A Comprehensive Analysis of Ontologies Related to Safety Related Traffic Information for Road Traffic

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ABSTRACT

Ontologies within the Semantic Web represent a transformative advancement, offering standardized data schemes that seamlessly interconnect with diverse vocabularies and facilitate efficient information exchange globally. This paper explores the intersection of ontologies and road safety, a domain critical to public well-being. The analysis focuses on existing ontologies related to Safety Related Traffic Information, delving into their implications for enhanced road safety, optimized traffic management, and streamlined safety-related data exchange. The study discerns common patterns, best practices, and areas for improvement across various ontological models, thereby contributing to the development of standardized solutions for managing road safety information. Using an ad hoc metrics system for this type of information will assist us in determining which ontology is most suitable and/or the need for its adaptation or utilization. Acknowledging the vital role of ontologies in promoting data interoperability, knowledge sharing, and informed decision-making, this research underscores the potential of integrating Semantic Web technologies and ontological models to revolutionize safety-related information management. The findings advocate for the transformative impact of ontologies in reducing road accidents and safeguarding human lives, emphasizing their significance in advancing the evolution of safer and more efficient road networks.

CCS CONCEPTS

• **Information systems → Graph-based database models**; **Semantic web description languages**; **Service discovery and interfaces**; • **Computing methodologies → Ontology engineering**.

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Traffic Ontology, Safety Road, Knowledge Representation, Semantic Web, Linked Data, Intelligent Transport.

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1 INTRODUCTION

The implementation of the ITS Directive 2010/40/EU [10] since August 2010 has laid a foundational framework for the widespread integration of Intelligent Transport Systems (ITS) across the European Union. This directive, originating from Action 6.1 of the Action Plan, coordinates ITS deployment in the road sector by addressing four Priority Areas aligned with key Action Areas.

Complementing this directive, Commission Delegated Regulations (EU) No 885/2013 [23], (EU) No 886/2013 [24], (EU) No 2015/962 [25], and (EU) 2017/1926 [26] establish specifications crucial for ensuring the compatibility, interoperability, and continuity of various ITS services, including safe parking, road safety-related traffic information, EU-wide real-time traffic information, and multimodal travel information services.

A pivotal component created under this regulatory framework is the DATEX II [28] standard format, designed to facilitate the exchange of traffic data among EU countries. DATEX II, employing Recommended Reference Profiles (RRPs) [27] for Safety Related Traffic Information (SRTI), plays a vital role in enhancing the publication of relevant information about incidents, adverse weather, and geographical locations.

This study builds upon this regulatory foundation by conducting a detailed analysis of existing vocabularies and ontologies related to SRTI. By employing metrics and tools, the study aims to enhance our understanding of semantic solutions and promote the effective use of ontologies in the realm of ITS research and applications.

This article delves into the ontological analysis conducted within the CEF LOD-RoadTran18 project [29], a venture co- financed by the European Union. The project centers around examining the data type "Priority C" or SRTI, with its primary aim being to facilitate the reuse of dynamic road traffic data in two Member States, namely the Czech Republic and Spain.

The methodology employed in this ontology analysis is structured, selecting ontologies based on their relevance to SRTI and their adoption within the intelligent transportation domain. Results, presented using metrics and tools, not only contribute insights but also serve as a guide for similar research in diverse contexts, fostering a more comprehensive understanding of semantic solutions and encouraging the utilization of ontologies in ITS research and applications.

This document is organized as follows: Section 2 details the scope of Safety Related Traffic Information. Section 3 discusses the evaluation process and the metric used. Section 4 describes the analysis and results using the metric described for each ontology and finally, Section 5 concludes with key observations.

2 SCOPE OF SAFETY RELATED TRAFFIC INFORMATION (SRTI)

Under Commission Delegated Regulation (EU) No 886/2013, the minimum universal traffic information service related to road safety encompasses specific categories of events or conditions crucial for ensuring road safety.

To foster efficient data exchange and interoperability, both data and service providers are mandated to furnish information in the DATEX II (CEN/TS 16157) format or any other fully compatible and interoperable machine-readable format accessible through an access point.

The DATEX II UML model within the SRTI profile is intricately crafted to accommodate the diverse categories outlined in Commission Delegated Regulation (EU) No 886/2013. This profile establishes a clearly defined hierarchy of classes, ensuring the seamless exchange of harmonized data for road safety-related information.

By strictly adhering to the DATEX II UML model within the SRTI profile, data and service providers not only ensure compliance with regulations but also actively contribute to the enhancement of road safety through the standardized exchange of traffic information. This adherence facilitates a unified approach to disseminating critical road safety data, ultimately supporting safer road networks.

3 EVALUATION PROCESS

In the evaluation of various semantic models, we have considered a set of indicators, detailed below.

3.1 Schema Metrics

3.1.1 Relationships richness of the Ontological model based on OntoQA. The "Relationships Richness" metric, employing OntoQA [20] , serves as a valuable tool to assess the diversity and distribution of relationships within an ontological model. This metric aids in evaluating the complexity of the ontology and assessing the extent to which relationships go beyond basic class subclass (SC) associations. The formula for calculating the "Relationships Richness" (RR) is as follows:

$$RR = \frac{P}{P + SC}$$

P represents the total number of non-subclass relationships defined in the schema. SC represents the total number of class subclass relationships in the ontology.

The result of RR is expressed as a percentage. If the RR value is close to zero, it indicates that most relationships in the ontology are class subclass relationships, making it more of a taxonomy.

Conversely, an RR value close to one indicates that the ontology contains diverse relationships beyond just class-subclass relationships, making it richer [20].

Based on the calculated RR value, we can categorize the "Relationships Richness" as follows:

- `RR > 0.66 and RR <= 1`: HIGH level.
- `RR > 0.33 and RR <= 0.66`: MEDIUM level.
- `RR >= 0 and RR <= 0.33`: LOW level.

3.1.2 Relationship Information Quality of the Ontological Model based on OntoQA. The metric for "Relationship Information Quality" focuses on appraising the thoroughness of domain and range definitions in the object properties (OP) within the ontology. This information is crucial for modeling class relationships, precisely outlining the classes linked through these properties. Object properties lacking defined domain or range, or with incomplete domain and range information, may impede the ontology's precision in representing relationships between classes.

To gauge the quality of relationship information, we scrutinize the percentage of object properties with a defined domain and range in the ontology. The calculation is derived from the following formula:

$$RIC = \left(\frac{\text{N.of OP with defined domain and range}}{\text{Total number of OP}} \right) \times 100$$

Relationship Information Quality Categorization:

- `HIGH`: >66% domain/range defined.
- `MEDIUM`: >33% and <=66% domain/range defined.
- `LOW`: >=0% and <=33% domain/range defined.

3.1.3 Attribute Richness of the Ontological Model based on OntoQA. The Attribute Richness metric, originating from OntoQA, assesses ontology design quality and the volume of information related to instance data. This metric gauges the quantity of attributes (slots) designated for each class, reflecting the depth of knowledge conveyed by the ontology. Formally, Attribute Richness (AR) is calculated as the average number of attributes (slots) per class. This computation involves dividing the total number of attributes (att) by the number of classes C present in the ontology [9].

$$AR = \frac{att}{C}$$

Attribute Richness Categories:

- `HIGH`: AR > 3 – Comprehensive attributes, high conveyed knowledge.
- `MEDIUM`: 1.5 <= AR <= 3 – Moderate attributes, moderate conveyed knowledge.
- `LOW`: AR < 1.5 – Limited attributes, potentially lower conveyed knowledge.

3.1.4 Attribute Information Quality. Attribute Information Quality categorizes attributes based on the completeness and accuracy of domain and range information in ontology data properties:

- `HIGH`: >66% domain and/or range information, indicating high completeness for accurate data modeling.
- `MEDIUM`: 33%-66% domain and/or range information, representing a moderate level of completeness.
- `LOW`: 0%-33% domain and/or range information, signifying a low level of attribute information quality with insufficient details.

3.1.5 Degree of coverage with DATEX II model. The extent to which the DATEX II model is covered is a crucial metric in evaluating the ontology within the SRTI scope. This assessment focuses on the incorporation of key DATEX II concepts and classes, including Accident, AnimalsPresenceObstruction, EnvironmentalObstruction, GeneralObstruction, MaintenanceWorks, NonWeatherRelatedRoadConditions, PoorEnvironmentConditions, VehicleObstruction, and WeatherRelatedRoadCondition.

These concepts are fundamental components in safety-related traffic information and road conditions, emphasizing the significance of their inclusion in a comprehensive ontology in the SRTI domain.

3.1.6 Spread of use of the ontology. The spread of use metric provides valuable insights into the adoption and utilization of the ontology across various sites and vocabularies within the SRTI domain.

By assessing the number of sites and vocabularies that incorporate the ontology, we can gauge its relevance and impact within the field of traffic and safety-related information. A higher spread of use indicates widespread recognition and acceptance of the ontology as a valuable resource for representing and exchanging critical transportation data.

4 ANALYSIS AND RESULTS

This section delves into the analysis of diverse vocabularies and ontologies relevant to traffic, with a specific focus on the Safety Related Traffic Information (SRTI) Scope. To gauge their effectiveness, OntoQA-based metrics are employed, drawing insights from the research of Megan Katsumi and Mark Stephen Fox [15] who carry out an analysis of ontologies in the field of transportation. These metrics serve as a crucial tool, fostering the consolidation of semantic solutions that intelligently leverage existing ontologies. By applying OntoQA-based metrics, a comprehensive and standardized evaluation of these ontologies occurs, allowing researchers and practitioners to understand their strengths and limitations thoroughly. This evaluative approach, particularly in transport, objectively measures the performance and relevance of each ontology, advancing semantic solutions in the transportation domain. Recognizing the importance of reusing and consolidating ontologies enhances knowledge sharing, integration, and overall interoperability, contributing to more efficient semantic systems in the traffic field.

4.1 Ontology for Transportation Networks

The Ontology for Transportation Networks (OTN), a crucial element of the REWERSE [5] project, a distinguished “Network of Excellence” in “Reasoning on the Web,” is funded by the EU Commission and Switzerland under the “6th Framework Programme.”

Focused on “Semantic-based knowledge systems,” the project aims to advance understanding in the Information Society Technologies (IST) sector. OTN, also known as Ontology-based Traffic Network, comprehensively addresses traffic network and transportation aspects, utilizing the ISO standard Geographic Data File format (GDF). OTN signifies REWERSE’s commitment to semantic-based knowledge systems, laying a structured foundation for transportation system analysis despite limited online availability.

See the analysis summary in Table 1.

Table 1: Ontology Analysis Summary Table for OTN

Metric	Value	A.Value
Relationships richness	0,1074	LOW
Relationship information quality	Approx 100 %	HIGH
Attribute richness	0,4166	LOW
Attribute information quality	100 %	HIGH
Coverage DATEXII	No Datex classes	LOW
Spread of use	Not used	LOW

4.2 Ontology Based Road Traffic Management

OSMonto is a meticulously crafted ontology [4] for representing OpenStreetMap tags, developed by a collaborative effort led by Mihai Codescu, Gregor Horsinka, Oliver Kutz, Till Mossakowski, and Rafaela Rau. Decomposing tags into a hierarchical structure based on keys, OSMonto enhances tag semantics and fosters interoperability by connecting with other ontologies. Accessible in .owl format, it facilitates exploration and visualization of tag relationships through tools like Protégé. As an open-source project on GitHub, OSMonto encourages community contributions, making it a valuable resource for managing and comprehending OpenStreetMap tags. Its hierarchical organization, open accessibility, and compatibility with widely used tools highlight its significance in advancing tag semantics and data exploration.

See Table 2.

Table 2: OSMONTO Analysis Summary Table

Metric	Value	A.Value
Relationships richness	0,0473	LOW
Relationship information quality	100 %	HIGH
Attribute richness	0,0579	LOW
Attribute information quality	100 %	HIGH
Coverage DATEX II	No Datex classes	LOW
Spread of use	Not used	LOW

4.3 Road Accident Ontology

The Road Accident Ontology, initially drafted by Daniel Dardailler for sharing during W3C Geek Week in July 2012, aims to provide a structured representation of road accidents, encompassing information about involved parties, accident locations, causes, and effects [6].

Despite its conceptual design, this ontology has not been practically utilized or implemented in real-world applications or datasets. As a result, no existing resources have been found that make use of this vocabulary.

See Table 3.

Table 3: Road Accident Ontology Analysis summary table

Metric	Value	A.Value
Relationships richness	0,4473	MEDIUM
Relationship information quality	Approx 100 %	HIGH
Attribute richness	1,875	MEDIUM
Attribute information quality	Approx 100 %	HIGH
Coverage DATEX II	No Datex classes	LOW
Spread of use	Not used	LOW

4.4 km4city, the DISIT Knowledge Model for City and Mobility

The Km4City platform stands as a powerful Smart City tool designed to implement the city's vision, monitor its evolution, and provide new services aimed at enhancing the quality of life for city users and fostering economic growth. By promoting user satisfaction and pride, Km4City aims to create attractive cities that thrive and produce [16]. This platform serves as an interconnected and versatile knowledge model enabling the description of smart cities, drawing data from diverse sources such as portals of the Tuscan region (MIIC, Muoversi in Toscana, Osservatorio dei Trasporti), Open Data, Linked Data, and contributions from individual municipalities, notably Florence.

See Table 4.

Table 4: km4city Analysis summary table

Metric	Value	A.Value
Relationships richness	0,15	LOW
Relationship information quality	Approx 100 %	HIGH
Attribute richness	0,3928	LOW
Attribute information quality	Approx 50 %	MEDIUM
Coverage DATEX II	No Datex classes	LOW
Spread of use	Not used	LOW

4.5 Transport Disruption ontology

The Transport Disruption ontology [7] provides a robust framework for modeling travel and transport-related events that disrupt planned travel. Divided into two main sections, it comprehensively addresses disruptive event characteristics and their impact on travel plans, offering a hierarchical structure for travel and transport-related events. Developers and researchers benefit from standardized representations, enabling insightful decision-making. Applied in the Social Journeys project, it leverages social media to disseminate real-time disruption information, enhancing passenger experience. Its integration with Vocab.datex showcases versatility, supporting seamless data integration. As a valuable contribution to transport modeling, its structured representation fosters reliability, efficiency, and resilience in evolving transportation systems.

See Table 5.

Table 5: Transport Disruption ontology Analysis summary table

Metric	Value	A.Value
Relationships richness	0,1561	LOW
Relationship information quality	Approx 100 %	HIGH
Attribute richness	0,1210	LOW
Attribute information quality	Approx 100 %	HIGH
Coverage DATEX II	No Datex classes	LOW
Spread of use	Not used	LOW

4.6 Vocab.linkeddata.es

Vocab.linkeddata.es, developed by the Ontology Engineering Group at the Polytechnic University of Madrid, is a valuable resource presenting a curated list of vocabularies for linked open data [11]. Focused on Spain's cities, it promotes semantic interoperability and standardization. Notably, it includes vocabularies for traffic and transport, providing a structured framework for consistent open data publication. Efficiently reusing elements from ontologies like Naptan, it emphasizes data integration and representation quality. This initiative empowers Spanish cities to embrace linked open data principles, facilitating collaboration and data-driven decision-making. The Ontology Engineering Group's dedication contributes to advancing urban data management, fostering a connected ecosystem for innovative applications in transportation and urban planning [3].

See Table 6.

Table 6: Vocab.linkeddata.es Analysis summary table

Metric	Value	A.Value
Relationships richness	0,3461	MEDIUM
Relationship information quality	Approx 50 %	MEDIUM
Attribute richness	0,3552	LOW
Attribute information quality	< 50 %	LOW
Coverage DATEX II	No Datex classes	LOW
Spread of use	Zaragoza	Zaragoza
Spread of use	Alcobendas	Alcobendas
Spread of use	CRTM Madrid	CRTM Madrid

4.7 Vocabulary for representing traffic data

The "Vocabulary for Representing Traffic Data" is a potent tool designed to efficiently capture and depict urban traffic situation data. An extension of the Semantic Sensor Network Ontology [14], it aligns with ongoing standardization, ensuring compatibility with visualization tools and diverse processing systems. For optimal integration, it's recommended to use this vocabulary alongside the city street map ontology, enhancing the representation of road sections key elements in urban traffic data [1]. Focused on traffic intensity, it establishes a standardized framework for consistent citywide traffic conditions, enabling valuable insights for stakeholders. Its flexibility accommodates future expansion, ensuring long-term relevance and adaptability to evolving traffic monitoring needs. This vocabulary promotes harmonized, interoperable data representation, fostering collaboration, accurate analysis, and innovative solutions in urban traffic management. Crucial for smart city initiatives, it aligns seamlessly with the Semantic Sensor Network Ontology, unlocking the full potential of urban traffic data. This forward-thinking ontology embodies a foundational resource for the pursuit of efficient, sustainable, and data-informed urban transportation systems.

See Table 7.

Table 7: Vocabulary for representing traffic data Analysis summary table.

Metric	Value	A.Value
Relationships richness	0,3758	MEDIUM
Relationship information quality	< 33 %	LOW
Attribute richness	0	LOW
Attribute information quality	< 33 %	LOW
Coverage DATEX II	No Datex classes	LOW
Spread of use	Zaragoza	Zaragoza
Spread of use	Alcobendas	Alcobendas

4.8 Vocabulary for the representation of data on traffic made by motor vehicles

The “Vocabulary for the Representation of Data on Traffic Made by Motor Vehicles” is a specialized ontology for detailing motor vehicle traffic within urban areas. Exclusively focusing on motorized vehicles, it defines the scope, covering Traffic Equipment, encompassing measuring devices, types, specific measurements, and their city locations. The vocabulary also includes Incidents, addressing various traffic-related disruptions on public roads, providing a detailed representation of their impact. Sections consider locations of equipment deployment and incident occurrences, facilitating precise, location-based data crucial for traffic management. Developed as part of the “Open, Collaborative, and Interoperable Government Platform” project, involving city councils like Madrid and Zaragoza, the collaborative effort emphasizes intercity cooperation in smart city initiatives [1]. Implementing this vocabulary empowers city authorities to efficiently collect, represent, and analyze motor vehicle traffic data, enhancing capabilities in traffic management and incident response, and promoting open and interoperable data practices within smart cities.

See Table 8.

Table 8: Vocabulary for the representation of data on traffic made by motor vehicles Analysis summary table

Metric	Value	A.Value
Relationships richness	0,3758	MEDIUM
Relationship information quality	> 66 %	HIGH
Attribute richness	0,8	LOW
Attribute information quality	Approx 100 %	HIGH
Coverage DATEX II	No Datex classes	LOW
Spread of use	Caceres	Caceres
Spread of use	Aragon	Aragon

4.9 Linked GTFS

The Linked General Transit Feed Specification (Linked GTFS) stands as a pivotal transformation of the GTFS in CSV reference to RDF (Resource Description Framework) [12]. This meticulous mapping preserves the core structure and semantics of the original CSV reference while introducing minor enhancements for improved usability. By representing GTFS data in RDF format, it unleashes the potential of Linked Data principles, fostering data integration, interlinking, and semantic enrichment. While prioritizing compatibility with existing GTFS datasets and tools, Linked GTFS [19] introduces enhancements for efficient exploration and analysis of transit data. This community-driven initiative signifies a leap in data interoperability, revolutionizing transit planning, route optimization, and passenger experiences.

See Table 9.

Table 9: Linked GTFS Analysis summary table

Metric	Value	A.Value
Relationships richness	0,7916	HIGH
Relationship information quality	Approx. 100 %	HIGH
Attribute richness	0,8	LOW
Attribute information quality	Approx 100 %	HIGH
Coverage DATEX II	No Datex classes	LOW
Spread of use	Caceres	Caceres
Spread of use	Aragon	Aragon

4.10 vocab.datex

The vocab.datex website,offers a valuable vocabulary for mapping DATEX II to an OWL Ontology, instrumental in a Belgian research program extending DATEX II’s standard scope. Developed collaboratively by entities such as the Biotope project, Open Transport Net project, ITS Belgium, iMinds, and Open Transport at Open Knowledge, it originated from the open Summer of Code in 2016 [18]. Though currently offline, the ontology continues to be employed in Spanish Open Data Portals, underlining its practical significance. Despite its unavailability, vocab.datex has left a lasting impact, exemplifying collaborative efforts enhancing data exchange and interoperability in transportation.

Available at https://lov.linkeddata.es/dataset/lov/vocabs/datex

See Table 10.

4.11 MobiVoc

MobiVoc, a vital standardized vocabulary tailored for mobility data, encompasses Electric Charging Points, Parking Facilities, and Highway Roadworks sites based on DATEX II standards [2]. In our rapidly advancing world, the fusion of innovative mobility concepts and enhanced data networking plays a pivotal role in global

Table 10: Vocab.datex Analysis summary table

Metric	Value	A.Value
Relationships richness	0,8266	HIGH
Relationship information quality	Approx. 0 %	LOW
Attribute richness	1,6373	MEDIUM
Attribute information quality	Approx. 0 %	LOW
Coverage DATEX II	HIGH (all classes)	HIGH
Spread of use	Caceres	Caceres

economic development. The latest August 2023 update introduced highway roadworks concepts, ensuring compliance with DATEX II standards. This enriched dataset proves instrumental in the LIMBO research project, optimizing routing for electric cars. By integrating with DATEX II, MobiVoc enhances its utility, remaining adaptable to future mobility advancements. Positioned as a valuable resource, MobiVoc's data-driven insights hold immense potential in shaping a sustainable and efficient transportation ecosystem.

See Table 11.

Table 11: MobiVoc Analysis Summary Table

Metric	Value	A.Value
Relationships richness	0,6875	HIGH
Relationship information quality	Approx. 100 %	HIGH
Attribute richness	1,3389	LOW
Attribute information quality	Approx. 100 %	HIGH
Coverage DATEX II	HIGH in Mobility	HIGH
Spread of use	Not used	LOW

4.12 DATEX II Ontology, University of València

The DATEX II standard model encompasses a comprehensive set of attributes and relationships related to traffic information, aiming to cover various real-world traffic scenarios. In response to the complexity and diversity of traffic situations, the University of Valencia undertook the development of an ontology focused on accommodating any possible traffic event that could occur in practical scenarios.

Within the DATEX II model, a hierarchy of situation types is defined, including situations arising from the actions of operators on the road, events unrelated to the road, and elements of situations due to traffic. The latter category further subdivides into specific types such as accidents and abnormal traffic. The University of Valencia's Ontology has considered these detailed subdivisions to ensure it can effectively represent a wide range of traffic-related situations.

While the University of Valencia has been actively involved in various works and publications related to traffic and DATEX II, the developed Ontology has not yet been officially published, and it is not currently in use. However, the Ontology was presented at the EATIS 2009 conference [21], indicating the team's dedication to advancing research in this domain.

See Table 12.

Table 12: DATEX II Ontology, Universitat de València Analysis summary table

Metric	Value	A.Value
Relationships richness	0,1567	LOW
Relationship information quality	Approx. 100 %	HIGH
Attribute richness	0,1576	LOW
Attribute information quality	Approx. 100 %	HIGH
Coverage DATEX II	HIGH (all classes)	HIGH
Spread of use	Not used	LOW

4.13 LOD SRTI DATEX II

In 2018, the European project LOD-RoadTran18 was initiated with the collaborative efforts of institutions from the Czech Republic and the General Directorate of Traffic (DGT) in Spain, aimed at facilitating the reuse of road traffic data with an SRTI (Safety Related Traffic Information) scope in two Member States. The project's primary objective was to enable the constant publication of a comprehensive set of traffic data from both Spain and the Czech Republic on the European Open Data Portal (https://data.europa.eu/). By achieving this, the data became locatable, accessible, interoperable, and reusable, fostering its connection with various other datasets through Linked Open Data (LOD) principles.

A major impact of the LOD-RoadTran18 project was its significant improvement in providing basic access services to open traffic data, complying with the requirements of the ITS Directive (2010/40/EU) [10]. Not only did it enhance the visualization and download of data, but it also enabled the extraction of valuable meaning from the data, leading to the development of new types of services made possible by LOD integration. The project was in line with the call for Public Open Data of the European Commission and was evaluated under the CEF Telecom 2018 Call – Public Open Data (CEF-TC-2018-5).

During the EATIS 2022 conference, the project's scope, including descriptions of its ontologies and solution architectures, was presented [13]. These presentations shed light on the overall vision of the project and its technical underpinnings.

One of the key accomplishments of the LOD-RoadTran18 project was the development of a traffic ontology, the LOD SRTI DATEX II, with a specific focus on SRTI [22]. This ontology not only encompassed the SRTI classes defined in the DATEX II model but also established links with other relevant vocabularies and ontologies, including that of the National Geographic Institute [9]. By incorporating such connections, the ontology achieved higher levels of semantic interoperability and enriched the potential applications of the data.

An important highlight is that the DGT [8] has already started publishing its linked SRTI semantic data based on the ontology developed within the LOD-RoadTran18 project [17]. This implementation demonstrates the practical relevance and success of the project's efforts in enabling effective data reuse and interoperability within the traffic domain.

The degree of coverage with the DATEX II model is assessed as high, meaning that the ontology aligns well with the entire DATEX model related to road safety. This alignment enhances semantic interoperability and facilitates the integration of traffic data with other relevant datasets.

In terms of practical application, the ontology is currently being utilized by significant transportation authorities. Specifically, it is in use by the DGT [8] in Spain and the national traffic center of the Czech Republic. This implementation in real-world scenarios highlights the ontology's relevance and successful adoption.

Overall, the analysis showcases both strengths and areas for improvement in the ontological model. Its balanced relationship richness, high information quality of P relationships, and high degree of coverage with DATEX II demonstrate its effectiveness in representing road traffic information. However, efforts can be made to increase attribute richness to further enhance data representation capabilities. The successful deployment of the ontology in traffic authorities underscores its practical value and confirms its role in supporting data exchange and interoperability in the context of road traffic safety.

The analysis for this model can be seen in Table 13 and a summary of all vocabularies in Table 14.

Table 13: LOD SRTI DATEX II Analysis summary table

Metric	Value	A.Value
Relationships richness	0,4990	MEDIUM
Relationship information quality	Approx. 86 %	HIGH
Attribute richness	Approx 0,328	LOW
Attribute information quality	Approx 68,1 %	HIGH
Coverage DATEX II	HIGH (all classes)	HIGH
Spread of use	Spain	HIGH
Spread of use	Czech Republic	HIGH

Table 14: Analysis summary table

Ontology	Relationship richness	Relationship information quality	Attribute richness	Attribute information quality	Degree coverage DATEX II	Spread of use of the ontology
Ontology for Transportation Networks	LOW	HIGH	LOW	HIGH	LOW	LOW
Ontology Based Road Traffic Management	LOW	HIGH	LOW	HIGH	LOW	LOW
Road Accident Ontology	MEDIUM	HIGH	MEDIUM	HIGH	LOW	LOW
km4city	LOW	HIGH	LOW	MEDIUM	LOW	LOW
Transport Disruption ontology	LOW	HIGH	LOW	HIGH	LOW	LOW
Vocab.linkeddata.es	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	Zaragoza,Alcobendas and CRTM
Vocabulary for representing traffic data	MEDIUM	LOW	LOW	LOW	LOW	Zaragoza and Alcobendas
Vocabulary for the representation of data on traffic made by motor vehicles.	MEDIUM	HIGH	LOW	HIGH	LOW	Caceres and Open Data Aragón
Linked GTFS	HIGH	HIGH	LOW	HIGH	LOW	Caceres and Open Data Aragón
vocab.datex	HIGH	LOW	MEDIUM	LOW	HIGH	Caceres
Moviboc	HIGH	HIGH	LOW	HIGH	HIGH Mobility	LOW
DATEX II Ontology, UV	LOW	HIGH	LOW	HIGH	HIGH	LOW
LOD SRTI DATEX II	MEDIUM	HIGH	LOW	HIGH	HIGH	Spain and Czech Republic

5 DISCUSSION AND CONCLUSIONS

This study meticulously explores various road traffic ontologies, focusing on their alignment with the DATEX II European traffic information exchange model. Among the examined ontologies, four demonstrate commendable coverage with the DATEX II model.

MobiVoc stands out for its robust alignment with DATEX II Mobility, providing extensive coverage within the Mobility Scope. Similarly, Vocab.datex shows significant alignment with the DATEX II SRTI profile, as indicated in Table 14. However, its ontology design reveals some incompleteness, particularly in modeling relationships and attributes. The unavailability of the hosting website adds a layer of concern regarding accessibility and usability.

The initial DATEX II ontology developed by the University of Valencia achieves high coverage in the DATEX II SRTI profile, excelling in relationships and attribute quality. However, it falls short in the richness of relationships and attributes, obtaining a low level in these quality metrics. Its non-current usage poses a challenge to practical applicability.

The LOD SRTI DATEX II ontology exhibits varying richness in attributes, suggesting acceptable schema quality. While its adoption of the original UML class model justifies its richness in the relationship's metric, it presents limitations in attribute richness. Notably, this ontology has found practical application in publishing semantic data, successfully adopted by the Directorate General of Traffic (DGT) in Spain and the Czech Republic. Its current usage recommends it for publishing road traffic information with an SRTI profile.

Key findings reveal alignments and deficiencies in several road traffic ontologies concerning the DATEX II model. MobiVoc and Vocab.datex show promise, albeit requiring refinement, especially for Vocab.datex.

In summary, the recommendation to adopt the LOD SRTI DATEX II Ontology for publishing road traffic information is based on its current usage and successful application, highlighting practical applicability. Analyzing ontologies using metrics, as demonstrated, is crucial for assessing quality, identifying strengths, and pinpointing areas of improvement. These metrics offer a systematic means to ensure alignment with standards and richness in relationships and attributes, fostering widespread adoption, as seen in successful cases like LOD-RoadTran18.

Future research should prioritize refining and updating existing ontologies, addressing identified deficiencies, and ensuring continuous accessibility. Adopting alternative approaches to ontology development, coupled with exploration into emerging technologies, can contribute to more comprehensive and effective road traffic ontologies.

In conclusion, the dynamic nature of the semantic web landscape necessitates ongoing efforts to align ontologies with evolving standards and technologies in road traffic management. By emphasizing the practical importance of ontologies through thorough analysis and fostering continuous refinement, this study lays the groundwork for advancements in data interoperability, knowledge sharing, and decision-making processes within the domain of road traffic safety.

REFERENCES

[1] 2021. Ciudades abiertas. (2021). https://github.com/CiudadesAbiertas/vocab-transporte-trafico
[2] Martin Brümmer, Annette Weilandt, and Niklas Petersen. 2019. MobiVoc: Open Mobility Vocabulary. (2019). http://schema.mobivoc.org/
[3] (CRTM) Javier Chamorro, José María Díez (Ayuntamiento de Burgos), (CRTM) Luis Criado, María Jesús Fernández Ruíz (Ayuntamiento de Zaragoza), Universidad Politécnica de Madrid Oscar Corcho (Ontology Engineering Group, LocaliData), and Rodrigo Medrano Calderón (Escuela Técnica Superior de Ingenieros Informáticos). 2018. Vocabulario para la representación de datos de la infraestructura de medios de transporte. (2018). http://vocab.linkeddata.es/datosabiertos/def/transporte/transporte-publico/index-en.html
[4] Christian Clausen. 2012. Osmonto ontolgy. (2012). https://raw.githubusercontent.com/doroam/planning-do-roam/master/Ontology/tags.owl
[5] European Comission. 2008. REWERSE . (2008). https://cordis.europa.eu/project/id/506779
[6] Daniel Dardailler. 2012. Road Accident Ontology. (2012). https://www.w3.org/2012/06/rao.html
[7] Peter Edwards David Corsar, Milan Markovic and John D. Nelson. 2015. The Transport Disruption Ontology. (2015). https://doi.org/10.1007/978-3-319-25010-6_22
[8] Ministerio de Interior. 2024. DGT. (2024). https://www.dgt.es/inicio/
[9] Ministerio de transportes (España). 2022. Instituto geográfico nacional. (2022). https://www.ign.es/web/ign/portal
[10] EL PARLAMENTO EUROPEO Y EL CONSEJO DE LA UNIÓN EUROPEA. 2010. Directiva ITS (2010/40/UE). . (2010). https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:207:0001:0013:ES:PDF
[11] Ontology Engineering Group. 2017. vocab.linkeddata.es. (2017). http://vocab.linkeddata.es/
[12] RDF Working Group. 2022. Resource Description Framework. (2022). https://www.w3.org/RDF/
[13] Julian Gutierrez, J. Javier Samper, Ana Delgado, Jose Rocha, Bures Petr, and Purkrabkova Zuzana. 2022. LOD-RoadTran18: Supporting the cross-border use of Road Traffic Data with Linked Open Data based on DATEX II. (2022). https://doi.org/10.1145/3544538.3544651
[14] S. Cox D. Le Phuoc K. Taylor H. Armin, J. Krzysztof and M. Lefrançois. 2023. Semantic Sensor Network Ontology, W3C OGC. (2023). http://w3c.github.io/sdw/ssn/
[15] Megan Katsumi and Mark Stephen Fox. 2018. Ontologies for Transportation Research: A Survey. (2018). https://www.researchgate.net/publication/324141407_Ontologies_for_Transportation_Research_A_Survey
[16] km4city@disit org DISIT lab: info@disit.org and Paolo Nesi Pierfrancesco Bellini Mirco Soderi. 2017. Km4city ontology source. (2017). http://wlode.disit.org/WLODE/extract?url=http://www.disit.org/km4city/schema
[17] Julian Gutierrez Moret and J. Javier Samper Zapater. 2022. LOD SRTI DATEX II ontology. (2022). https://cef.uv.es/lodroadtran18/def/transporte/dtx_srti/
[18] Open Summer of Code. 2016. Open Summer Code 2016. (2016). https://2016.osoc.be/
[19] Andrew Byrd (Conveyal). Pieter Colpaert (Open Knowledge | iMinds Ghent University MultiMedia Lab). 2016. Linked GTFS. (2016). https://github.com/OpenTransport/linked-gtfs
[20] Amit Sheth Michael Moore Samir Tartir, Ismailcem Budak Arpinar. 2005. OntoQA: Metric- based ontology quality analysis. (2005). https://www.researchgate.net/publication/266795541_OntoQA_Metric-Based_Ontology_Quality_Analysis
[21] J. Javier Samper, F. Javier Adell, Jose Fco. García, J. José Martinez, and Jose Vidal. 2009. Semantic traffic applications based on DatexII. (2009). https://doi.org/10.1145/1551722.1551729
[22] J. Javier Samper-Zapater, Julián Gutiérrez Moret, Jose Macario Rocha, Juan José Martinez-Durá, and Vicente R. Tomás. 2024. Semantic Modelling Approach for Safety-Related Traffic Information Using DATEX II. *INFORMATION* (2024). https://doi.org/10.3390/info15010003
[23] EUROPEAN UNION. 2013. Commission Delegated Regulation (EU) No 885/2013. (15 May 2013). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0885&from=EN
[24] EUROPEAN UNION. 2013. COMMISSION DELEGATED REGULATION (EU) No 886/2013 . (2013). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0886&from=BG
[25] EUROPEAN UNION. 2015. Commission Delegated Regulation (EU) No 2015/962 . (23.6. 2015). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R0962&from=EN
[26] EUROPEAN UNION. 2017. Commission Delegated Regulation (EU) 2017/1926. (21.10. 2017). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1926&from=EN
[27] EUROPEAN UNION. 2021. DATEX II SRTI REFERENCE PROFILE. (2021). https://docs.datex2.eu/profiles/srti.html
[28] EUROPEAN UNION. 2022. DATEX II. (2022). https://docs.datex2.eu/
[29] European Union. 2022. LOD-RoadTran18. Supporting the cross-border use of Road Traffic Data with Linked Open Data based on DATEX II. (2022). https://cef.uv.es/lodroadtran18/index.php/en/