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Transport and Transportation Ontologies

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ABSTRACT

The objective of the study described in the article was to analyse the features of application of ontologies in the field of transport and transportation. It referred to the exploration of the methods of building ontologies as well as to the information uncertainty hampering building ontologies, based on introduced terms of «transport and transportation ontologies», «ontological management» and «ontological information uncertainty».

The main research methods comprised system, ontological, qualitative and comparative analysis.

Since the use of ontologies for transport management has been practiced for the last twenty years, the accumulated experience in that field, development of ontologies and the current state of transport infrastructure technology provide grounds for introducing the concepts of «transport and transportation ontology» and «ontological management». The approaches based on those concepts are critically important for further development of transport system, digital transport, efficient management of transport infrastructure objects. A brief analysis of the application of ontologies in the field of transport and transportation refers also to the building of applied ontologies that embrace among others transport and transportation ontology.

The study highlights the significance of semantic relationships for building applied ontologies, describes problems of information integration and offers rationale for the use of ontological units of information for building ontologies. It is noted that since a generally shared method of building ontologies is missing, transport and transportation field is now characterised by prevalence of private ontologies, some of them are listed in the article. While highlighting labelling method to build ontologies and describing application of graph databases for modelling semantics, it is shown that building of ontologies is hindered by the diversity of information systems and by a large amount of factual data used in modern transport management that objectively entail information uncertainty, the types there-of as well as methods of their elimination being described.

Keywords: transport and transportation, management, information integration, linked geodata, attribute data uncertainty, semantic terminological network, transport and transportation ontology, ontological units of information, ontological management.

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INTRODUCTION

The always increasing role of knowledge for modern transport management is especially characteristic of intelligent and unmanned transport [1]. This entails a growing significance of ontologies which can be considered as «transport and transportation ontologies» as a type of applied ontologies playing the role of the basis for intelligent and cyber-physical management [2]. In the technological aspect, they serve as the basis for making decisions based on experience, consequently we can introduce the concept of «ontological experience». A feature of ontological experience is a reduction in the number of options considered when making decisions in complex situations and in conditions of large amounts of data [3; 4]. To compress information when solving management problems, a model stereotype approach is used that consists in using model stereotypes that contain generalised management experience in specific situations. The use of dynamic spatio-temporal models is typical for management and control of mobile objects [5]. The use of model stereotypes requires specific information about the management situation and the state of the object. Unlike model stereotypes, metamodels contain generalisations of management experience regardless of a specific situation. They generalise management in a typological group of situations. To form metamodels, it is necessary to study groups of situations. It can be summarised that metamodels generalise theoretical experience, and model stereotypes use practical experience. Metamodels allow transition to ontologies that contain knowledge.

The *objective* of the work is to analyse the features of building and applying ontologies in the field of transport and transportation, comprising aspects of information uncertainty hampering ontology building.

RESULTS

Transport and transportation ontologies can be defined as «ontologies generalising experience in the field of transport and transportation management, including management of stationary objects».

At present, to ensure the reliability of cargo transportation, transport and transportation are now managed using ontological and architectural approaches [6] applying transport and transportation ontologies. A feature of transport and transportation ontology is that it uses existing knowledge, helps to solve management problems and creates new spatial knowledge [7]. Among private transport and transportation ontologies, we can refer to ontologies of transportation networks (OTN) [8], which are formed as generalisation of geodata files. The private ontology of transport disruptions is also of note [9], which provides a formal structure for modelling events related to trip planning.

Development of the application of ontologies

The very first ideas of using ontology are associated with the philosophy of the ancient world. Ontologies and the system of ontologies were used to describe the existing world order [10]. In modern conditions, development of an ontological model of an enterprise at the initial stage requires formation of a glossary of terms and concepts that define the domain of activity of a specific enterprise [11], and while the term «enterprise» can be replaced by another object, for example, «cyberspace» or «transport infrastructure», the essence of the ontology construction will not change.

An ontological glossary can be considered as a systematised set of ontological units of information. Ontological units of information within transport and transportation ontology correspond to objects of the real world, comprising individuals, buildings, vehicles, railways, etc. If possible, this glossary, as the basis for ontology, should include concepts related to functioning of the transport infrastructure, comprising transport systems, technical, organisational, economic, managerial, information [12] and even cyber-spatial concepts. At the second stage, formation of ontologies requires the description or compilation of entity models formed from these concepts and related semantically. Currently, it is proposed to use the ontological approach to form semantic relationships [6].

The applied ontology or domain ontology can be considered as a technology for generalising the semantic web and a technology for generalising linked data, helping to improve the shared use or repeated use of data.

It is fully applicable to situations and management decisions in transport and transportation sphere. Thanks to digital transformation, information about entities related to transport infrastructure management can now be collected automatically. The concept of «entities» is related to the concept of «ontology», so transport and transportation ontologies can

represent knowledge in the transport domain and can use the information for digital management [13]. Transport ontologies as a type of applied ontologies are general representations of knowledge about the transport domain that define terms and relationships between them while transport and transportation ontologies are characterised by a specificity that lies in the need to generate information in real time [14].

The use of ontology to solve any management problem is based on integration of information that is carried out through various private schemes and contexts, since there is currently no general methodology [13]. The main problem of information integration for obtaining ontologies is heterogeneity of original information arrays that is because transport information is collected by different devices, sensors and systems and within application of different technologies. One of the ideas [6] of integration is based on the approach that it should be built based on standard information models and information structures. This entails the need to standardise information models and, ultimately, leads to the idea of standardised units of information or ontological units of information. Within the ontology, ontological units of information that form the entity of an enterprise are defined based on the business terms. This once again emphasises the importance of a business glossary for formation of ontologies.

Ontologies are characterised by a high level of generalisation. Due to this, ontologies are common regarding their formation. Ontology as a model is new in its provision of an unambiguous formalised information structure. As for transport and transportation ontology, it serves as a basis for structuring and integrating data and information to build a holistic management situation in which a moving object is located. A set of ontologies in digital form can serve as a tool for developing management applications based on network models which include a semantic network of terms and related data. Ontologies developed based on network models are useful for technology and strategic management specialists, as well as for academic researchers working in the field of transport, where there is a problem of forming a taxonomy of information integration methods for building ontologies.

Building of ontologies and, particularly, solving of problems of semantics organisation while working with big data, has recently involved artificial intelligence methods [3] and graph databases (GDB) that allow generalising and compressing information, highlighting entities, effective describing and processing related geodata [3].

Ontologies are also formed using the technology called «information labelling» which includes the processes of supplementing descriptive information with empirical information: image sets, measurements received with sensors. Labelling is widely used in Petri nets and serves as a tool for process analysis which has allowed to propose, based on the labelling method, an approach to creating an automotive global ontology (AGO) [3] comprising creation of graph databases for modelling semantics in the automotive domain.

The problem of information systems.

The presence of many information systems in the transport and transportation domain does not guarantee by itself an effective transport and transportation management. Experience in implementing various systems shows that their value for the transport business is often lower than expected and, in some projects, the correlation of efficiency of transport companies with implementation of information systems [6] is traced mainly through optimisation of document flow and accountancy, and respective reduction in transaction costs. One of the conclusions drawn from the analysis of expertise is that strategically the growth in efficiency of management and activity as well as in competitiveness of transport companies depends first on coordination of the operation of implemented information systems, and ideally on the emergence of a synergistic effect from their joint use. It is a main prerequisite for a recent emergence of a basic concept of forming a single information management space for enterprises and transport facilities through enterprise architecture.

Over time, it became clear that only optimal construction of architecture is not enough for functioning of a transport enterprise. It is necessary to additionally develop methods for complementary behaviour of all parts and elements of the architecture. For this, it is necessary to use information about their entities, which inevitably leads to the use of the concepts of ontology and the need for a coordinated application of ontological and architectural approaches.

An additional feature of transport system is that the diversity of information systems leads to a variety of data formats and types. Big arrays of factual information used in modern transport management objectively contains information

uncertainty [15] which becomes an obstacle to building ontologies and should be eliminated.

Information uncertainty has different causes that can be associated with a certain attribute and thus such uncertainty can be defined as attributive information uncertainty.

For example, uncertainty in information volume is caused by the difficulties of analysing large volumes of information and replacing a complete analysis with a fragmentary one.

There is also uncertainty in diversity of information types caused by diversity of types of information models and the lack of experience of working with new types. As a result, new types or models are replaced by old ones, which entails inadequate results. This type of uncertainty is typical of multi-aspect electronic atlases [16] that can be considered as a graphical ontological glossary once they are systematised and spatial and terminological relations are consistent in it.

There is uncertainty in the fuzzy information caused by the objective situation of combination of quantitative and qualitative data, which is partially fuzzy. Such information cannot be processed without the theory of fuzzy sets.

There is also uncertainty in contradictory information [17] caused by the presence of explicit contradictory information and implicit contradictory information in the original content. To eliminate these contradictions, additional analysis is required.

There may be uncertainty in time, which is caused by the fact that a small time slot is allocated for decision-making, during which it is impossible to conduct a full analysis of the entire information array.

Reducing uncertainty requires the use of ontologies and special modelling [18]. Fuzzy or probabilistic information also demands application of ontologies and probabilistic measures [19]. Eliminating information uncertainty in contradiction requires a transition from formal logical reasoning to reasoning schemes that allow contradictions. All these schemes are included in the preprocessing of ontology building. Information uncertainty is also reduced with methods of systematisation, classification and semantic analysis. Clustering of heterogeneous information is used as a primary method [20].

Elimination of information uncertainty is of great importance in management of unmanned transport, digital railways [21], in transport cyber-physical systems [2; 22].

Elimination of uncertainty is necessary for immediate technological management and as a preliminary stage of ontology construction the use of which allows us to introduce the concept of «ontological management».

CONCLUSIONS

The experience cumulated in transport management, development of ontologies, as well as current technological pattern provide grounds for application of concepts and methodology based on «transport and transportation ontology» and «ontological management», which is essential for development of a full-fledged transportation system and modern management of transport infrastructure.

Nevertheless, currently, a single general ontology has not been created that would adequately describe cargo transportation. This problem is due to the relationship between the particular and the general, to the problems of integrating transport information from diverse sources, which increases the relevance of research in this area.

Experience shows that formation of a transport and transportation ontology should be performed in two stages. The first stage in a simple version includes compilation of an ontological glossary. In the system version, the first stage includes creation of a system of ontological units of information, which has more related terminological relations. At the second stage of creating a transport ontology, it is necessary to create a semantic network that will serve as the basis for the ontology. When creating such a network and in addition to it, it is advisable to use a graph database.

The problem of diversity of information systems in transport and transportation management requires particular attention since it often complicates management and formation of ontologies. Such a diversity creates information uncertainty, which has different causes and, accordingly, different types, within a set of which it is possible to identify a group of types of information uncertainties that hinder the normal construction of ontologies and ontological management. This group can be called «ontological uncertainty». Elimination of such ontological uncertainty is a mandatory stage of information preprocessing when forming ontologies.

Generally, from the standpoint of information management, ontologies can be considered as

a method of information compression and elimination of contradictions in the management system.

The proposed approaches to assessment of the role of transport and transportation ontologies and their construction are inherent components of a complex scientific problem and suppose systemic interdisciplinary research of a diversity of its interconnected aspects.

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