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ІНФОРМАЦІЙНО-КОМУНІКАЦІЙНІ ТЕХНОЛОГІЇ ТА МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ

UDC 004.02:625.1

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Ontological Support for Harmonization and Integration of Ukrzaliznytsia Information Systems Data

Purpose. The development strategy of Ukrzaliznytsia includes the following areas: integration and standardization of information systems, increasing the truthfulness of data and automating business processes. The integration of railway information systems is possible by ontological means without changing their structure. In this work, the main aim is the analysis of existing transportation ontological developments and determination of approaches to the application of related domains developments to the objectives of Ukrzaliznytsia's development. **Methodology.** Ontological developments are systematized according to the type and format of their resources, the level of data integration, and the goals of ontology-based software. Methods of system analysis are used. **Findings**. The analysis showed that European Union railway transport ontologies are used to integrate infrastructure description data, train timetables, and others. At the same time, insufficient attention is paid to the regulatory support of the transportation process. There are software tools for annotating texts, extracting knowledge from tables and developing ontologies, but they are not used to support the Ukrainian railway transportation process. It has been determined that the actual problem is normative documentation annotation to establish a link between the ontology and the regulation texts. **Originality.** The basis for achieving the development goals of Ukrzaliznytsia by ontological means was laid, using the analysis and systematization of existing ontological developments of transport and related domains. The possibilities of using ontological means in railway transport are scientifically substantiated for: formalization of regulatory support; data transformations; data integration; checking the consistency of information systems data and regulations. **Practical value**. The work made it possible to identify the most significant ontological projects in transport. The foundations for the implementation of the conceptualization of the tabular representation of knowledge and the development of an ontology for the integration of models of railway subsystems have been laid.

Keywords: ontology; system analysis; railway; knowledge base; conceptualization

Introduction

Recently, the information systems of Ukrzaliznytsia (UZ) have undergone significant changes, such as the automation of many workplaces and their integration into the United Automated Management System of Freight Traffic of Ukrzaliznytsia (AMS FT UZ-U). However, due to the manual chain of data exchange and retrieval, errors may be made, which are detected by specialists of the relevant railway subsystems. Integration of information systems data and checking of their consistency with regulatory documents by ontological means helps to improve the safety of train traffic.

It is shown that the ontological modelling of the railway infrastructure and related domains is widely used in European countries and can be used for the development of UZ information systems.

Purpose

The development strategy of UZ includes the following areas: integration and standardization of information systems, increasing the truthfulness of data and automating business processes. One of the ways for solving the tasks set is the integration of

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railway information systems by ontological means without changing their structure.

In this work, the following tasks are solved:

– analysis of existing ontological developments in transport;

– determination of approaches to the application of developments in related domains to the objectives of the UZ development.

Methodology

Systematization of ontological developments was developed according to:

– purpose of their non-ontological resources for the development of the ontology schema (normative documents, standards and training materials);

– format of initial data (db, csv);

– level of data integration;

– the goals of ontology-based software.

Such methods of system analysis are used, as the input-process-output (IPO) model. The method of IPO systems for writing a literature review on Wikipedia is used in [4545]. In it, articles are grouped according to the criterion of describing the Wikipedia input and output data. The review [46] is devoted to transport ontologies.

Information systems of Ukrzaliznytsia.

According to [1], the information support of UZ includes the following systems:

– AMS FT UZ-U – the United Automated Management System of Freight Traffic of Ukrzaliznytsia;

– AMS PT UZ – Automated Management System for Passenger Transportation;

– AMSP – Automated Property Management System;

– AAS FOBOS – Automated accounting system of the structural subdivision of the railway.

– AWP A – The automated workplace of the Acceptor;

– AWP TD – The automated workplace of a train dispatcher;

– AS MESPLAN – an automated document management system for orders for the transportation of goods and the formation of plans;

– AS Client – an automated system for the formation of electronic transportation documents

– AMS ERPC – automated control system for the operation and repair of passenger cars.

According to [69], databases are siloed and fragmented.

Theoretical Foundations of Ontology Development.

There are various definitions and classifications of ontologies. According to Gruber, an ontology is an explicit specification of a conceptualization [37].

According to [16], «an ontology defines the common words and concepts (meanings) used to describe and represent an area of knowledge, and so standardizes the meanings. An ontology includes the following:

– classes (general things) in the many domains of interest;

– instances (particular things);

– relationships among those things;

– properties (and property values) of those things;

– functions of and processes involving those things;

– constraints on and rules involving those things».

Ontologies are classified as top-level ontologies, domain ontologies, task ontologies and application ontologies in [38], generic ontologies and specific ontologies in [43], upper ontology (generic common knowledge), middle ontology (domain-spanning knowledge), lower ontology (individual domains), the lowest ontology (subdomains) in [16]. Top-level ontologies and domain ontologies are related by a specialization relation [38].

Other classifications have heavyweight and lightweight ontologies.

Lightweight ontology is an ontology having inexpressive semantics, and a vocabulary, such as Good relations. Lightweight ontologies can be thesauri, such as AGROVOC (based on SKOS) and NCI Thesaurus.

«Heavyweight ontology is a lightweight ontology … enriched with axioms» [33]. For example, in Cell ontology [53] and Collections Ontology [12] rules are presented in OWL as logical definitions and SWRL, respectively.

There are several complementary domain-independent ontology development methods: 101 [57], methontology [30], neon [73], extreme [64], generative mappings [71, 72], modular ontology development [41].

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The methods differ in their granularity. Methontology [30] has general steps: conceptualization, formalization, implementation, and maintenance. 101 [57] has a more detailed (slightly modified) general process for ontology schema development, corresponding to the definition of an ontology [16]:

– enumerate important terms in the ontology;
– define the classes and the class hierarchy;
– define the properties of classes – slots;
– define the restrictions;
– define the rules;
– create instances.

Ontology conceptualization can be done using non-ontological resources [73] or patterns [64] to unify development by non-experts. Modular ontology development facilitates the maintenance and reuse of ontologies [41]. An example of a module is Error ontology [62] which is used in publishing workflow ontology [34] and collections ontology [14]. Where collections ontology [14] is a module of the Rail Core Ontology (RaCoOn) [76]. At the same time, modularity is one of the principles for developing the RaCoOn ontology [76], where, in addition to collections, the authors develop such modules as «Asset Management», «Rail Core» and others.

A feature of the development of an ontology class hierarchy is the need to exclude polyhierarchies due to their complex maintenance [66]. Instead of strong subclass relationships, logical definitions are developed, as in Cell ontology [53].

Upon completion of the development of the ontology, its testing is performed by SPARQL queries [64]. The transport ontology knowledge base can be queried to search for all railway stations [76], the number of trips starting in the zone at a certain time [47], and speed limits for a road segment [79].

Findings

Ontological developments are classified as those that make it possible to perform data integration, formalization of natural language texts, knowledge extraction from a tabular data representation, and consistency checking data and regulatory documents.

Formalization of regulatory and legal documentation by ontological means.

UZ development strategy [2] has the standardization of information systems, an integral part of which is the railway transportation regulatory and legal support. In UZ, for example, such standard tools already are used as the XML schema for the CIM/SMGS consignment note and the design of wagons in SolidWorks, which supports the STandard for Exchange of Product Model Data (STEP). It is planned to introduce such European standards as Infrastructure Register (RINF) [27], and Network Statement.

It should be noted that for the time being, railway regulations are not presented in a standard language based on logic. Regulation formalization is the process of transforming regulations texts into classes, relationships, restrictions, and if-then rules (Table 1). The input data are texts, and the output data is an ontology schema (or instances, as in [54, 11]). According to [73], the process of transforming a non-ontological resource is as follows:

– search for a suitable pattern for re-engineering non-ontological resources;
– use the pattern to guide the transformation;
– perform an ad-hoc transformation;
– manual refinement.

Where ontologydesignpatterns.org resource patterns are used for converting thesauri and classification schemes. At the ad-hoc transformation step, the universal process [57] can be applied.

Non-ontological instructional resources for conceptualization are normative documents [69], educational materials [28, 32], and standards [60, 76].

Standards are represented as railML XML schemas, UML Core Product Model [31], RailTopoModel and texts [27].

Table 1

Formalization of instructional materials in existing ontological developments

Input	Output
OSHA, 1926.706 Requirements for masonry construction	The Construction Safety Ontology [78]
IEEE Standard Classification for Software Anomalies	ontology of software defects, errors and failures [25]
ISO/IEC 11404:2007 – General Purpose Datatypes	Generic ontology of datatypes [60]

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Continuation of Table 1

Input	Output
European EN 12354-3:2000 standard Sound insulation of external noise	The IFC (Industry Foundation Classes) ontology, The construction element ontology [61]
ISO-10303 STandard for Exchange of Product Model Data	Onto STEP [49]
Network Statement [27]	Network Statement Checker Ontology [77]
ESC guidelines for the diagnosis and treatment of acute and chronic heart failure	Heart Failure Ontology [44]
«Materials science and engineering: an introduction»	Functionally Graded Materials Ontology [32]
Handbook of Probability Theory and Mathematical Statistics	OntoMathPro [28]
Rules for the technical operation of Ukrainian railways	The base ontological model of AMS FT UZ-U [69]
The Core Product Model, The Open Assembly Model	Ontology for Assembly Representation [31]
railML [5]	Rail Core Ontology [76]
RailTopoModel	Rail Topology Ontology [7]

Depending on the type of constructs presented in the standard, they can be the basis for classes, relationships, etc., for example, classification schemes are the basis for the ontology class hierarchy, and text instructions may contain constructs that are the basis for the «if, then» rules. There are also high-level abstraction ontologies for representing any normative documents, like the Legal Knowledge Interchange Format ontology [42]. Of these, in transport, the formalization of standards is carried out in [7, 76, 77].

A network statement is a standard text document used to describe rail infrastructure in Europe. Instructions for its development contain a listing of the chapters of the Network Statement and their purpose. Network Statement Checker ontology [77] allows one to build train routes on infrastructure with different characteristics located in different countries. The chapters of the standard are the basis of ontology classes (Fig. 1).

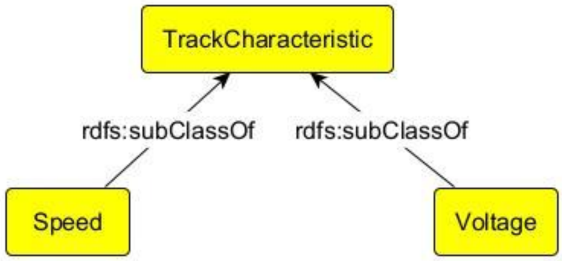

Fig. 1. Network Statement Checker ontology classes based on a text standard

RailTopoModel is a standard UML model for representing rail infrastructure based on a connexity graph and the Rail Topology Ontology basis [7]. The UML has constructs for representing cardinality constraints that are the basis of OWL ontology class descriptions (Fig. 2). For example, the RailTopoModel contains a PositionedRelation class to represent the direction of travel on a railway track and has a restriction of 2 nodes (cardinality) associated with it.

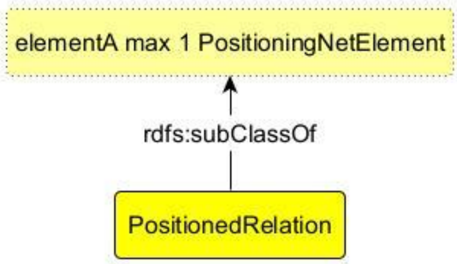

Fig. 2. Rail Topology Ontology restriction based on the UML format standard

Procedural knowledge (for example, the need to check the speed restriction of a warning issued to the driver) is presented in text instructions and formalized as logical definitions, relationship compositions and SWRL rules, for example, as in [78]. The construction Safety Ontology includes a rule (Fig. 3) to check the consistency of construction projects and regulations.

In transport the standards of the railway infrastructure are represented by ontological means in [7, 76, 77]. Using AMS FT UZ-U relational databases, the formalization of the transportation pro-

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cess was performed. With its help, it is difficult to represent the rules of regulatory support, for example, «Train management rules». In related domains, standards representing procedural knowledge are formalized by ontological means [61, 78]. A possible further work is the formalization of railway regulations by ontological means, as in [69].

```
SWRL

Masonry_Wall(?mw) ∧ hasHeight(?mw, ?h) ∧
Task_Masonry_Wall(?act) ∧ produce(?act, ?mw) ∧
consistOf(?act, ?sub) ∧Masonry_Operation(?sub) ∧
consistOf(?sub, ?pb) ∧ Placing_Brick(?pb) ∧
swrlb:greaterThan(?h, 2438.4) →
needResources(?pb, Masonry_Wall_Bracing)
```

Fig. 3. The rule of The Construction Safety Ontology, based on a text standard

Knowledge extraction from the tabular presentation of transportation process data.

UZ development strategy [2] has business processes automation. In UZ, there are already systems such as «AS Client», where an electronic form is filled out for issuing a transportation document. There are still many technological processes that involve manual data extraction from heterogeneous documents, for example, the process of commissioning connection tracks. Profile calculation is performed in Excel, drawing – in AutoCAD, railway track characteristics can be stored in databases. Traction calculations for the development of train timetables are also performed in Excel.

The knowledge extraction process consists of two sub-processes: data wrangling and ontology population.

Data wrangling is the process of transforming data formats, such as from xls to RDF (Table 2). The transformation can be performed by various software tools, such as OpenRefine. The input data is the data and schema of the ontology, and the output data is the instances of the ontology.

The process is as follows:

– development of an ontology scheme;

– import of ontology and data files into the data wrangler (Cellfie, Ontop [9], OpenRefine, Karma [48]);

– annotating the contents of tables with ontology classes and relations;

– RDF data export.

Ontology population is the process of filling ontology with data from text [35] or tables [10]. During database transformation into instances, ontology is populated automatically using ports. If there are two files: an ontology schema and RDF data, ontology is populated using the owl:import construct in the schema file or both files into a new ontology file.

Table 2

Data wrangling in existing ontological developments

Data	Data wrangler
Tables https://covid19.who.int	Cellfie
Association of Train Operating Companies (ATOC)	OpenRefine
GTFS tables	Karma [48]
Smithsonian American Art Museum (SAAM) Database	
OpenStreetMap, LIDAR data, Yellow Pages and White Pages	
Tata Steel plant database	Ontop [9]
ArcGIS GFX datasets	
STEP Models	Onto STEP [49]

Depending on the format, Excel spreadsheet data is converted using the Protégé Cellfie plugin as in [26], databases – Protégé Ontop [9] as in [5, 47], STEP – Protégé OntoSTEP [49].

The drawing table data is extracted by Tabula into a CSV file. To convert such data into ontology instances, universal (compatible with various formats) software tools such as OpenRefine and Karma [4848] are used, as in [47, 74, 75].

Of these, on the transport, the data of the MCA (Common Interface File) format ATOC working timetables are converted into ontology instances to fill the ontology RaCoOn [76]. This format is typical for Network Rail's (infrastructure manager in Great Britain) Integrated Train Planning System and is difficult to work with, so in [76] it is converted to a relational database before being imported into OpenRefine. Fig. 4 shows an example of instances generated from the General Transit Feed Specification «stop times» table of the Irish Railways website transportforireland. These resources

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are alike to ATOC in that the table also contains routes with stops and arrival/departure times.

In transport domain, ontological means is used to transform the train timetable data of the MCA format into ontology individuals [76]. Using «AS Client» data input of UZ transportation documents is automated. In related domains, ontological means are used to extract and transform data in db, csv, xls, and pdf formats. A possible future work is to increase the number of tasks for which data extraction is automated. The use of RDF standards will allow data consistency checking with normative documents and integrating data with others that have the same ontology scheme.

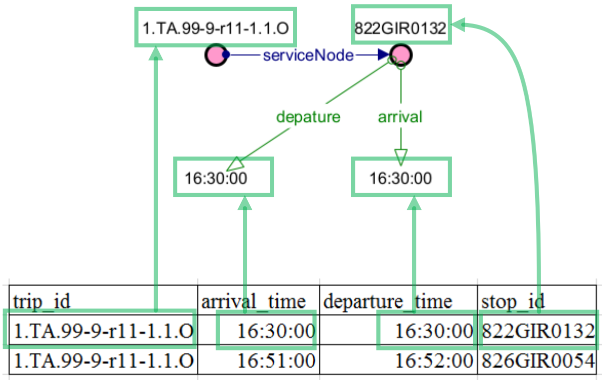

Fig. 4. Extraction of knowledge from the train schedule based on the RaCoOn ontology

Integration of disparate information systems by ontological means.

UZ development strategy [2] has information system integration. In UZ there is already the AMS FT UZ-U system, where integration is carried out by the exchange of electronic and telephone messages, based on a relational database. Information support remains fragmented and does not meet the requirements of its extensibility.

Data integration by ontological means is the process of filling an ontology with data from various sources to check their consistency (Table 3). The input data are various data sources (not necessarily heterogeneous), and the output is a logical conclusion about the consistency of the ontology. The process is as follows:

– development of an ontology scheme;

– conversion of data from several sources using a single scheme;

– importing data into the ontology using the owl mechanism: import if schema and data are separate files, adding instances manually if development is done in Protégé, or programmatically if using java libraries owlapi, Jena, python libraries owlready.

– Data can be integrated within one or several enterprises. To integrate several enterprise data, the ontology must include a sufficient set of concepts. Ontologies like Steel cold rolling ontology [5] contain only concepts about metal, while ontologies like The Transport Disruption Ontology [15] – concepts for both transport and incidents, allow one to integrate two different data sets.

Of these, data integration in transport is carried out in [15, 47, 51, 76, 79], and corresponds to such UZ goals as meeting the needs of people with disabilities, and promoting domestic tourism. Transformation of open data published by UZ under the «Regulation on data sets to be made public in the form of open data» into linked open data as [23] for transport is substantiated in [63].

Table 3

Data integration in existing ontological developments

Data	Domain ontology
ATOC Working, timetable, Wheel Impact load Measurement	Rail Core Ontology [76]
wheel impact load measurement (WILM) systems and hot axle box detector (HABD)	Railway infrastructure ontology [51]
GTFS specification of vehicle routes, (2) reports on subway incidents, and (3) data on the real-time locations of transit vehicles	iCity [47]
Reports [on incidents] from transport authority, TransXChange bus services, the NaPTAN and NPTG access points to public transport	The transport disruption ontology [15]
Accessibility, incidents and infrastructure	Mobility and Accessibility Ontology (MAnto) [8]
Database tables the Roll, Roll Grinding, and Roll Storage tables	Steel cold rolling ontology [5]

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Continuation of Table 3

Data	Domain ontology
Museum Data	Europeana [23]
The Statute Staple, The Down Survey, The Books of Survey and Distribution, Dictionary of Irish Biography and the Oxford Dictionary of National Biography	Ontologies based on The Dictionary of Irish Biography, The Oxford Dictionary of National Biography [56]
GPS sensor data and speed limits of different roads	Map Ontology, Control Ontology, Car Ontology [79]
The Stanford Tissue Microarray Database, The Gene Expression Omnibus	N.C.I. Thesaurus [68]

iCity ontologies [47] of three levels of abstraction have been developed, as well as several prototype applications, including ones for studying traffic flows, as well as displaying roads and points of interest on a map. In the first case, GTFS specification of vehicle routes, (2) reports on subway incidents, and (3) data on the real-time locations of transit vehicles are mapped onto the ontology. The second application integrates Neighborhood, Land Use, Land Cover, Point of Interest, and Road Segment GFX datasets.

Fig. 5 shows a simplified data integration example similar to «Integration with ArcGIS» using iCity ontologies [47]. The figure is based on the iCity project [47] Public Transit Ontology and Location Ontology and the datasets vicroadsopendata «Bluetooth sites» and «Cycle routes». Data integration allows one to make SPARQL queries «how to get to a Bluetooth-equipped place on a bicycle».

ATOC Working Timetable and Wheel Impact Load Detector are integrated using the RaCoOn ontology [76] to determine the location of faulty trains on the map after data integration with OpenStreetMap. RaCoOn integrates British Railways data.

The integration of WILM and HABD is performed to determine the most urgent train repairs [51].

In [79], the integration of vehicle speed and speed limits map data is carried out by ontological means to detect speeding.

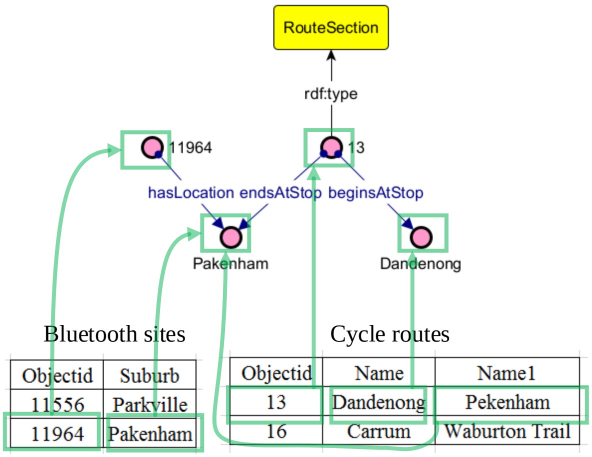

Fig. 5. Route and point of interest data integration based on iCity ontologies

Integration of information systems can be performed at the data level as in [5, 51] or the ontology level.

Ontology integration is the process of linking ontologies (Table 4). Ontologies are input and output. The process is as follows:

- development of an ontology scheme;
- bridging ontology (axioms) development to link it to some other ontology;
- import of the developed ontology, bridging ontology and some other ontology into a new ontology.

Integration is performed with the top-level ontology as in [40, 32], bridging ontology – [53], other relevant ontologies – [76], DBpedia – [28].

Table 4

Integration of ontologies in existing ontological developments

Other relevant ontologies	Domain ontology
Basic Formal Ontology [3]	Functionally Graded Materials Ontology [32]
DOLCE [24]	An ontology for software [58]
Information Artifact Ontology [12]	Ontology of Datatypes [60]
	Software ontology [52]
The Unified Foundational Ontology [39]	Software Process Ontology [40]
	Ontology of Software Defects, Errors and Failures [25]
UBERON [55]	Cell Ontology [53]

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Continuation of Table 4

Other relevant ontologies	Domain ontology
Good Relations	Linked-Open Tenders Electronic Daily LOTED2 [22]
Wikipedia	OntoMathPro [28]
Collection ontology [14]	Rail Core Ontology [76]
InteGRail ontology [65]	Network Statement Checker Ontology [77]
Basic Geo WGS84 ontology	The transport disruption ontology [15]
Toronto Virtual Enterprise [29]	iCity [47]
Error ontology [62]	Publishing Workflow Ontology [34]
	Collections Ontology [14]

Of these, on transport in [15, 47, 76, 77]. The route of the train is represented using Collections ontology [14], location of transport events and bus routes is represented using Basic Geo WGS84 ontology.

LOTED2 [22] and Good relations ontologies are integrated with a relations composition (Fig. 6) that allows one to represent service providers and customers in the public procurement domain.

In transport maps and train schedules [76], vehicle speed [79], equipment for disabled people [8], and other data are integrated using ontological means. UZ AMS FT UZ-U station, wagon, train and other models were integrated using relational databases. In related domains, domain enterprise ontologies representing clients [22] are integrated using ontological means. A possible further work is the development of ontological support for the integration of UZ data, as in [69].

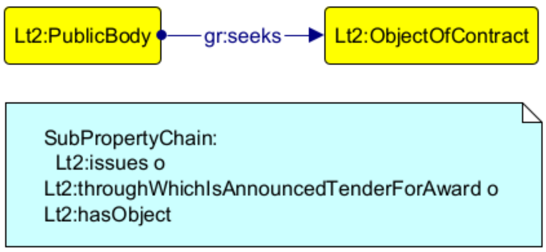

Fig. 6. Integration of LOTED2 and Good Relations ontologies

Checking the consistency of table data with regulatory documentation or a model by ontological means.

UZ development strategy [2] has the provision of structural units with reliable information. At UZ, each stage of data transfer is accompanied by a check by specialists. For example, when warnings are sent, they are checked against the speed limit warning book under the «guidelines for issuing warnings». When issuing a speed restriction, it is checked by the energy dispatcher for the sufficiency of measures to ensure safety under the «safety rules for the operation of the contact network and power supply devices for automatic blocking of railways».

Checks on the structure of data sources are to some extent automated in databases, but not in such spreadsheet and drawing programs used in UZ, such as AutoCAD.

Ontology consistency checking is the process of applying rules and constraints to data (Table 5). The input data is the ontology schema and data, and the output is an ontology that includes semantic control of the resource. The process is as follows:

– ontology vocabulary development;
– rules development – the second part of the ontology scheme;
– filling the ontology with instances;
– ontology consistency checking by a reasoner for OWL – Hermit, Pellet, for SWRL – Drools, for The Shapes Constraint Language (SHACL) – TopBraid SHACL API, etc.

Depending on the functional requirements (data transformation or data consistency check with regulations) of the software, resource or domain ontologies are used. For example, to formalize the standard, the Generic ontology of datatypes [60] was developed, and CSVW is used to describe the data resources.

To check the consistency of data and models, for example, ontologies were developed for analyzing the reliability of engines [50], for risk analysis of construction projects [21], for the publication process [34], for calculating performance indicators in transport (integration of the KPIONTO ontology [19] and the Transmodel model) [6], metal rolling [5], descriptions of statistical analysis in the biological domain [80].

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Table 5

Data consistency checking in existing ontological developments

Way of the resource representation	Domain ontology
MappingMaster [59]	COvid-19 Ontology [26]
RDB to RDF Mapping Language (R2RML)	iCity [47]
JSON script	Rail Core Ontology [76]
R2RML	Geospatial ontology [75]
R2RML, Ontop	Steel cold rolling ontology [5]
R2RML, Ontop	iCity [47]
R2RML	SAAM ontology [74]
RDF Data Cube	Organization Ontology [36]
CSV on the Web (CSVW)	Function Ontology [13, 17]

The CSVW cardinality restriction is developed as a text «A table *must have one or more* columns and the order of the columns within the list is significant and must be preserved by applications» because it is an RDF schema, a lightweight ontology.

For lightweight ontologies like RDF Data Cube and GeoSPARQL, constraint packages [18, 36, 67] are being developed using SHACL and Shape expressions language (ShEx).

Consider an example of checking data consistency with the OBCS ontology model [80] using OWL. The cardinality constraint for the description of the class «one dimensional cartesian spatial coordinate datum» the presence of two values for the coordinate x in a rectangular coordinate system in the ontology is excluded (situation of Fig. 7).

In transport ontological means are used to check the consistency of the formulas for calculating performance indicators [6]. Specialists of the relevant UZ departments check the consistency of data and regulatory documents. In adjacent domains, ontological means check the consistency of data with regulations [78]. Possible further work on transport is to check the AMS FT UZ-U data for compliance with the normative documentation by ontological means, as in [69]. In the direction of automated ontology population on railway transport – checking of the data resource structure using ontologies like [70].

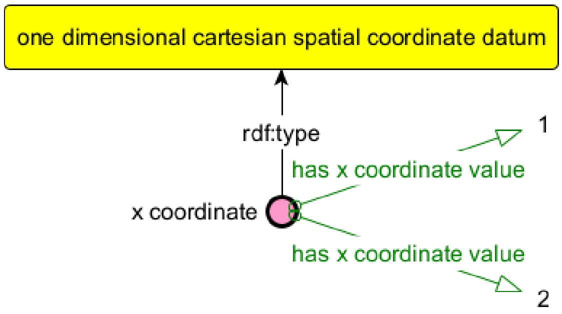

Fig. 7. Inconsistent OBCS ontology with two x-coordinate values

Discussion

The paper identifies aspects of existing ontological developments that are given insufficient attention: checking the data structure when it is transformed into ontology instances and checking the consistency of data with the transportation process regulations.

We have conceptualized the tabular representation of data sources, which makes it possible to check and integrate the table data developed in different software environments [70]. Unlike other studies, conceptualization allows modelling the full range of table-based data structures.

Ontologies of AMS FT UZ-U station, train, wagon and freight models have been developed, which makes it possible to integrate the AMS FT UZ-U models [69]. Unlike others, it allows one to check the consistency of the data and the railway regulations.

Originality and practical value

Originality. For the first time, the foundation was laid for achieving the development goals of Ukrzaliznytsia [2] by ontological means, using the analysis and systematization of existing transportation and related domain ontological developments.

The possibilities of using ontological means in railway transport are elicited for:

– formalization of regulatory support, which is confirmed by the works [7, 32, 47, 51, 78];

– data wrangling, which is confirmed by works [49, 74, 76];

– data integration, which is confirmed by works [23, 56, 76, 79];

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– checking of consistency of information systems data and regulations, which is confirmed by works [19, 78, 80].

Practical value. The work made it possible to identify the most significant ontological works on transport. The foundations for the implementation of the conceptualization of the tabular representation of knowledge and the development of an ontology for the integration of railway subsystems models have been laid.

Conclusions

The analysis showed that ontologies in the railway transport of the European Union are used to integrate infrastructure description data, train timetables, and others. At the same time, insufficient attention is paid to the transportation process regulatory support.

There are software tools for annotating texts, extracting knowledge from tables and developing ontologies, but they are not used to support the transportation process in the Ukrainian railway transport.

It has been determined that the actual problem is to annotate the normative documentation to establish a connection between the ontology and the regulation texts.

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Онтологічна підтримка узгодження та інтеграції даних інформаційних систем АТ «Укрзалізниця»

Мета. Стратегія розвитку АТ «Укрзалізниця» передбачає такі напрями: інтеграція та стандартизація інформаційних систем, підвищення достовірності даних та автоматизація бізнес-процесів. Інтеграція інформаційних систем залізниці можлива онтологічними засобами без зміни їхньої структури. У цій роботі поставлено за основну мету проаналізувати наявні онтологічні розробки на транспорті та визначити підходи до застосування розробок суміжних галузей для задач розвитку АТ «Укрзалізниця». **Методика.** Виконано систематизацію онтологічних розробок відповідно до типу та формату їх ресурсів, рівня інтеграції даних, цілей програмного забезпечення, заснованого на онтології. Використано методи системного аналізу. **Результати**. Аналіз показав, що онтології на залізничному транспорті Євросоюзу використовують для інтеграції даних опису інфраструктури, розкладу поїздів тощо. Водночас недостатньо уваги приділяють нормативному забезпеченню перевізного процесу. Існують програмні засоби для анотування текстів, отримання знань із таблиць та розробки онтологій, але їх не застосовують для підтримки перевізного процесу на залізничному транспорті України. Визначено, що актуальним завданням є анотування нормативної документації для встановлення зв'язку між онтологією та текстами інструкцій. **Наукова новизна.** Закладено основу для досягнення цілей розвитку АТ «Укрзалізниця» онтологічними засобами, із застосуванням аналізу та систематизації наявних онтологічних розробок транспортної та суміжних галузей. Науково обґрунтовано можливості використання на залізничному транспорті онтологічних засобів для: формалізації нормативного забезпечення; перетворення даних; інтеграції даних; перевірки узгодженості даних інформаційних систем та інструкцій. **Практична значимість**. Робота дозволила виявити найважливіші онтологічні проєкти на транспорті. Закладено основи для концептуалізації табличного представлення знань та розробки онтології для інтеграції моделей підсистем залізниці.

Ключові слова: онтологія; системний аналіз; залізниця; база знань; концептуалізація

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