crossings with signalling system with traffic lights without barriers. In terms of both relative and

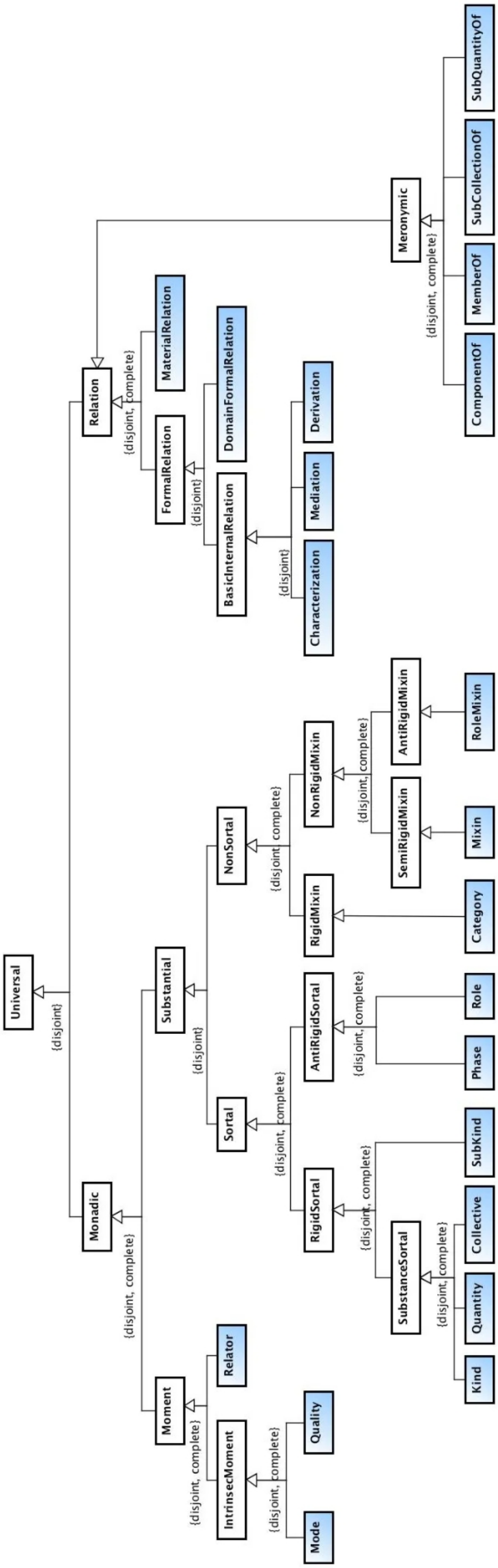

FIGURE 2. OntoUML metamodel [2].

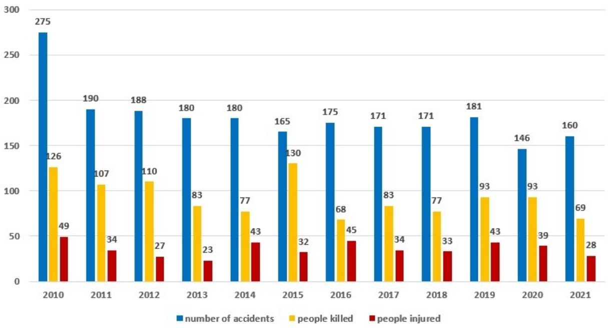

Figure 3. Evolution of the number of accidents at level crossings [9].

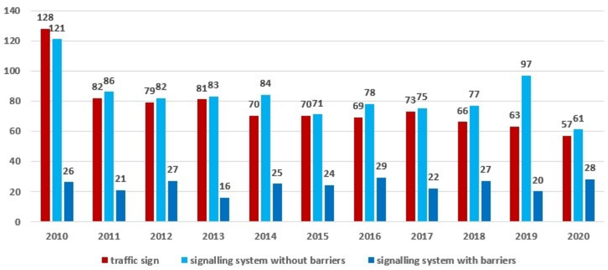

Figure 4. Evolution of the number of accidents at level crossings by type of protection [9].

absolute accident rates, this type of protection poses the greatest risk for road users. The above conclusions of the analysis of the level of safety at level crossings in the Czech Republic clearly indicate a necessity for a more detailed analysis of the presented issues in order to achieve a socially acceptable level of safety of traffic on roads in accordance with the European transport policy and the national road safety strategy.

Research by the author of this article focuses on solving this problem. A number of interacting parameters have a direct or indirect influence on the issue of risk analysis at level crossings. For this reason, organizing these parameters by creating an ontology seems to be effective in terms of subsequent safety analyses. At the same time, this method limits possible misinterpretation of individual terms or relationships between terms.

4. Practical Application

A fundamental premise for assessing the risk of level crossings is a comprehensive approach, both in terms of defects of the road and the railway infrastructure. The safety of a level crossing is determined by the probability of occurrence of risks. The potential occurrence of an incident is influenced by the parameters by which the level crossing and its surroundings are described. The main influence on the level of safety is the current qualitative state of the specified parameters. It is essential to reflect that the parameters are interdependent within a single system (level crossing) and influence each other. Generally, situations are considered to be at risk when a level crossing is in a

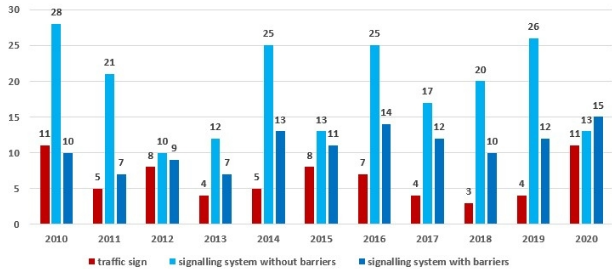

Figure 5. Evolution of the number of persons killed in accidents at level crossings by type of protection [9].

state where a risk condition is identified for several specific parameters.

Specifically, the following set of parameters in Table 1 has been defined that influence the level of risk at level crossings. The following defined parameters describe the level crossing in detail in terms of three specific groups of defined parameters. It is a group of parameters belonging to the road and a group of parameters parametrizing the railway segment of the issues. The last group of parameters contains those parameters that cannot be clearly classified into one of the two above-mentioned categories but are necessary for the completion of the complex parameterisation of the level crossing.

If we consider the ontology as a unified knowledge base that not only stores the data itself, but also defines the relationships between these data, it can be described as a clearly suitable tool to describe the risks at level crossings.

5. Discussion

The next steps in the project are the validation of the model based on ontological principles within a test database of selected level crossings. At the same time, a database of appropriate remediation measures is being created to be addressed to the identified risks. The main potential problem of the research is the limited scope of literature and information sources about the issue. Unified Foundational Ontology is very well described in Dr. Guizzardi's dissertation. However, there are few practical examples or examples of work dealing with ontologies UFO-B and UFO-C.

6. Conclusion

The perspective and effectiveness of this project consists primarily in the development of a unified decision-making tool for a comprehensive evaluation of the level of traffic safety at level crossings. The resulting determination of the risk level of individual level crossings will be based on the proposed and validated ontological model. This ontological model will be complemented by the knowledge base of the researcher regarding the risk rating of individual parameters, or a combination of interrelated parameters if they are in an inadequate state.

Rail	Road	Others
Intensity of rail transport	Road traffic intensity	Number of accidents
Importance of the railway	Road category	Railway crossing angle
Number of tracks	Speed limit	Location – urban/rural area
Line speed	Layout of the road	Assessment of obstacles in the clearance zone
Level of protection	Vertical curvature of the road	
Layout of the railway	Technical condition of traffic signs	
Validity of the regulation S 4/3	Perceptibility of the level crossing	
Type of railway signalling system	Variability of the road width	
	Technical condition of crossing road	
	Possibility of glare	
	Distance between level crossing and intersection	
	Perceptibility of traffic signs	
	Walking route across level crossing	

TABLE 1. List of defined parameters.

In parallel with the identification of traffic safety defects, a database of specific appropriate remedial measures is being created. These measures appropriately address the identified traffic safety risks. In the case of practical implementation of this clearly defined methodological approach to the evaluation of risks related to level crossings and the design of appropriate remediation measures, a socially acceptable level of transport safety at level crossings will be ensured.

Acknowledgements

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