M4.2.4. Technical specifications

Updates

Supporting the RTTI delegated regulation with INSPIRE and TN-ITS

A report by NAPCORE SWG 4.2 TN-ITS

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Supporting the RTTI delegated regulation with INSPIRE and TN-ITS

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Action requested

☒ To be revised by partners involved in the preparation of the document

☒ For review/ approval by the Core Alignment Team

☐ For approval by the NAPCORE Steering Committee

Abstract

This report identifies requirements from the EU Delegated Regulation 2022/670 (RTTI) where the INSPIRE and TN-ITS specifications are relevant, how the specifications may be used to fulfil the requirements, and how the TN-ITS specification should be further developed to fit current and future needs. The report concludes that a combination of INSPIRE and TN-ITS with extensions is the recommended solution for providing the required information concerning the infrastructure, regulations and restrictions defined in articles 4 and 5 of the DR and further detailed in points 1, 2 and 3 in the annexe of the DR.

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Abbreviations

Abbreviation	Meaning
EC	European Commission
CAT	Core Alignment Team
CEN	European Committee for Standardization
GDF	Geographic Data Files (ISO 20524)
GDD	Graphic Data Dictionary (ISO 14823)
INSPIRE	Infrastructure for Spatial Information in Europe
ISO	International Organization for Standardization
MDA	Model-Driven Architecture
NAP	National Access Point
NAPCORE	National Access Point Coordination Organisation for Europe
OWL	Web Ontology Language
RDF	Resource Description Framework
RTTI	Commission Delegated Regulation with regard to the provision of EU-wide real-time traffic information services
SC, SCOM	Steering Committee
SCS	Steering Committee Support
SWG	Sub-working Group
TN-ITS	Transport Network – Intelligent Transport Systems
UML	Unified Modelling Language
WG	Working Group
WP	Working Programme

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1. Introduction

NAPCORE SWG 4.2 focuses on integrating the TN-ITS standardization activities within the scope of NAPCORE. Task 4.2.3 addresses the further development of the TN-ITS technical specifications. It covers the envisaged harmonization across subSWGs, the exploration of new data-sharing methods, the procedures and& governance for the maintenance of the technical specifications, and the support to service implementers of the technical specification, including tools and& recommendations.

The scope of this deliveryMilestone report is to identify requirements for NAPs where the TN-ITS and INSPIRE specifications are relevant. Furthermore, it describes how the TN-ITS specification may be used to fulfil the requirements and how it should be further developed to fit current and future needs.

The work in the previous PSA CEF project, "TN-ITS GO", is an essential part of the input for the deliverythis document, along with the report M3.1 "Data content requirements, existing gaps, data dictionaries and supporting material" from NAPCORE WG 3 (MYLONAS, STAVARA, NICULESCU, & TRANDAFIRIDIS, 2022).

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2. Methodology

The methodology applied to reach the objective of this ~~delivery~~report is illustrated in Figure 1~~Figure 1~~.

First, relevant descriptions and their interpretation from legal text into data requirements were based on the work in NAPCORE WG-3, with further specializations scoped for implementation through TN-ITS and INSPIRE conceptual models and implementation schemas. The relevant requirements for TN-ITS and INSPIRE were found in the Commission Delegated Regulation 2022/670 (see section 3.1).

Second, the categorization was compared to the conceptual models for TN-ITS (see section 3.3) and INSPIRE Transport Networks (see section 3.2). This comparison identified how the existing specification could serve the requirements and where changes and extensions were needed.

Finally, a delivery structure based on revised conceptual models was suggested and presented with examples.

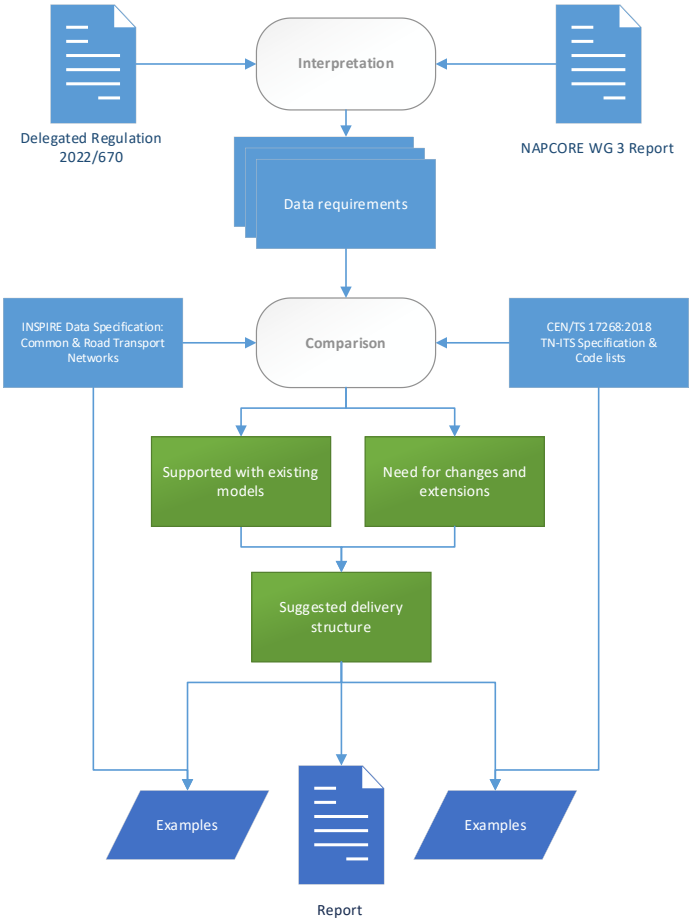

Figure 1: Methodology

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3. The legal and technical framework

3.1. The ITS Directive and the RTTI Delegated Regulation

The following quoted paragraphs are taken from the NAPCORE WG3 M3.1 report "Data content requirements, existing gaps, data dictionaries and supporting material" (MYLONAS, STAVARA, NICULESCU, & TRANDAFIRIDIS, 2022). They are included in this report to describe the bigger picture:

"The EU policy framework for Intelligent Transport Systems (ITS) has been established by the Directive 2010/40/EU, which sets a framework to support the coordinated and coherent deployment and use of ITS within the Union, while also provides for the development of specifications and standards for the respective applications. More specifically, according to the Directive, the ITS priority areas are the optimal use of road, traffic and travel data, the continuity of traffic and freight management services, ITS road safety and security applications and vehicle to infrastructure (V2I) communication. In addition, the Directive sets the priority actions within the aforementioned areas, which are the pan-European information services for multimodal travel, real-time traffic information, road safety related minimum universal traffic information, safe parking places as well as reservation services for trucks and commercial vehicles and the interoperability of eCall.

National Access Points (NAPs) play a significant role as enablers of the EU ITS policy framework. Accessible databases for both dynamic and static, infrastructure and traffic data derived from relevant public authorities and the private sector are essential to ensure the required standards for optimal ITS use and development. Moreover, the timely update of the provided data, the assurance of a minimum uniform level of data quality and the effective assessment of compliance of all parties involved, are key to the development of useful and reliable ITS services.

In addition to the ITS Directive, EU has adopted four Delegated Regulations (DRs) to provide specifications for the priority actions and are discussed one by one in the subsequent subsections."

Among the Delegated Regulations, the "*Delegated Regulation with regard to the provision of EU-wide real-time traffic information services"* (RTTI) is considered the most relevant for the scope of this report, as also described in the WG-3 report. The first version of the DR on RTTI – DR No 2015/962 (European Parliament and the Council of the European Union, 2014) defined RTTI as either static or dynamic. For dynamic data, Article 5 mandated the use of the DATEX II format, while Article 4 required the use of *"a standardized format, if available"* for static data.

The second version of the DR on RTTI – DR No 2022/670 (European Parliament and the Council of the European Union, 2022) groups the information into four main categories: *"data on infrastructure"* (Article 4), *"data on regulations and restrictions"* (Article 5), *"data on the state of the network"* (Article 6) and *"data on the real-time use of the network"* (Article 7). Articles 6 and 7 mandate the use of DATEX II for data on the state of the network and on the real-time use of the network, while Articles 4 and 5 mandate the use of *"a standardized format such as the INSPIRE data specification on transport networks, TN-ITS (CEN/TS17268 and subsequently upgraded versions) or DATEX II (EN 16157, CEN/TS 16157 and subsequently upgraded versions)."*

The annexes to DR no 2015/962 and DR no 2022/670 list the data types included in the main categories. Besides the new grouping in DR no 2022/670, there are some new data types as well, as listed in table 5 in ~~the WG3 Report~~M3.1 (MYLONAS, STAVARA, NICULESCU, & TRANDAFIRIDIS, 2022). This report is based on the annex~~e~~ to DR no 2022/670, where points 1, 2 and 3 concern articles 4 and 5, as listed below:

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(1) The types of data on infrastructure:
  (a) road network links and their physical attributes:
    (i) geometry;
    (ii) road width;
    (iii) number of lanes;
    (iv) gradients;
    (v) junctions;
  (b) road classification;
  (c) location of tolling stations;
  (d) location of service areas and rest areas;
  (e) location of recharging points for electric vehicles and the conditions for their use;
  (f) location of compressed natural gas, liquefied natural gas, liquefied petroleum gas stations;
  (g) location of refuelling points and stations for all other fuel types;
  (h) location of delivery areas.

(2) The crucial types of data on regulations and restrictions:
  (a) static and dynamic traffic regulations, where applicable:
    (i) access conditions for tunnels;
    (ii) access conditions for bridges;
    (iii) permanent access restrictions;
    (iv) speed limits;
    (v) freight delivery regulations;
    (vi) overtaking bans on heavy goods vehicles;
    (vii) weight/length/width/height restrictions;
    (viii) one-way streets;
    (ix) boundaries of restrictions, prohibitions or obligations with zonal validity, current access status and conditions for circulation in regulated traffic zones;
    (x) direction of travel on reversible lanes;
  (b) traffic circulation plans.

(3) Other types of data on regulations and restrictions:
  (a) the location and identification of traffic signs reflecting traffic regulations and identifying dangers:
    (i) access conditions for tunnels;
    (ii) access conditions for bridges;
    (iii) permanent access restrictions;
    (iv) other traffic signs reflecting traffic regulations;
  (b) static and dynamic traffic regulations, where applicable, other than traffic regulations referred to in point (2);
  (c) identification of tolled roads, applicable fixed user charges and available payment methods (including retail channels and fulfilment methods);
  (d) variable road user charges and available payment methods, including retail channels and fulfilment methods.

3.2. The INSPIRE Directive and the INSPIRE Data Specifications

On the official website for the INSPIRE Directive, https://inspire.ec.europa.eu/about-inspire/563, it is stated that the EU Directive 2007/2 – INSPIRE (European Parliament and the Council of the European Union, 2007) *"…aims to create a European Union spatial data infrastructure for the purposes of EU environmental policies and policies or activities which may have an impact on the environment. This European Spatial Data Infrastructure will enable the sharing of environmental spatial information among public sector organizations, facilitate public access to spatial information across Europe and assist in policy-making across boundaries. INSPIRE is based on the infrastructures for spatial information established and operated by the Member States of the European Union. The Directive addresses 34 spatial data themes needed for environmental applications."*

Furthermore, https://inspire.ec.europa.eu/data-specifications/2892 states that *"The INSPIRE Implementing Rules on interoperability of spatial data sets and services (IRs) and Technical Guidelines (Data Specifications) specify common data models, code lists, map layers and additional metadata on*

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the interoperability to be used when exchanging spatial datasets. Datasets in scope of INSPIRE are ones which come under one or more of the 34 spatial data themes … set out in the INSPIRE Directive."

The INSPIRE Data Specifications are modelled as conceptual models in the Unified Modelling Language (UML), based on rules from ISO/TC 211 standards for geospatial information, in particular ISO 19109 – Rules for application schemas (ISO/TC 211, 2015). Resources for implementation are derived from the conceptual models, following a Model-Driven architecture (MDA). Implementation schemas are available in the standardized geospatial XML-based format GML (ISO/TC 211, 2020). Besides, online register items for feature concepts, code lists, enumeration values, and more are available in the INSPIRE Registry (https://inspire.ec.europa.eu/registry) in diverse formats, including XML, RDF-XML, JSON and CSV.

A set of base models lays the fundament for the conceptual models in Data Specifications. The Generic Network Model (INSPIRE, 2013) lays the fundament for the network models in, among others, the Transport Networks theme. The network model defines a geometric and topologic network of links and nodes as shown in Figure 2 – and means for positioning network properties on the links by linear referencing, as shown in Figure 5.

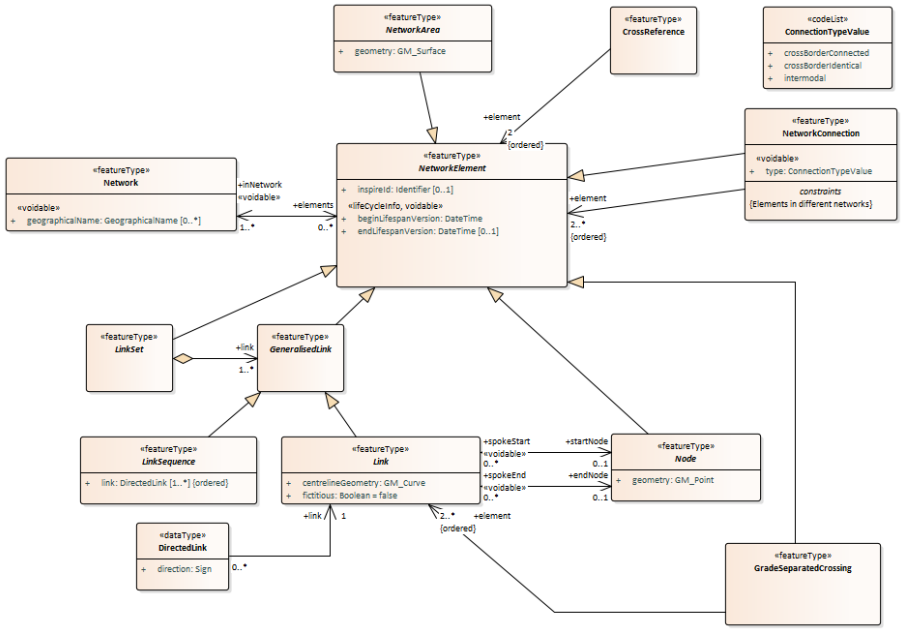

Figure 2 The Generic Network Model. From (INSPIRE, 2013). Original on https://inspire-mif.github.io/uml-models

Among the 34 spatial themes, the Transport Networks theme is particularly essential in the scope of this report (https://inspire.ec.europa.eu/Themes/115/2892) (INSPIRE, 2014). The Transport Networks model is divided into six submodels, one for each of five distinct transportation modes and one model for common transport elements.

The Road Transport Network model defines (1) a Road-specialized network model based on the Generic Network Model and the Common Transport Elements model (see Figure 3) and (2) a set of Road network properties such as speed limits and road width (see Figure 4). Besides, the Common

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Transport Elements Model defines several network properties independent of transportation mode (see Figure 5).

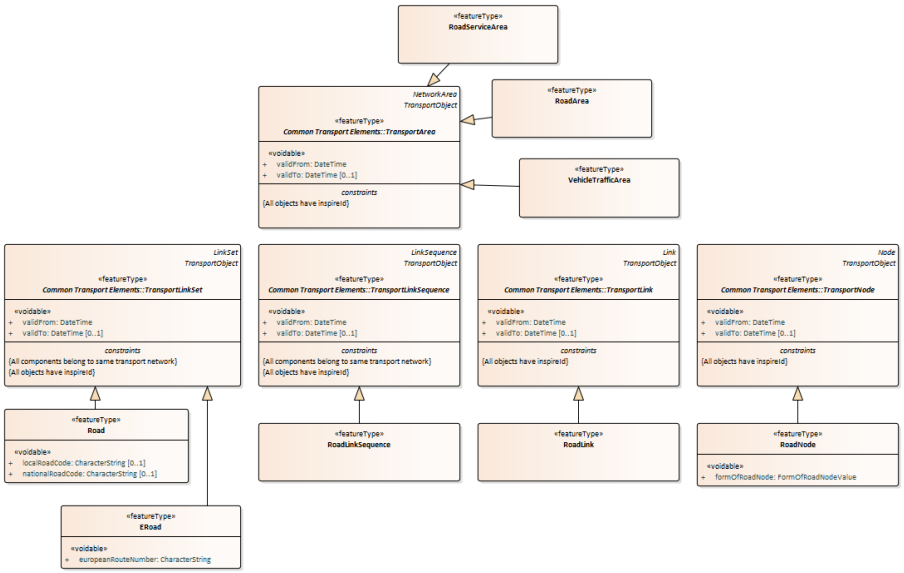

Figure 3 The Road Transport Network Model.From (INSPIRE, 2014). Original on https://inspire-mif.github.io/uml-models

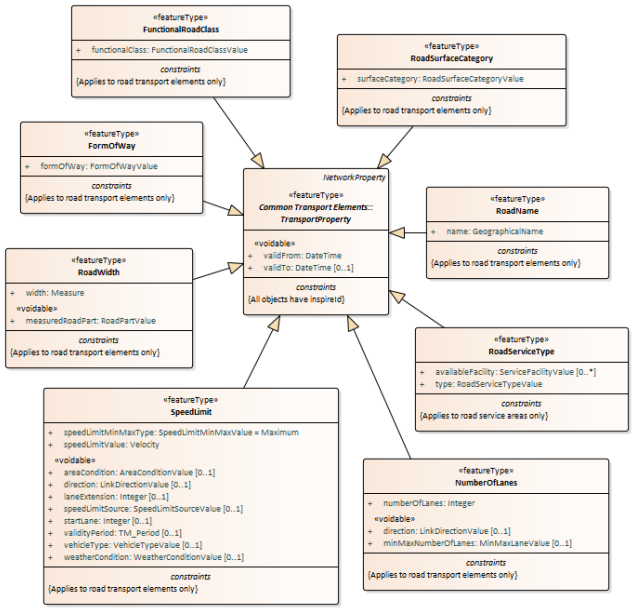

Figure 4 Road Network Properties. From (INSPIRE, 2014). Original on https://inspire-mif.github.io/uml-models

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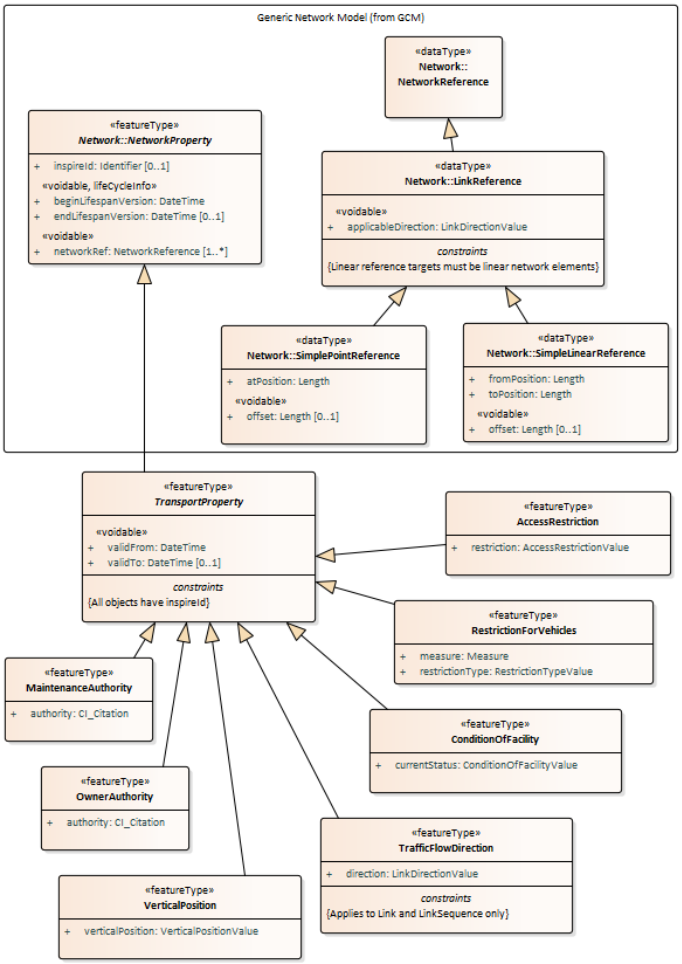

Figure 5 Common Transport Properties and network positioning of properties. From (INSPIRE, 2014). Original on https://inspire-mif.github.io/uml-models

3.3. The TN-ITS Specification

The TN-ITS specification was first developed in cooperation between road authorities and commercial map providers in the ROSATTE project (Wikström, et al., 2009). The specification was further developed through the European Union Location Framework Transportation Pilot (Borzacchiello, Boguslawski, & Pignatelli, 2016) and finally standardized by CEN/TC 278 (CEN/TC 278, 2018). The scope of the specification is the exchange of road-related spatial information according to a conceptual UML model and external code lists for types, properties and values. Implementation schemas for the GML format (see http://spec.tn-its.eu/schemas/) are derived from the conceptual model following the same MDA principles as the INSPIRE Data Specifications. An experimental OWL Ontology representing the TN-ITS model with code lists and enumerations is also available (see https://github.com/ERTICO-TN-ITS/TN-ITS-Open).

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A standardized service for data provision is described in the specification as well. Services according to the TN-ITS specification are implemented in several European states, providing authoritative road-related information to map and service providers. A list of services can be found at https://tn-its.eu/tn-its/.

Commented [MI1]: Even though it's currently only used by map provider to our knowledge, our hope is to reach users beyond map industry.
BTW, map sounds for me too static, map database providers could be better.

Unlike the INSPIRE Transport Networks model, the TN-ITS conceptual model is very generic, with one class representing any road feature and one class representing any property for a feature. The classification of features and properties into types is handled by the code lists, which are maintained at http://spec.tn-its.eu/codelists/. Figure 6 shows a part of the TN-ITS conceptual model, while Figure 7 shows some values for the code list for road feature types.

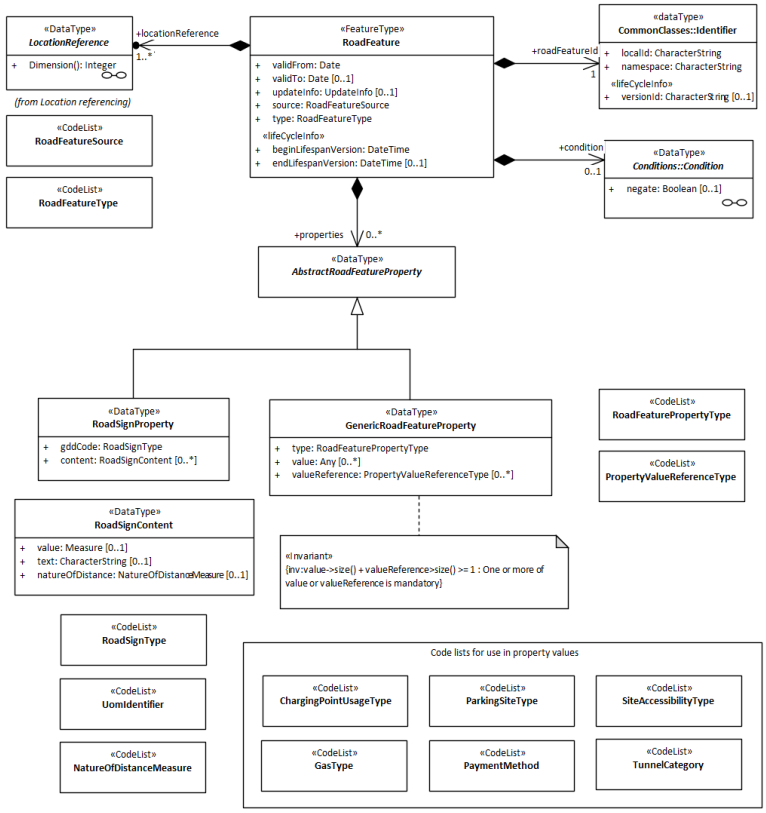

Figure 6 The TN-ITS Road Feature model. From (CEN/TC 278, 2018).

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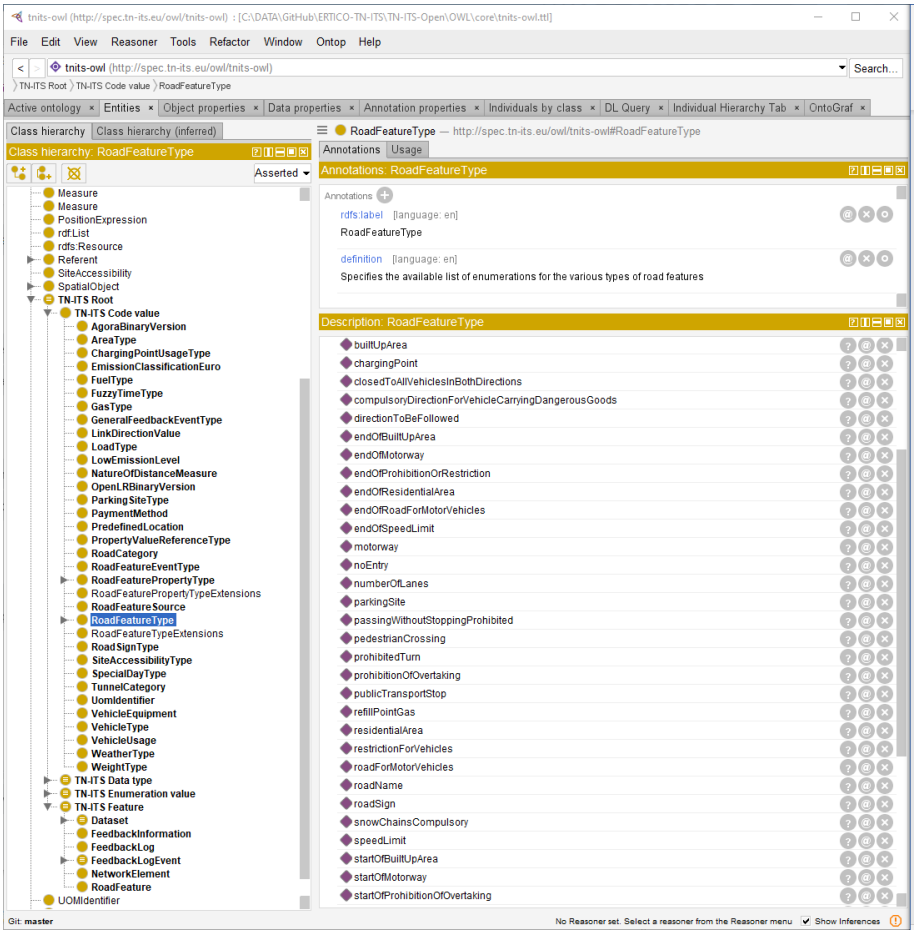

Figure 7 Some values from the TN-ITS ReadFeatureType code list. From the experimental TN-ITS Ontology.

The TN-ITS model does not include a network model. However, the linear referencing mechanism described in the Location Reference model is prepared for positioning road features in the INSPIRE road network, as shown in Figure 8.

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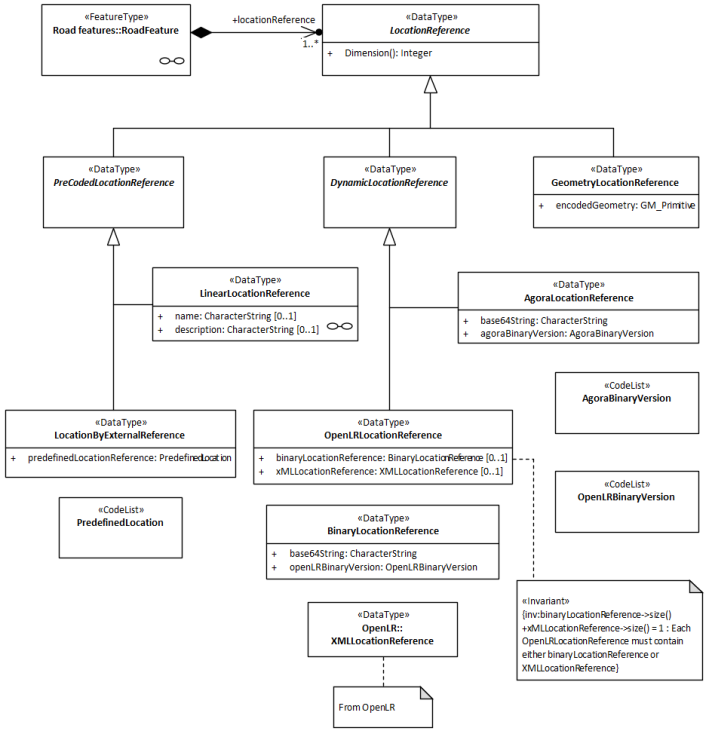

Figure 8 TN-ITS Classes for location referencing. From (CEN/TC 278, 2018)

The Conditions model is an essential part of the TN-ITS model. The model is adapted from the DATEX II model and may be used to describe conditions where the road feature is valid or invalid. The model includes classes for describing conditions related to areas, lanes, time, vehicle characteristics, weather, and road categories, or combinations. Figure 9 shows the core Conditions model. Figure 10 shows the detailed model for vehicle conditions, and Figure 11 shows the detailed model for time conditions.

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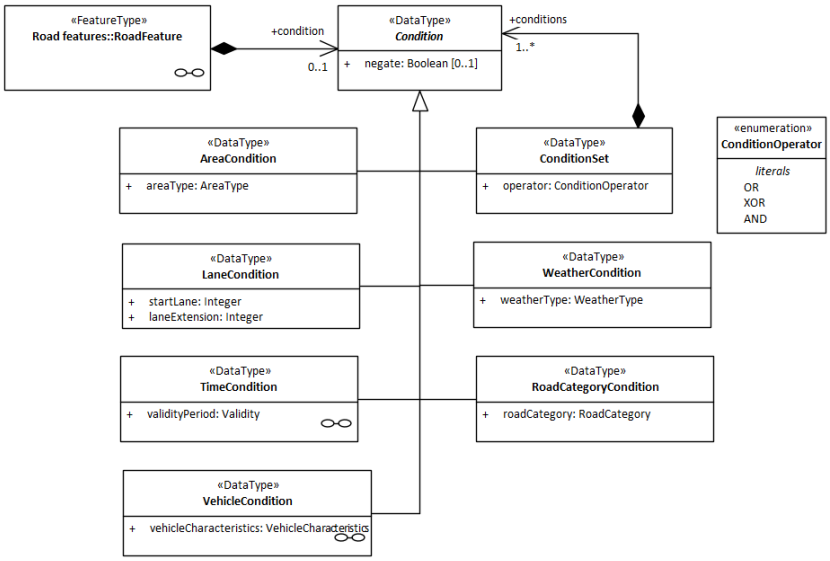

Figure 9. The TN-ITS Conditions model. From (CEN/TC 278, 2018)

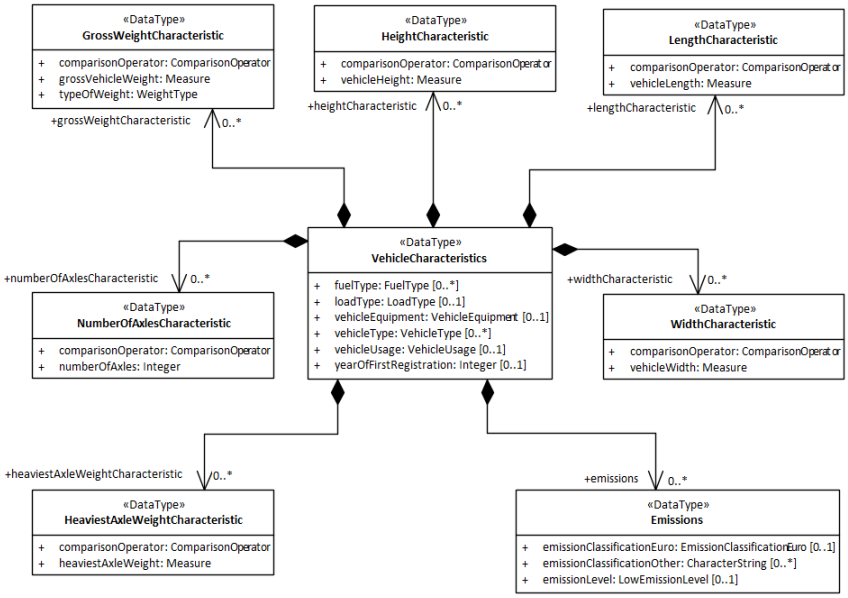

Figure 10. The TN-ITS model for vehicle characteristics. From (CEN/TC 278, 2018)

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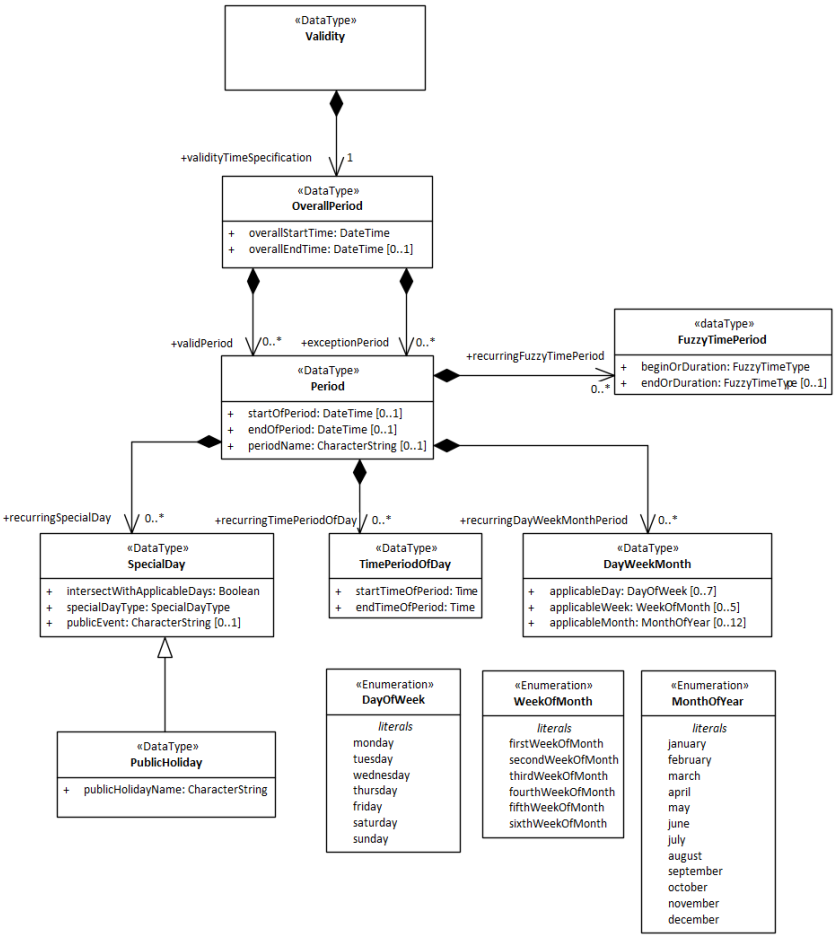

Figure 11. The TN-ITS model for time conditions. From (CEN/TC 278, 2018)

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4. Interpretation of RTTI into data requirements

In Table 1, the legal text from the annexe of DR No 2022/670 (European Parliament and the Council of the European Union, 2022) is interpreted and translated into data requirements. The translation is based on the parallel translation of the annexe of DR No 2015/962 (European Parliament and the Council of the European Union, 2014) in Table 26 in the WG3 report (MYLONAS, STAVARA, NICULESCU, & TRANDAFIRIDIS, 2022), supported by the explanations in the CROW Report (CROW, 2022).

NOTE: The table does not include location referencing methods for each category. Several location referencing methods may be possible, as shown for TN-ITS in Figure 8.

Category	RTTI Ref.	Interpretation	Possible content and structure
Infrastructure	*1*		
Network link geometry	1.a.i	Simplified representation (connected centreline links and nodes) of the road network geometry.	Line and point geometry
Road width	1.a.ii	The width of a road segment measured as an average value.	Measure with real number value and unit of measure = meter Alphanumeric values from harmonized code list: • Measured part (paved surface, carriageway etc.)
Number of lanes	1.a.iii	The number of lanes of a road segment.	Integer value Alphanumeric values from harmonized code list: • The direction which the value concerns (the integer value may represent the number of lanes in distinct directions or both directions)
Network link gradients	1.a.iv	The gradient of rise or fall along a road segment measured as an average value.	Measure with real number value and unit of measure = percentage Positive value = rise, negative value = fall

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Category	RTTI Ref.	Interpretation	Possible content and structure
Network junctions	1.a.v	Connection facilitating the movement of traffic through a crossing between two or more roads. Note: GDF (ISO/TC 204, 2020) differentiate between junctions, intersections, and interchanges: • A junction is the connection point between roads at the most detailed level. • An intersection is a generalization of junctions in a complex crossing into one point. In simple crossings, intersections and junctions are equivalent. • An interchange is a complex feature composed of all roads and junctions forming a crossing between two or more roads. When RTTI uses the term "junction", the expected delivery for complex crossings is probably generalized (and numbered/named) intersections or interchanges, not the individual junctions.	Alfanumeric values for • Junction number • Junction name
Road classification	1.b	Classifications of roads according to commonly applied approaches, such as Form of Way, Functional Road Class, Road Name and Road Number.	Alphanumeric values from harmonized code lists for • Form of way • Functional road class Alfanumeric values for • Road name • Road number
Tolling stations	1.c	The location and nature of toll booths where the road usage is automatically or physically registered and possibly paid.	Per vehicle class: • Alphanumeric value from harmonized code list: Vehicle class • Measure with real number value and unit of measure describing currency type: Fixed charge For all: • Alphanumeric value from harmonized code list: Payment method(s) (cash, credit card etc.)

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Category	RTTI Ref.	Interpretation	Possible content and structure
Service and rest areas	1.d	The location of service and rest areas along roads, with available facilities.	Alfanumeric value for • Area name Alphanumeric values from harmonized code lists for • Area type (parking, rest area etc.) • Facilities (food, picnic area, toilets etc.)
Recharging and refuelling stations	1.e 1.f 1.g	The location, type and usage conditions of • Recharging stations for electric vehicles (1.e) • Gas stations for CNG, LNG and LPG (1.f) • Refuelling stations for all other fuel types (1.g)	Alfanumeric value for • Operator name Alphanumeric values from harmonized code lists for • Energy type(s) (electricity, CNG, LNG, biodiesel, petrol etc.) • Accessibility (public, restricted etc.) • Payment method(s) (cash, credit card etc.)
Delivery areas	1.h	Not clearly defined. Has been interpreted as storage and transfer points, pick-up points or loading zones.	Alphanumeric values from harmonized code lists for • Area type(s) (instaboxes, warehouse storage, loading zone etc.) • Accessibility (public, restricted etc.)

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Crucial restrictions	*2*		
Access conditions	2.a.i 2.a.ii 2.a.iii	Permanent, legal or physical limitations for accessing road segments, including • Tunnels (2.a.i) • Bridges (2.a.ii) • Other permanent restrictions (2.a.iii) For example, restrictions based on vehicle class, such as lorries, motor vehicles, bikes, and agricultural vehicles but also on propulsion technology due to environmental zones. NOTE: Overlap to some extent with weight and extent restrictions (2.a.vii)	Alphanumeric values from harmonized code lists for • Type(s) of restriction (axle weight, height, length, vehicle types, energy type etc.) Measure with real number value and SI unit of measure: • Value (limit)
Speed limits	2.a.iv	Speed limits for road segments	Measure with integer value and unit of measure = kmph
Freight delivery regulations	2.a.v	Regulations for delivering freight in restricted road segments or areas.	Alphanumeric values from harmonized code lists for • Type(s) of restriction (vehicle types, energy type etc.) Measure with real number value and SI unit of measure: • Value (limit) Date and time schedules • Opening hours
Overtaking bans for heavy vehicles	2.a.vi	Road segments where overtaking is forbidden for heavy vehicles.	Alphanumeric values from harmonized code lists for • Vehicle type(s)
Vehicle weight and extent restrictions	2.a.vii	Road segments where access is restricted due to vehicle weight, length, width, or height. NOTE: Overlap to some extent with access conditions (2.a.i-iii)	Alphanumeric values from harmonized code lists for • Type(s) of restriction (axle weight, height, length etc.) Measure with real number value and SI unit of measure: Value (limit)

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One-way streets	2.a.viii	Road segments where traffic is allowed in only one direction.	Alphanumeric values from harmonized code lists for • Exceptions (bicycles, emergency vehicles etc.)
Restriction zones	2.a.ix	Boundaries and conditions for zones where restrictions, prohibitions or obligations apply for all road sections. NOTE: Overlap to some extent with other categories, such as access conditions (2.a.i-iii), speed limits (2.a.iv) and freight delivery regulations (2.a.v).	Alphanumeric values from harmonized code lists for • Type(s) of restriction (vehicle types, energy type etc.) Measure with real number value and SI unit of measure: • Value (limit) Date and time Opening hours
Reversible lanes	2.a.x	Road segments with reversible lanes, including the schedule for the direction of travel.	Date and time schedules For each period: • Direction of travel
Traffic circulation plans	2.b	Information such as network guidance or enclose of the elements of TMPs and UVARs (requires further analysis and breakdown).	
Other restrictions	*3*		
Traffic signs reflecting regulations and dangers	3.a.i 3.a.ii 3.a.iii 3.a.iv	The location and type of traffic signs reflecting regulations and dangers concerning • Access to tunnels (3.a.i) • Access to bridges (3.a.ii) • Other permanent access restrictions (3.a.iii) • Other traffic regulations (3.a.iv) NOTE: Represents the sign position for restrictions defined in 2.a.	Alphanumeric values from harmonized code lists for • International sign number (GDD) Measure with real number value and SI unit of measure: • Value (limit) Alphanumerical: • Additional text
Other traffic regulations	3.b	Road segments with other, not specified traffic regulations.	

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Tolling and road user charges	3.c 3.d	Road segments with tolling (3.c) or road user charges (3.d), including fixed and variable charges and payment methods. NOTE: Represents the segments related to tolling stations defined in 1.c.	Per vehicle class: • Alphanumeric value from harmonized code list: Vehicle class • Measure with real number value and unit of measure describing currency type: Fixed charge For all: Alphanumeric value from harmonized code list (cash, credit card etc.) • Payment method(s):

Table 1: Data categories interpreted from the legal text

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5. Comparing RTTI requirements with INSPIRE and TN-ITS

5.1. Infrastructure

5.1.1. Network link geometry

Description

Simplified representation (connected centreline links) of the road network geometry.

INSPIRE

The INSPIRE model for Road Transport Networks covers links and nodes, relations between them, and sequences and sets of links. Each instance of 'Link' and 'Node' carries the geometry.

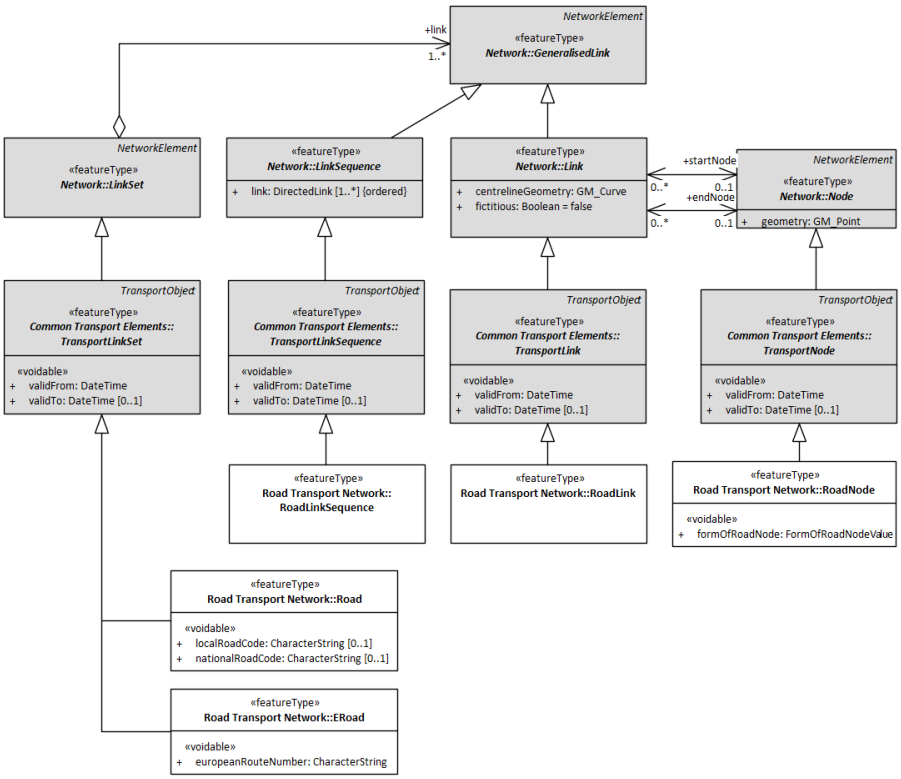

Figure 12. The INSPIRE Road Transport Networks Model with complete inheritance

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TN-ITS

The CEN/TS 17268 has no code values for providing network geometry. However, it is possible to use codes from the INSPIRE Registry for that purpose, as presented bellow.

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/RoadLinkSequence
- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/RoadNode
- RoadFeature.type: https://inspire.ec.europa.eu/featureconcept/RoadLink

The centreline geometry of road links and the point geometry of nodes may be provided with the 'GeometryLocationReference' data type (see Figure 8). However, the network topology is better represented with the full INSPIRE Network model.

5.1.2. Road width

Description

The width of a road segment measured as an average value.

INSPIRE

The INSPIRE model has a feature type, 'RoadWidth', for describing the width of a road segment (either the part of the road reserved for traffic or the paved area).

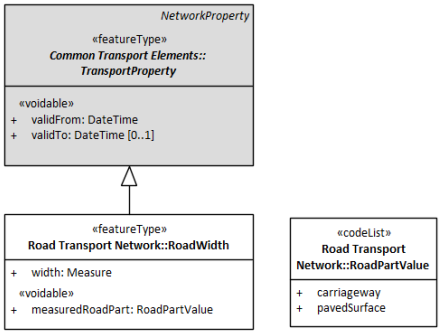

Figure 13. The INSPIRE model for road width

TN-ITS

The CEN/TS 17268 has no code values for providing the width of a road segment. However, codes from the INSPIRE Registry may be used for that purpose:

- RoadFeature.type: https://inspire.ec.europa.eu/featureconcept/RoadWidth
- RoadFeatureProperty.type: https://inspire.ec.europa.eu/codelist/RoadPartValue
- RoadFeatureProperty.valueReference:
  - http://inspire.ec.europa.eu/codelist/RoadPartValue/carriageway
  - http://inspire.ec.europa.eu/codelist/RoadPartValue/pavedSurface

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Suggested extension to TN-ITS Codelists:

Extensions are needed to the TN-ITS Codelists for providing the width value:

- RoadFeaturePropertyType:
  - For the road width property: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#width

5.1.3. Number of lanes

Description

The number of lanes of a road segment.

INSPIRE

The INSPIRE model has a feature type, 'NumberOfLanes', for describing the number of lanes of a road segment. The direction of the counted lanes may also be provided.

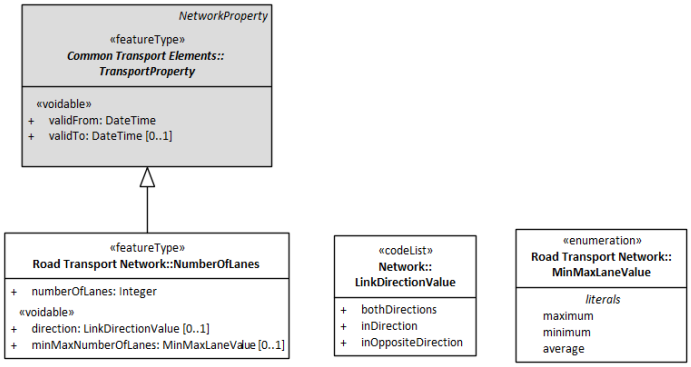

Figure 14. The INSPIRE model for the number of lanes

TN-ITS

The CEN/TS 17268 has no code values for providing the number of lanes, but values are included in the extended code lists maintained by ERTICO:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#numberOfLanes
- RoadFeatureProperty.type
  - For the number of lanes in the direction of the link: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#laneCountInDirection
  - For the number of lanes in the opposite direction: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#laneCountInOppositeDirection
  - For the number of lanes in both directions: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#laneCountBothDirections

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This feature type has a structural difference between the INSPIRE and TN-ITS models. With the INSPIRE model, only one (1) value for the number of lanes can be described for one feature. Two features are needed to describe the number of lanes in each direction on a two-way road segment: One with direction 'inDirection' and one with direction 'inOppositeDirection'. With the TN-ITS code values, one single feature can have values for each direction as different properties, which is an advantage of the TN-ITS model.

5.1.4. Network link gradients

Description

The gradient of rise or fall along a road segment measured as an average value.

INSPIRE

The INSPIRE model has no feature type for gradients, but the information may be derived from the link geometry.

TN-ITS

The CEN/TS 17268 has no code values for providing gradients. However the information may be provided by extending the TN-ITS code lists.

Suggested extension to TN-ITS Codelists:

- RoadFeatureType:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#gradient
- RoadFeaturePropertyType
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#horizontalGradient
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#verticalGradient

5.1.5. Network junctions

Description

Connection facilitating the movement of traffic through a crossing between two or more roads.

Note: When RTTI uses the term "junction", the expected delivery for complex crossings is probably generalized (and numbered/named) intersections or interchanges, not the individual junctions.

INSPIRE

The INSPIRE model has no specific feature type for junctions. The junctions may be derived from the network topology, from road nodes where more than two links are connected. However, this would then be what GDF defines as a junction and not the generalized intersections.

TN-ITS

The CEN/TS 17268 has no code values for providing network junctions. However the information may be provided by extending the TN-ITS code lists.

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Suggested extension to TN-ITS Codelists:

- RoadFeatureType:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#junction
- RoadFeaturePropertyType
  - Junction number: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#junctionNumber
  - Junction name: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#junctionName

5.1.6. Road classification

Description

Classifications of roads according to commonly applied approaches, such as Form of Way, Functional Road Class, Road Name and Road Number.

INSPIRE

The INSPIRE model has several feature types for road classification: 'FunctionalRoadClass', 'FormOfWay', and 'RoadName'. There is no feature type for road numbers.

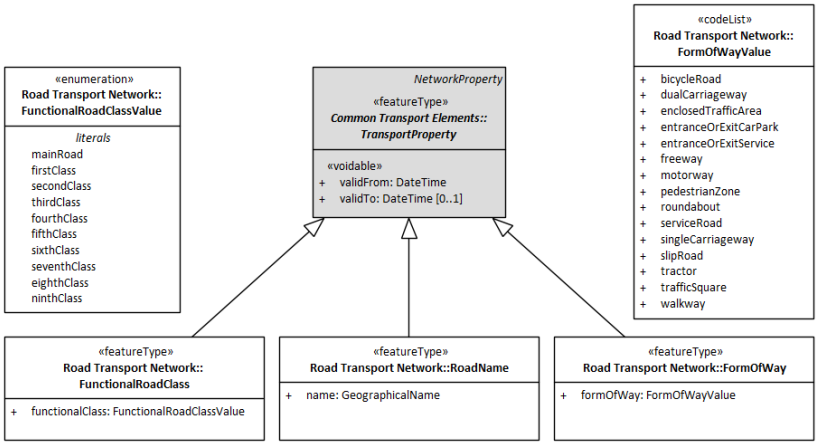

Figure 15. The INSPIRE model for road classifications

TN-ITS

The CEN/TS 17268 has no code values for providing road classifications. However, code values for road names are included in the extended code lists maintained by ERTICO. For functional road class and form of way, INSPIRE values may be used.

Functional Road Class:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/FunctionalRoadClass

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- RoadFeatureProperty.type: https://inspire.ec.europa.eu/enumeration/FunctionalRoadClassValue
- RoadFeatureProperty.valueReference:
  - http://inspire.ec.europa.eu/enumeration/FunctionalRoadClassValue/mainRoad
  - http://inspire.ec.europa.eu/enumeration/FunctionalRoadClassValue/firstClass
  - …
  - http://inspire.ec.europa.eu/enumeration/FunctionalRoadClassValue/ninthClass

Form of way:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/FormOfWay
- RoadFeatureProperty.type: http://inspire.ec.europa.eu/codelist/FormOfWayValue
- RoadFeatureProperty.valueReference:
  - http://inspire.ec.europa.eu/codelist/FormOfWayValue/bicycleRoad
  - http://inspire.ec.europa.eu/codelist/FormOfWayValue/dualCarriageway
  - …
  - http://inspire.ec.europa.eu/codelist/FormOfWayValue/walkway

Road number:

Suggested extension to TN-ITS Codelists:

Extensions for providing road numbers:

- RoadFeature.type:
  - For the feature type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#roadNumber
- RoadFeatureProperty.type
  - For the number property: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#officialNumber

Road name:

Code values for road names are included in the extended code lists maintained by ERTICO:

- RoadFeature.type:
  - For the feature type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#roadName
- RoadFeatureProperty.type
  - For the name property: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#officialName

For improved harmonization and interoperability between INSPIRE and TN-ITS, the INSPIRE feature concept may be used instead of the TN-ITS code value for the road name feature type:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/RoadName

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The INSPIRE RoadName.name property is of a complex type 'GeographicalName', where the actual name is a subproperty 'spelling.text', and additional properties for language, source, status, pronunciation and more may be provided (see Figure 16). This level of detail is probably outside of the scope of RTTI. The existing extension for property type value, 'officialName', may be considered a simplification of a geographical name where the 'nameStatus'='official'. Therefore, the existing extension may be used instead of a more complex INSPIRE structure.

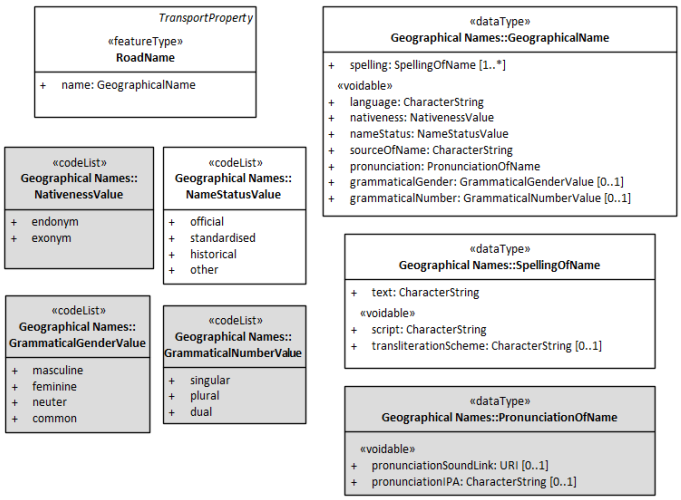

Figure 16. The INSPIRE model for geographical names

Suggested changes to TN-ITS Codelists:

Consider deprecating the extension of code list values

- RoadFeature.type:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#roadName

5.1.7. Tolling stations

Description

The location and nature of toll booths where the road usage is automatically or physically registered and possibly paid.

INSPIRE

The INSPIRE model has no specific feature type for tolling stations. However, tolling stations may be provided as 'RoadServiceType' with 'type' = 'toll' (see Figure 18).

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TN-ITS

The CEN/TS 17268 has the feature type code 'tollStation' for providing toll stations:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#tollStation
- RoadFeatureProperty.type:
  - For the charge: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#fixedCharge
  - For the payment method: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#paymentMethod
- RoadFeatureProperty.valueReference – PaymentMethodCode:
  - http://spec.tn-its.eu/codelists/PaymentMethodCode#cash
  - http://spec.tn-its.eu/codelists/PaymentMethodCode#creditCard
  - http://spec.tn-its.eu/codelists/PaymentMethodCode#electronicTollPayment
  - http://spec.tn-its.eu/codelists/PaymentMethodCode#tollStickers

Besides, the TN-ITS 'Conditions' model can be used for specifying charges for specific vehicle classes, specific hours (e.g., rush hours) and more. For example:

- Small cars
  - VehicleCharacteristics.vehicleType: http://spec.tn-its.eu/codelists/VehicleTypeCode#smallCar
- Large cars:
  - VehicleCharacteristics.vehicleType: http://spec.tn-its.eu/codelists/VehicleTypeCode#largeCar

Time conditions, such as rush hours, are more complex by nature. Typically, rush hours are defined as one time period in the morning and one in the evening every Monday to Friday. In the Conditions model, this can be described by one instance of the datatype 'Period', containing the valid weekdays and the two time periods:

- TimeCondition.validityPeriod.validityTimeSpecification.OverallPeriod.validPeriod.Period with one recurring set of days and two recurring time periods:
  - The days where specific rush hours charges are valid, given with one occurrence of 'recurringDayWeekMonthPeriod' for the instance of Period, with multiple values for 'applicableDay':
    - .recurringDayWeekMonthPeriod.DayWeekMonth.applicableDay: http://spec.tn-its.eu/owl/tnits-owl#DayOfWeek.monday
    - …
    - .recurringDayWeekMonthPeriod.DayWeekMonth.applicableDay: http://spec.tn-its.eu/owl/tnits-owl#DayOfWeek.friday
  - The time period in the morning where specific rush hours charges are valid, given with one occurrence of 'recurringTimePeriodOfDay' with start and end times:
    - .recurringTimePeriodOfDay.TimePeriodOfDay.startTimeOfPeriod: 06:30
    - .recurringTimePeriodOfDay.TimePeriodOfDay.endTimeOfPeriod: 09:00
  - The time period in the evening where specific rush hours charges are valid, given with one occurrence of 'recurringTimePeriodOfDay' with start and end times:
    - .recurringTimePeriodOfDay.TimePeriodOfDay.startTimeOfPeriod: 15:00
    - .recurringTimePeriodOfDay.TimePeriodOfDay.endTimeOfPeriod: 17:00

NOTE: As can be seen in Figure 6, conditions in TN-ITS are related to individual features and not individual properties. Therefore, distinct features are needed for each charge. For example, suppose a

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tolling station has different charges for two vehicle classes (small car and large car) and different charges for rush hours and other times. In that case, four features are needed, each with time conditions for describing the valid time period:

- One for the charge for small cars during regular hours.
- One for the charge for small cars during rush hours
- One for the charge for large cars during regular hours
- One for the charge for large cars during rush hours

If conditions could be related to the properties instead, only one feature would be needed, but then with four occurrences of properties of type 'fixedCharge'. Figure 17 shows a possible model for conditional properties.

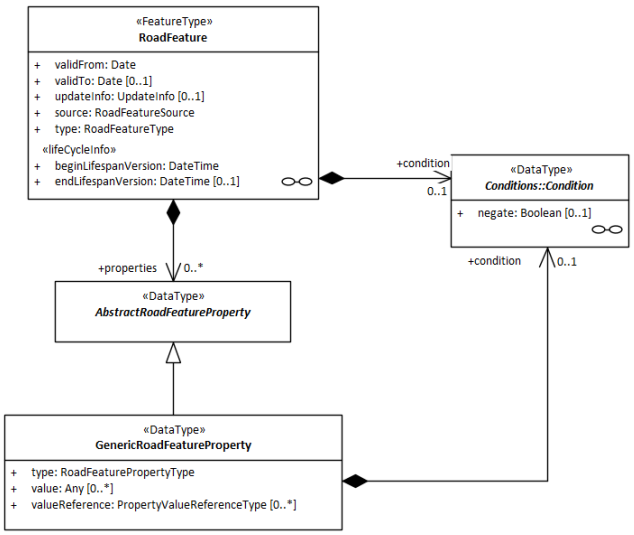

Figure 17. Conditional properties

Suggested improvement of the TN-ITS model:

Add conditions to the GenericRoadFeatureProperty data type.

5.1.8. Service and rest areas

Description

The location of service and rest areas along roads, with available facilities.

INSPIRE

The INSPIRE model has the 'RoadServiceType' feature type to represent service and rest areas. Service areas can be provided as the relevant types 'busStation', 'parking' or 'restArea', and with additional information about types of available facilities.

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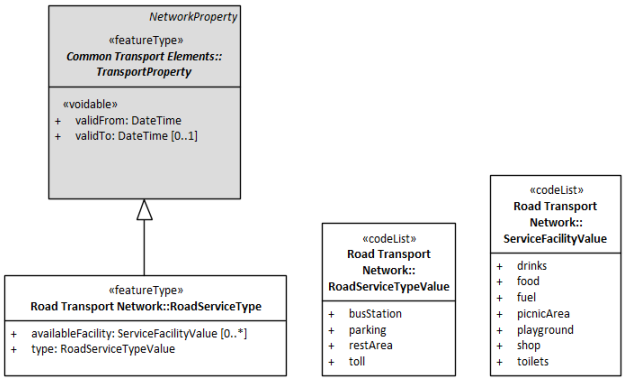

Figure 18. The INSPIRE model for road services

TN-ITS

The CEN/TS 17268 has code values for providing information about parking sites:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#parkingSite
- RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#parkingSite
- RoadFeatureProperty.valueReference – ParkingSiteTypeCode:
  - http://spec.tn-its.eu/codelists/ParkingSiteTypeCode#interUrbanParkingSite
  - http://spec.tn-its.eu/codelists/ParkingSiteTypeCode#specialLocationParkingSite
  - http://spec.tn-its.eu/codelists/ParkingSiteTypeCode#urbanParkingSite

Besides, INSPIRE codes for road services may be used for other services:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/RoadServiceType
- RoadFeatureProperty.type: https://inspire.ec.europa.eu/codelist/ServiceFacilityValue
- RoadFeatureProperty.valueReference:
  - http://inspire.ec.europa.eu/codelist/ServiceFacilityValue/drinks
  - http://inspire.ec.europa.eu/codelist/ServiceFacilityValue/food
  - …
- RoadFeatureProperty.type: https://inspire.ec.europa.eu/codelist/RoadServiceTypeValue
- RoadFeatureProperty.valueReference:
  - http://inspire.ec.europa.eu/codelist/RoadServiceTypeValue/busStation
  - http://inspire.ec.europa.eu/codelist/RoadServiceTypeValue/parking
  - http://inspire.ec.europa.eu/codelist/RoadServiceTypeValue/restArea
  - http://inspire.ec.europa.eu/codelist/RoadServiceTypeValue/toll

Suggested extension to TN-ITS Codelists:

Extensions are needed to the TN-ITS Codelists for providing additional information:

- RoadFeaturePropertyType:
  - Area name: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#areaName

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5.1.9. Recharging and refuelling stations

Description

The location, type and usage conditions of

- Recharging stations for electric vehicles
- Gas stations for CNG, LNG and LPG
- Refuelling stations for all other fuel types

INSPIRE

The INSPIRE model has no specific feature type for recharging and refuelling stations. However, fuel stations may be provided as 'RoadServiceType' with 'availableFacility' = 'fuel' (see Figure 18).

TN-ITS

Recharging stations

The CEN/TS 17268 has code values for providing information about recharging stations:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#chargingPoint
- RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#chargingPointUsageType
- RoadFeatureProperty.valueReference – ChargingPointUsageTypeCode:
    - http://spec.tn-its.eu/codelists/ChargingPointUsageTypeCode#electricBikeOrMotorcycle
    - http://spec.tn-its.eu/codelists/ChargingPointUsageTypeCode#electricVehicle

Refill points for gas

The CEN/TS 17268 has code values for providing information about refill points for gas:

- RoadFeatureType.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#refillPointGas
- RoadFeaturePropertyType.type: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#gasType
- RoadFeatureProperty.valueReference – GasTypeCode
    - All: http://spec.tn-its.eu/codelists/FuelTypeCode#all
    - CNG: http://spec.tn-its.eu/codelists/GasTypeCode#cNG
    - LNG: http://spec.tn-its.eu/codelists/GasTypeCode#lNG
    - LPG: http://spec.tn-its.eu/codelists/LinkDirectionValueCode#lPG
    - Other: http://spec.tn-its.eu/codelists/LoadTypeCode#other

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Refuelling points for other fuel types

The CEN/TS 17268 has no code values for providing information about fuel stations with fossil fuels. However, codes for fuel types are provided for the vehicle conditions part of the conditions model and may be used as value references:

- RoadFeatureProperty.valueReference – FuelTypeCode
  - http://spec.tn-its.eu/codelists/FuelTypeCode#biodiesel
  - http://spec.tn-its.eu/codelists/FuelTypeCode#petrol
  - http://spec.tn-its.eu/codelists/FuelTypeCode#ethanol
  - …and more

Information about fuel stations may be provided by adding a feature type value for refuel points and a property type value for fuel type and then specifying the type of fuel with the fuel type code values.

Suggested extension to TN-ITS Codelists:

Extensions for providing other fuel types:

- RoadFeature.type:
  - For the feature type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#refuelPoint
- RoadFeatureProperty.type
  - For the number property: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#fuelType

Common: Accessibility and payment methods

Accessibility and payment methods are expected to be relevant for all kinds of energy refills for vehicles.

- RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#siteAccessability
- RoadFeatureProperty.valueReference – SiteAccessibillityType
  - http://spec.tn-its.eu/codelists/SiteAccessibilityCode#publicAccessible
  - http://spec.tn-its.eu/codelists/SiteAccessibilityCode#restrictedAccess
  - http://spec.tn-its.eu/codelists/SiteAccessibilityCode#unspecified

- RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#paymentMethod
- RoadFeatureProperty.valueReference – PaymentMethodCode:
  - http://spec.tn-its.eu/codelists/PaymentMethodCode#cash
  - http://spec.tn-its.eu/codelists/PaymentMethodCode#creditCard

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Suggested extension to TN-ITS Codelists:

Extensions for payment methods:
New payment methods such as RFID chips, mobile apps and electronic sign recognition may be added to the code list for payment methods (http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#paymentMethod).

Suggested extension to TN-ITS Codelists:

Extensions for providing additional information:

- RoadFeaturePropertyType:
  - Operator name: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#operatorName

5.1.10. Delivery areas

Description

Not clearly defined. Has been interpreted as storage and transfer points, pick-up points or loading zones.

INSPIRE

The INSPIRE model has no specific feature type for delivery areas.

TN-ITS

The CEN/TS 17268 has no code values for providing information about delivery areas. However, the information can be supported by adding a new feature type value for delivery area, alongside a feature property type value for area type and a code list for area type values.

Suggested extension to TN-ITS Codelists:

Extensions for providing road numbers:

- RoadFeature.type:
  - Delivery area: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#deliveryArea
- RoadFeatureProperty.type
  - Delivery Area type: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#deliveryAreaType
- Code list for delivery area types: http://spec.tn-its.eu/codelists/DeliveryAreaTypeCode
- Possible code values for delivery area types (needs further discussion):
  - Transfer point
  - Unserviced boxes for private pickup (‘instaboxes’)
  - Storage/depot
  - Loading zone
  - …

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Besides, the existing property and code list for accessibility may be used as in the following example:

- RoadFeatureType.type – Delivery area:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#deliveryArea
- RoadFeaturePropertyType.type – Delivery area type:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#deliveryAreaType
- RoadFeatureProperty.valueReference – Loading zone:
  - http://spec.tn-its.eu/codelists/DeliveryAreaTypeCode#loadingZone
- RoadFeatureProperty.type – Site accessibility:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#siteAccessability
- RoadFeatureProperty.valueReference – Publicly accessible:
  - http://spec.tn-its.eu/codelists/SiteAccessibilityCode#publicAccessible

5.2. Crucial restrictions

5.2.1. Access conditions

Description

Permanent, legal or physical limitations for accessing road segments, including

- Tunnels (2.a.i)
- Bridges (2.a.ii)
- Other permanent restrictions (2.a.iii)
- NOTE: Overlap to some extent with access conditions (2.a.i-iii). See section 5.2.5.

INSPIRE

The INSPIRE model has the general feature type 'AccessRestriction' to represent restrictions on access to a transport element. Besides, the model has a feature type, 'RestrictionForVehicles', which will be discussed in section 5.2.5.

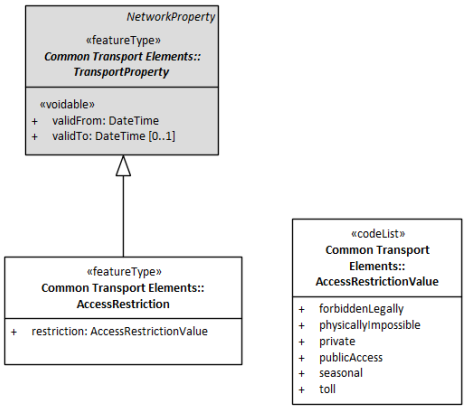

Figure 19. The INSPIRE model for access restrictions

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TN-ITS

The CEN/TS 17268 has the feature type code 'closedToAllVehiclesInBothDirections', which can be used without any properties:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#closedToAllVehiclesInBothDirections

NOTE: "Closed to all vehicles in both directions" is a specific restriction that could be better described with a more generic access restriction (like in INSPIRE). The TN-ITS conditions model could then define appropriate directions and vehicle categories.

Besides, the feature type code 'tollRoad' describes tolled roads (See also section 5.3.3.):

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#tollRoad

NOTE: "Tolled roads" overlaps the scope of the INSPIRE code value "toll".

No other code values for providing access restrictions exist in the TN-ITS code lists. However, codes from the INSPIRE Registry may be used for that purpose:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/AccessRestriction
- RoadFeatureProperty.type: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue
- RoadFeatureProperty.valueReference:
    - Access is forbidden by law: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/forbiddenLegally
    - Access impossible due to the presence of barriers or other physical obstacles: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/physicallyImpossible
    - Access restricted because of private ownership: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/private
    - Open to public access: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/publicAccess
    - Access depends on the season: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/seasonal
    - Access is subject to toll: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/toll

Besides these classifications of access restrictions, the conditions model in TN-ITS may be used for relating access restrictions to special times, vehicle types and more.

As noted, there is an overlap between the code values for TN-ITS and INSPIRE for this category. The INSPIRE model is more generic and concerns the type of restriction, while the TN-ITS values are specific. For harmonization, it would be better if TN-ITS reused values from the INSPIRE Registry instead of having its own.

Suggested changes to TN-ITS Codelists:

Consider deprecating the code list values

- RoadFeature.type:
    - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#closedToAllVehiclesInBothDirections
    - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#tollRoad

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5.2.2. Speed limits

Description

Speed limits for road segments.

INSPIRE

The INSPIRE model has the 'SpeedLimit' feature type representing speed limits for road segments. Speed limit features can be provided with only the speed limit and its type or as a more detailed feature that includes the conditions where the speed limit is valid: area type, direction, lane, time period, vehicle type and weather conditions.

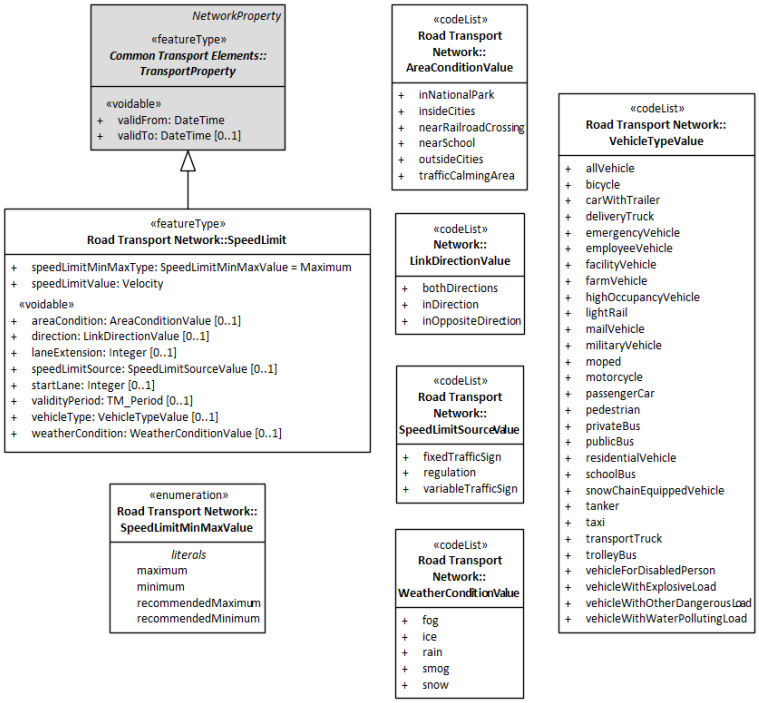

Figure 20. The INSPIRE model for speed limits

TN-ITS

The CEN/TS 17268 has two options for providing speed limit features:

- As speed limits for road segments:
  - RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#speedLimit
- Alternatively, as the start- and stop points for the speed limit:
  - RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#startOfSpeedLimit

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  - RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#endOfSpeedLimit

Like in the INSPIRE model, different types of speed limits may be provided:

- Regular (maximum) speed limits:
  - RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#maximumSpeedLimit
- Recommended (advisory) maximum speed:
  - RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#advisorySpeed
- Compulsory minimum speed:
  - RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#compulsoryMinimumSpeed

Besides these classifications of speed limits, the conditions model in TN-ITS may be used for describing special conditions when the speed limit is valid. Compared to the INSPIRE model for speed limits, the conditions model in TN-ITS is more flexible and provides more opportunities for describing complex conditions.

5.2.3. Freight delivery regulations

Description

Regulations for delivering freight in restricted road segments or areas.

INSPIRE

The INSPIRE model has no specific feature type for freight delivery regulations that fits the definition above.

TN-ITS

The CEN/TS 17268 has no code values for providing freight delivery regulations. However, a combination of the INSPIRE model for access restrictions and the TN-ITS model for conditions may be used:

- The feature type:
  - RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/AccessRestriction
- The property type:
  - RoadFeatureProperty.type: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue
- The value reference for access forbidden by law:
  - RoadFeatureProperty.valueReference: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/forbiddenLegally

The TN-ITS model for conditions may be used to describe that the restriction concerns (or is an exception for) a ‘vehicleUsage’ = ‘cityLogistics’ at specific times, as well as other conditions such as valid time periods.

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5.2.4. Overtaking bans for heavy vehicles

Description

Road segments where overtaking is forbidden for heavy vehicles.

INSPIRE

The INSPIRE model has no specific feature type for overtaking bans that fit the description above.

TN-ITS

The CEN/TS 17268 has the feature type code 'prohibitionOfOvertaking' for overtaking bans, which can be used without any properties:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#prohibitionOfOvertaking

Besides, the conditions model in TN-ITS may be used for relating bans to vehicle characteristics, time periods and more. For example, for simply specifying heavy vehicles:

- VehicleCharacteristics.vehicleType: http://spec.tn-its.eu/codelists/VehicleTypeCode#heavyVehicle

5.2.5. Vehicle weight and extent restrictions

Description

Road segments where access is restricted due to vehicle weight, length, width, or height.

NOTE: Overlap to some extent with access conditions (2.a.i-iii). See section 5.2.1.

INSPIRE

The INSPIRE model has the general feature type 'RestrictionForVehicles' for restrictions on the use of a transport element. Restrictions are described with a type and a measured value.

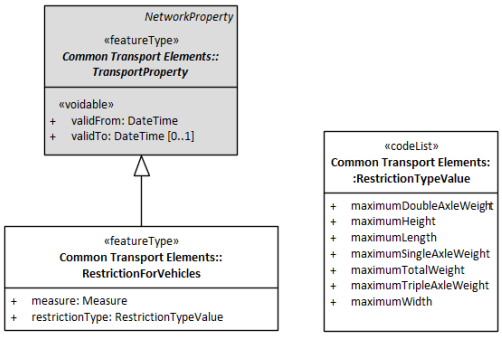

Figure 21. The INSPIRE model for restrictions for vehicles

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TN-ITS

The CEN/TS 17268 has a similar model as INSPIRE for restrictions concerning weight and extent, with the feature type 'restrictionForVehicles' with additional property types for the different kinds of restrictions:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#restrictionForVehicles
- RoadFeatureProperty.type – Maximum height:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumHeight
- RoadFeatureProperty.type – Maximum length:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumLength
- RoadFeatureProperty.type – Maximum single axle weight:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumWeightPerSingleAxle
- RoadFeatureProperty.type – Maximum laden weigth:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumLadenWeight
- RoadFeatureProperty.type – Maximum width:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumWidth

As can be seen, there is not a 1:1 relationship between the code values for TN-ITS and INSPIRE on this category. INSPIRE has more values for weight restrictions related to the number of axles. For harmonization, it would be better if TN-ITS reused values from the INSPIRE Registry instead of having its own:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/RestrictionForVehicles
- RoadFeatureProperty.type:
  - http://inspire.ec.europa.eu/featureconcept/RestrictionTypeValue/maximumDoubleAxleWeight
  - http://inspire.ec.europa.eu/featureconcept/RestrictionTypeValue/maximumHeight
  - http://inspire.ec.europa.eu/featureconcept/RestrictionTypeValue/maximumLength
  - http://inspire.ec.europa.eu/featureconcept/RestrictionTypeValue/maximumSingleAxleWeight
  - http://inspire.ec.europa.eu/featureconcept/RestrictionTypeValue/maximumTotalWeight
  - http://inspire.ec.europa.eu/featureconcept/RestrictionTypeValue/maximumTripleAxleWeight
  - http://inspire.ec.europa.eu/featureconcept/RestrictionTypeValue/maximumWidth

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Suggested chenges to TN-ITS Codelists:

Consider deprecating the code list values

- RoadFeature.type:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#restrictionForVehicles
- RoadFeatureProperty.type
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumHeight
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumLength
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumWeightPerSingleAxle
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumLadenWeight
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#maximumWidth

5.2.6. One-way streets

Description

Road segments where traffic is allowed in only one direction.

INSPIRE

The INSPIRE model has the feature type 'TrafficFlowDirection' for representation of the allowed direction of flow. One-way streets can be defined with 'direction' = 'inDirection' or 'inOpositeDirection'.

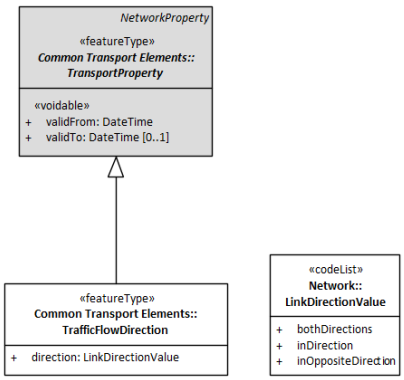

Figure 22. The INSPIRE model for traffic flow direction

TN-ITS

The CEN/TS 17268 has no code values for providing the allowed flow direction on a road segment. However, codes from the INSPIRE Registry may be used for that purpose:

- RoadFeature.type: https://inspire.ec.europa.eu/featureconcept/TrafficFlowDirection

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- RoadFeatureProperty.type: https://inspire.ec.europa.eu/codelist/LinkDirectionValue
- RoadFeatureProperty.valueReference:
  - https://inspire.ec.europa.eu/codelist/LinkDirectionValue/bothDirections
  - https://inspire.ec.europa.eu/codelist/LinkDirectionValue/inDirection
  - https://inspire.ec.europa.eu/codelist/LinkDirectionValue/inOppositeDirection

Besides, the conditions model in TN-ITS may be used for allowing excepts for specific traffic groups such as bicycles:

- VehicleCharacteristics.vehicleType: http://spec.tn-its.eu/codelists/VehicleTypeCode#bicycle
- VehicleCharacteristics.negate (inherited from Condition): True (the condition concerns all vehicles except bicycles)

Also, schedules for reversible lanes may be handled by the conditions model. Ref section 5.2.8.

5.2.7. Restriction zones

Description

Boundaries and conditions for zones where restrictions, prohibitions or obligations apply for all road sections.

NOTE: Overlap to some extent with other categories, such as access conditions (2.a.i-iii), speed limits (2.a.iv) and freight delivery regulations (2.a.v).

INSPIRE

The INSPIRE model has no mechanisms for providing restriction zones. All features are positioned in the network with linear references. In theory, linear references can point to a network area, but linear referencing to areas is not clearly defined. Another option is to position a feature on all road sections where the feature shall apply. However, this would lead to a long list of location references for a feature.

TN-ITS

One feature type defined in the TN-ITS code lists specifically concerns restriction zones: Residential areas. These areas may have implicit restrictions, such as speed limits, defined by national or regional regulations.

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#residentialArea

Besides, any restriction provided as a feature according to the TN-ITS model can be positioned with any one or several of the defined location referencing types. Features describing restriction zones can typically have location references as area geometries ('GeometryLocationReference') or by using references to externally defined zone polygons, such as city limits ('LocationByExternalReference').

- RoadFeature.locationReference.GeometryLocationReference.encodedGeometry: Any type of geometry
- RoadFeature.locationReference.LocationByExternalReference.predefinedLocationReference: Any URI

Therefore, any restriction provided by TN-ITS can be described as restriction zones. Besides, the conditions model in TN-ITS may express additional conditions, such as when the restrictions are valid (or not).

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5.2.8. Reversible lanes

Description

Road segments with reversible lanes, including the schedule for the direction of travel.

INSPIRE

The INSPIRE model has no specific feature type for reversible lanes as described above, only the static TrafficFlowDirection described in section 5.2.6.

TN-ITS

The CEN/TS 17268 has no code values for providing reversible lanes. However, the INSPIRE codes for TrafficFlowDirection (see section 5.2.6) may be used in combination with TN-ITS conditions (time validity and lane condition) for describing schedules for the distinct travel directions. Schedules are similar to rush hour times, as shown in the example in section 5.1.7.

For example, for a reversible lane with number = 3, going in one direction in the morning and the opposite direction in the evening:

- RoadFeature.type: https://inspire.ec.europa.eu/featureconcept/TrafficFlowDirection
- RoadFeatureProperty.type: https://inspire.ec.europa.eu/codelist/LinkDirectionValue
- RoadFeatureProperty.valueReference:
    - https://inspire.ec.europa.eu/codelist/LinkDirectionValue/inDirection
    - Or https://inspire.ec.europa.eu/codelist/LinkDirectionValue/inOppositeDirection

Lane condition:

- LaneCondition.startLane = 3
- LaneCondition.laneExtension= 1

Time condition (morning):

- TimeCondition.validityPeriod.validityTimeSpecification.OverallPeriod.validPeriod.Period with one recurring set of days and one recurring time period:
    - The days where the schedule is valid, given with one occurrence of 'recurringDayWeekMonthPeriod' for the instance of Period, with multiple values for 'applicableDay':
        - .recurringDayWeekMonthPeriod.DayWeekMonth.applicableDay: http://spec.tn-its.eu/owl/tnits-owl#DayOfWeek.monday
        - …
        - .recurringDayWeekMonthPeriod.DayWeekMonth.applicableDay: http://spec.tn-its.eu/owl/tnits-owl#DayOfWeek.friday
    - The time period in the morning where the schedule is valid, given with one occurrence of 'recurringTimePeriodOfDay' with start and end times:
        - .recurringTimePeriodOfDay.TimePeriodOfDay.startTimeOfPeriod: 00:00
        - .recurringTimePeriodOfDay.TimePeriodOfDay.endTimeOfPeriod: 12:30

Time condition (evening):

- TimeCondition.validityPeriod.validityTimeSpecification.OverallPeriod.validPeriod.Period with one recurring set of days and one recurring time period:

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- The days where the schedule is valid, given with one occurrence of 'recurringDayWeekMonthPeriod' for the instance of Period, with multiple values for 'applicableDay':
  - .recurringDayWeekMonthPeriod.DayWeekMonth.applicableDay: http://spec.tn-its.eu/owl/tnits-owl#DayOfWeek.monday
  - …
  - .recurringDayWeekMonthPeriod.DayWeekMonth.applicableDay: http://spec.tn-its.eu/owl/tnits-owl#DayOfWeek.friday
- The time period in the morning where the schedule is valid, given with one occurrence of 'recurringTimePeriodOfDay' with start and end times:
  - .recurringTimePeriodOfDay.TimePeriodOfDay.startTimeOfPeriod: 13:00
  - .recurringTimePeriodOfDay.TimePeriodOfDay.endTimeOfPeriod: 23:30

NOTE: As described for Tolling stations in section 5.1.7, conditions in TN-ITS are related to individual features, not individual properties. Therefore, different features are needed for the different direction schedules. If conditions could be related to the properties instead, only one feature would be required, with one occurrence of the property "LinkedDirectionValue" for each period.

Suggested improvements of the to TN-ITS model:

Add conditions to the GenericRoadFeatureProperty data type.

5.2.9. Traffic circulation plans

Description

Information such as network guidance or enclose of the elements of TMPs and UVARs. This category requires further analysis and breakdown.

5.3. Other restrictions

5.3.1. Traffic signs reflecting regulations and dangers

Description

The location and type of traffic signs reflecting regulations and dangers concerning

- Access to tunnels (3.a.i)
- Access to bridges (3.a.ii)
- Other permanent access restrictions (3.a.iii)
- Other traffic regulations (3.a.iv)

NOTE: Represents the sign position for restrictions defined in 2.a.

INSPIRE

The INSPIRE model has no feature type for traffic signs.

TN-ITS

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The CEN/TS 17268 TN-ITS model has a generic feature type, 'roadSign', and an accompanying specific data type, 'RoadSignProperty', for providing road signs and their content:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#roadSign

The RoadSignProperty data type contains properties for describing the kind of road sign with international codes from ISO 14823 Graphic data dictionary – GDD (ISO/TC 204, 2017) and the content as a value and/or text. Figure 23 shows the TN-ITS Road sign model.

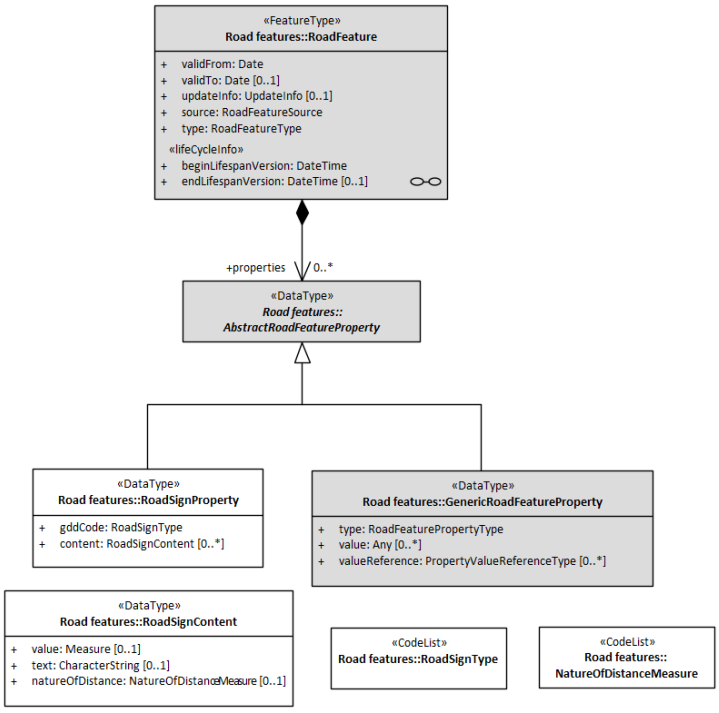

Figure 23. The TN-ITS Road sign model

Based on the model, any sign defined in the ISO 14823 dictionary can be provided, for example, for a sign with category 12, pictogram 421, which defines no access for goods vehicles:

- RoadSignProperty.gddCode = http://spec.tn-its.eu/codelists/RoadSignTypeCode#12_421
- RoadSignProperty.content.RoadSignContent:
  - text = some possible additional description, such as weight limit.

Road signs that are not defined in the GDD can be described with the GenericRoadFeatureProperty:

- GenericRoadFeatureProperty.type = http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#roadSignType
- GenericRoadFeatureProperty.value = (The type of sign and its content)

Besides, the conditions model in TN-ITS may be used to describe additional conditions, such as when the restrictions defined by the sign are valid (or not valid) or weight limits for heavy vehicles.

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5.3.2. Other traffic regulations

Description

Road segments with other, not specified traffic regulations.

INSPIRE

The INSPIRE model has no additional feature types for traffic restrictions except those already described.

TN-ITS

The CEN/TS 17268 has several feature-type codes for restrictions that may fit this category:

- Mandatory routes or turns to be followed: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#directionToBeFollowed
- Motorway with implicit restrictions: http://spec.tn-its.eu/codelists/RoadCategoryCode#motorway
- Blocked road sections: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#noEntry
- Stopping prohibited: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#passingWithoutStoppingProhibited
- Prohibited turn: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#prohibitedTurn
- Road for motor vehicles: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#roadForMotorVehicles
- Snow chains compulsory: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#snowChainsCompulsory
- Prohibition on the use of audible warning devices: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#useOfAudibleWarningDevicesProhibited

These feature types are mostly provided without additional properties but possibly with time or vehicle category conditions.

5.3.3. Tolling and road user charges

Description

Road segments with tolling (3.c) or road user charges (3.d), including fixed and variable charges and payment methods.

NOTE: Represents the segments related to tolling stations defined in 1.c.

INSPIRE

The INSPIRE model has no feature type for tolling, except for tolling as a general access restriction, as described in section 5.2.1.

TN-ITS

The CEN/TS 17268 has the feature type code 'tollRoad' for tolled roads. Charges and payment methods can be provided with the same properties and conditions as for tolling stations, as described in section 5.1.7.

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#tollRoad

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NOTE: As described for access restrictions in section 5.2.1, there is an overlap between the TN-ITS code value 'tollRoad' and the INSPIRE model for access restrictions. It would be preferable for harmonization if TN-ITS would reuse INSPIRE values:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/AccessRestriction
- RoadFeatureProperty.type: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue
- RoadFeatureProperty.valueReference:
    - Access is subject to toll: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/toll

Suggested changes to TN-ITS Codelists:

Consider deprecating the code list values

- RoadFeature.type:
    - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#tollRoad

NOTE: As described for tolling stations and reversible lanes, a possible improvement of the model would be to add relations between conditions and properties in addition to the existing relation between conditions and features.

Suggested improvements of the TN-ITS model:

Add conditions to the GenericRoadFeatureProperty data type.

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6. Input from TN-ITS GO and TN-ITS WG 2

6.1. Suggested extensions

Several suggested extensions of the TN-ITS code lists have been collected from countries through the TN-ITS GO project and the continuous work in TN-ITS Working Group 2. The following list summarises the suggested extensions and references to RTTI Data categories.

The analysis in section 5 handles some of the suggestions, which are not further discussed in this report. For the other suggestions, a more detailed description of a suggested implementation is given in the next section.

Proposer	Suggestion	Reference to RTTI	Reference to section 5
Portugal	Road names	1.b	5.1.6
Portugal	Road numbers	1.b	5.1.6
Portugal	Road length		
Germany	Bicycle lanes, for bike maps		
Sweden	Carry capacity of the road	2.a.vii	
Sweden	Number of lanes	1.a.iii	5.1.3
Sweden	Restriction zones	2.a.ix	5.2.7
Sweden	Dynamic speed limits	2.a.iv	
Sweden	Maintenance Authority		
Sweden	Road surface		
Sweden	Intersection	1.a.v	5.1.5
Sweden	Physical barriers		
Sweden	U-turn possibility		
Sweden	Mandatory stop	3.a.iv	
Finland	maximumWeightPerTwoAxesBogie	2.a.vii	5.2.5
Finland	maximumWeightPerThreeAxesBogie	2.a.vii	5.2.5
Lithuania	Time validity information for seasonal speed limits	2.a.iv	
Flanders	Additional road signs	3.a.iv	5.3.1
TN-ITS	Additional road signs for ISA	3.a.iv	5.3.1
TN-ITS	ISAD Levels		

Table 2. Suggested extensions from TN-ITS GO and TN-ITS WG 2

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6.2. Implementation of suggestions

6.2.1. Road length

Neither the INSPIRE model nor the CEN/TS 17268 has any feature types for describing the length of a road segment. However, a code value for road length is included in the extended feature property code lists maintained by ERTICO:

- RoadFeatureProperty.type
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#roadLength

Suggested extension to TN-ITS Codelists:

A code value for a road length feature type is needed in addition to the property:

- RoadFeature.type: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#roadLength

6.2.2. Road surface

The INSPIRE model has a feature type, 'RoadSurfaceCategory', for the specification of the state of the surface of a road segment. The property 'surfaceCategory' describes whether a road is paved or unpaved.

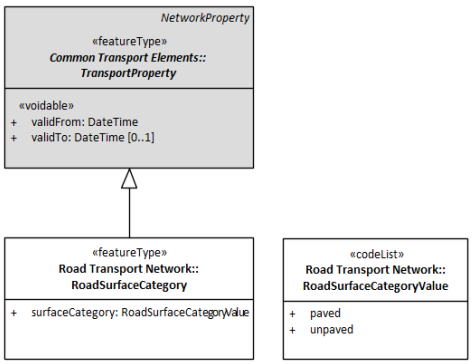

Figure 24. The INSPIRE model for road surface

The CEN/TS 17268 has no code values for providing road surface information. For this purpose, the codes from the INSPIRE Registry may be used:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/RoadSurfaceCategory
- RoadFeatureProperty.type: http://inspire.ec.europa.eu/codelist/RoadSurfaceCategoryValue
- RoadFeatureProperty.valueReference:
  - http://inspire.ec.europa.eu/codelist/RoadSurfaceCategoryValue/paved
  - http://inspire.ec.europa.eu/codelist/RoadSurfaceCategoryValue/unpaved

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Suggested extension to TN-ITS Codelists:

If more details on the type of pavement are needed, additional properties and accompanying code list values will be needed, possibly from other sources.

6.2.3. Maintenance Authority

The INSPIRE model has a feature type, 'MaintenanceAuthority', for specification of the authority responsible for maintenance of the transport element. The property 'authority' identifies the authority through the data type 'CI_Citation' from the standard ISO 19115 Metadata.

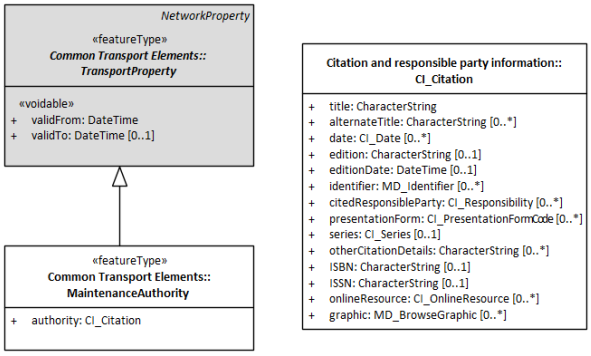

Figure 25. The INSPIRE model for maintenance authority.

The CEN/TS 17268 has no code values for providing information on maintenance authority. For this purpose, the feature types from the INSPIRE Registry may be used:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/MaintenanceAuthority

Suggested extension to TN-ITS Codelists:

A code value for the authority property is needed in addition:

- RoadFeatureProperty.type
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#authority

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6.2.4. Bicycle lanes

The request for describing bicycle lanes was raised for the purpose of producing bike maps. I practice, paths for bicycling can be separated into two categories:

1. Specific bicycle roads (or combined pedestrian/bicycle)

The INSPIRE model for Form of way can describe bicycle roads:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/FormOfWay
- RoadFeatureProperty.type: http://inspire.ec.europa.eu/codelist/FormOfWayValue
- RoadFeatureProperty.valueReference:
  - Bicycle road: http://inspire.ec.europa.eu/codelist/FormOfWayValue/bicycleRoad
  - Pedestrian zone: http://inspire.ec.europa.eu/codelist/FormOfWayValue/pedestrianZone
  - Walkway: http://inspire.ec.europa.eu/codelist/FormOfWayValue/walkway

NOTE: The rules for riding bicycles on walkways and in pedestrian zones may differ between countries.

2. Bicycle lanes as part of a regular road

Regular roads, as well as walkways, can have reserved lanes for bicycles. Similarly, specific lanes for other road users may exist as well, such as lanes for public transport or heavy vehicles. Therefore, a methodology for describing bicycle lanes should be generic and possible to use for other lane usages as well.

The DATEX II model (https://docs.datex2.eu/v3.0/level2user/level2UMLdatamodel.html) has a supplementary positional descriptions model which includes mechanisms for positioning published information to specific lanes, as shown in Figure 26.

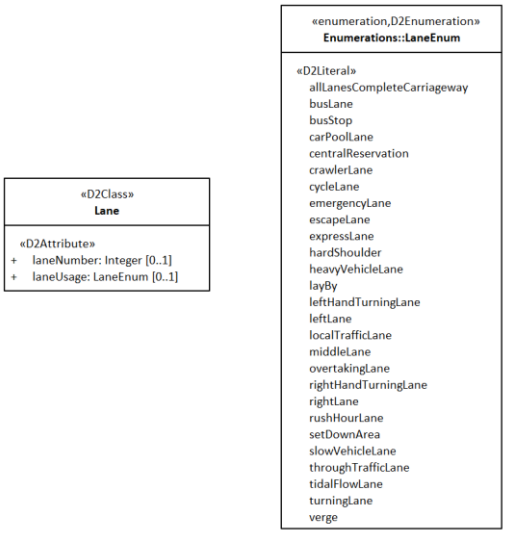

Figure 26. The DATEX II Lane model for supplementary positioning.

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The structure in the DATEX II Lane model may be adapted into TN-ITS as well and may then be used for two different purposes:

- For location referencing on lane level, like in DATEX II, or
- For describing what kind of lanes exist on a road segment, such as bicycle lanes.

The model can easily be adapted into TN-ITS Code lists, with a feature type for lanes, properties for lane number and lane usage, and a code list for usage codes. With these extensions, a TN-ITS RoadFeature may be defined as a Lane, with properties and code values describing the numbering of the specific lane and for what it is used.

NOTE: Alternatively, if the DATEX II elements had been available in separate files with unique identifiers for each value (like the INSPIRE code values), they could be referred to directly instead of extending the TN-ITS code lists. Unfortunately, the DATEX II values are packed into the DATEX II XML Schemas.

Suggested extension to TN-ITS Codelists:

Adapt the DATEX II Lane model into TN-ITS core values:

- RoadFeature.type for lane information:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#lane
- RoadFeatureProperty.type for lane numbering:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#laneNumber
- RoadFeatureProperty.type for lane usage:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#laneUsage
- New code list for lane usage: http://spec.tn-its.eu/codelists/LaneUsageCode
- Code values for RoadFeatureProperty.valueReference, duplicating the values from the LaneEnum code list in DATEX II (see Figure 26):
  - http://spec.tn-its.eu/codelists/LaneUsageCode#...
  - http://spec.tn-its.eu/codelists/LaneUsageCode#busLane
  - http://spec.tn-its.eu/codelists/LaneUsageCode#...
  - http://spec.tn-its.eu/codelists/LaneUsageCode#cycleLane
  - http://spec.tn-its.eu/codelists/LaneUsageCode#...

6.2.5. Carry capacity

Information about the carry capacity of roads and bridges is an essential part of route planning for heavy vehicles. For example, in the Nordic countries, the information is used for route planning for timber transport. The classification is closely related to restrictions for weight (ref 5.2.5) but describes groups and exceptions for such restrictions in classes. Furthermore, the classification seems to be individually defined in distinct countries. For example, in Sweden, four categories are used:

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- BK1 Max 64 tonnes gross weight is allowed. The permissible gross weight may be lower depending on the vehicle's wheelbase and axle pressure.
- BK2 Max 51.4 tonnes gross weight. The permissible gross weight may be lower
- depending on the vehicle's wheelbase and axle pressure.
- BK3 Max 37.5 tonnes gross weight. The permissible gross weight may be lower
- depending on the vehicle's wheelbase and axle pressure.
- BK4 Max 74 tons gross weight with unchanged axle pressure requirements compared to BK1, but the permitted gross weight may be lower depending on the vehicle's wheelbase.

Neither the INSPIRE model nor the CEN/TS 17268 has any feature types for describing such classifications. A new generic feature type code for road classification along with a property type code for carry capacity may be used, along with code values for carry capacity classes. However, since the classifications are defined for individual countries, a common code list is probably not appropriate.

Suggested extension to TN-ITS Codelists:

- RoadFeature.type for road classification:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#roadClassification
- RoadFeatureProperty.type for carry capacity:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#carryCapacity
- Each nation will need to define code lists for the classification; for example
  - http://someSwedishUri/codelists/Barighetsklasse
- Code values for RoadFeatureProperty.valueReference in national code lists:
  - http://someSwedishUri/codelists/Barighetsklasse#BK1
  - http://someSwedishUri/codelists/Barighetsklasse#BK2
  - http://someSwedishUri/codelists/Barighetsklasse#BK3
  - http://someSwedishUri/codelists/Barighetsklasse#BK4

6.2.6. Physical barriers

Physical barriers are typically placed, for example, at the entrance of private roads to the forest or the entrance of a pedestrian zone. There is a significant difference between a legal restriction and a physical barrier: A legal restriction can be ignored in a case of emergency, while a physical barrier may be more challenging. This difference, and whether it is possible at all to pass through a road section blocked by a physical barrier, must be reflected in the information provided by authorities. **Error! Reference source not found.**~~**Fout! Verwijzingsbron niet gevonden.**~~Figure 27 shows an example of a physical barrier on a forest road in Sweden that may be opened with a key and where emergency vehicles can be equipped with such a key. The text below the sign says that the restriction does not apply to necessary traffic.

As discussed in section 5.2.1, INSPIRE and TN-ITS have feature types for access restrictions. It is suggested to remove two TN-ITS code values and use the INSPIRE feature type 'AccessRestriction' also in TN-ITS. The INSPIRE code list for access restrictions ('AccessRestrictionValue') contains values for legal as well as physical restrictions and may be used for providing information about the physical barrier.

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In addition, a property for barrier type with accompanying code values could be applied to include information about whether the physical barrier is possible to pass — for example, values 'lockedWithKey', 'permanent', 'remoteControl' etc.

Figure 27. Example of a physical barrier in Sweden

An example physical barrier may then be described as listed:

- RoadFeature.type: http://inspire.ec.europa.eu/featureconcept/AccessRestriction
- RoadFeatureProperty.type: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue
- RoadFeatureProperty.valueReference:
  - Access impossible due to the presence of barriers or other physical obstacles: http://inspire.ec.europa.eu/codelist/AccessRestrictionValue/physicallyImpossible
- RoadFeatureProperty.type: http://spec.tn-its.eu/codelists/barrierType
- RoadFeatureProperty.valueReference:
  - Locked with key: http://spec.tn-its.eu/codelists/BarrierTypeCode#lockedwithKey

Suggested extension to TN-ITS Codelists:

- RoadFeatureProperty.type for barrier type:
  - http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#barrierType
- Code list for barrier types:
  - http://spec.tn-its.eu/codelists/BarrierTypeCode
- Code values for RoadFeatureProperty.valueReference in national code lists:
  - http://spec.tn-its.eu/codelists/BarrierTypeCode#lockedWithKey
  - http://spec.tn-its.eu/codelists/BarrierTypeCode#permanent
  - http://spec.tn-its.eu/codelists/BarrierTypeCode#remoteControl
  - …

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6.2.7. U-turn possibility

Neither the INSPIRE model nor the CEN/TS 17268 has any feature types for describing where U-turns are possible. The TN-ITS code list for feature types has a value for the inverse situation: Prohibited turn (http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#prohibitedTurn). A similar feature type may also be used for U-turn possibilities, possibly with conditions for defining (e.g.) specific times when U-turns are allowed.

Suggested extension to TN-ITS Codelists:

- RoadFeature.type for U-turns:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#uTurnPossible

6.2.8. Mandatory stop

An intersection with a mandatory stop is a stricter version of the duty to give way. In the RTTI DR, such a restriction may be considered "other traffic regulations" (3.a.iv). Neither the INSPIRE model nor the CEN/TS 17268 has any feature types for describing this restriction.

A similar solution as the one suggested for U-Turns may be used for a mandatory full stop.

Suggested extension to TN-ITS Codelists:

- RoadFeature.type for mandatory full stop:
  - http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#fullStopMandatory

6.2.9. Variable speed limits

The main scope of TN-ITS is information that can be considered relatively static, such as specified speed limits for a road section. However, also variable speed limits have a static nature if they follow a defined regularity. Examples can be speed limits near schools, where the speed limit is set to a lower value in the time around the start and end of school days, weather-conditioned speed limits, speed limits for snow or icy roads, or seasonal speed limits.

Variable speed limits with a defined regularity may be described in TN-ITS by adding conditions to a RoadFeature. As has been described for tolling stations (5.1.7) and reversible lanes (5.2.8), different speed limit features will be needed, each with validity conditions.

For example:

1. Regular variation during weekdays

For speed limits near schools, there will typically be one speed limit for the morning and evening when extra care needs to be taken and one speed limit for the rest of the day.

Regular speed limit

- Property: maximumSpeedLimit (example value 50 km/h)

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- TimeCondition – validity period (exemption, meaning that the feature is valid at all times except in the given periods):
    - Morning period: Period with a set of recurring days (Monday-Friday) and one recurring time period (07:00-09:00)
    - Evening period: Period with a set of recurring days (Monday-Friday) and one recurring time period (14:00-17:00)

Reduced speed limit

- Property: maximumSpeedLimit (example value 40 km/h)
- TimeCondition – validity period:
    - Morning period: Period with a set of recurring days (Monday-Friday) and one recurring time period (07:00-09:00)
    - Evening period: Period with a set of recurring days (Monday-Friday) and one recurring time period (14:00-17:00)

2. Weather-related variations

Speed limits that are defined for specific weather conditions may be described with the data type 'WeatherCondition':

Regular speed limit

- Property: maximumSpeedLimit (example value 90 km/h)
- WeatherCondition – weather type (exemption, meaning that the feature is valid except in the given condition):
    - http://spec.tn-its.eu/codelists/WeatherTypeCode#fog
    - http://spec.tn-its.eu/codelists/WeatherTypeCode#ice
    - http://spec.tn-its.eu/codelists/WeatherTypeCode#snow

Reduced speed limit

- Property: maximumSpeedLimit (example value 70 km/h)
- WeatherCondition – weather type:
    - http://spec.tn-its.eu/codelists/WeatherTypeCode#fog
    - http://spec.tn-its.eu/codelists/WeatherTypeCode#ice
    - http://spec.tn-its.eu/codelists/WeatherTypeCode#snow

3. Seasonal variations

Seasonal variations may be described with time conditions, either with clearly defined start and end dates or as fuzzy time periods:

Seasonal speed limit, valid for a specified time period:

- Property: maximumSpeedLimit (example value 80 km/h)
- Time Condition – validity period:
    - Period with a defined start and end

Seasonal speed limit, valid for a fuzzy time period

- Property: maximumSpeedLimit (example value 70 km/h)

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- Time Condition – validity period with recurring fuzzy time period:
    - Begin or duration: http://spec.tn-its.eu/codelists/FuzzyTimeTypeCode#winter

6.2.10. CCAM & ISAD levels

Neither the INSPIRE model nor the CEN/TS 17268 has any feature types for describing CCAM classifications of the road networks, such as ISAD levels. However, code values are included in the extended code lists maintained by ERTICO:

- RoadFeature.type
    - CCAM Level: http://spec.tn-its.eu/codelists/RoadFeatureTypeCode#ccamLevel
- RoadFeatureProperty.type
    - ISAD Classification: http://spec.tn-its.eu/codelists/RoadFeaturePropertyTypeCode#isadLevel
- RoadFeatureProperty.valueReference:
    - ISAD A: http://spec.tn-its.eu/codelists/ISADLevelCode#A
    - ISAD B: http://spec.tn-its.eu/codelists/ISADLevelCode#B
    - ISAD C: http://spec.tn-its.eu/codelists/ISADLevelCode#C
    - ISAD D: http://spec.tn-its.eu/codelists/ISADLevelCode#D
    - ISAD E: http://spec.tn-its.eu/codelists/ISADLevelCode#E

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7. Input from NAPCORE

Input from other parts of the NAPCORE project will come later. The input is expected to include, for example, the following:

- Changes to the TN-ITS Metadata model to harmonize with an overall NAPCORE metadata model coming out of NAPCORE SWG 4.4.
- Harmonization with the other NAPCORE standards DATEX II for dynamic data (SWG 4.1) and Transmodel, NeTEx and SIRI for multimodal data (SWG 4.3). Especially the conditions model of TN-ITS may need updates to reflect the latest changes in the DATEX II model.

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8. Technology considerations

8.1. TN-ITS and NAPCORE in the broader perspective

The INSPIRE and ITS Directives describe Spatial Data Infrastructures and National Access Points for ITS-related information, where data and information can be searched and accessed. While SDIs and NAPs are essential for providing authoritative information to users, there is a growing international focus on integrating information from multiple sources into knowledge infrastructures. UN-GGIM (UN-GGIM, 2022), as well as Geospatial World (Geospatial World, 2021) have stated that users (humans and machines) need knowledge, not data.

Geospatial Knowledge Infrastructures (GKI) expand from portals for data provision to the generation of knowledge by combining multiple information sources into a broader digital ecosystem where *"geospatial technologies, data, people, processes, and algorithms make up the geospatial component of knowledge across the whole digital ecosystem"* (Geospatial World, 2021). It is expected that the automation of knowledge will be a major disruptor for the next ten years (UN-GGIM, 2022).

An essential fundament for GKIs is *"continuously updated, trusted and authoritative fundamental geospatial information"* that *"…becomes more important in the future, not less. Governments have to ensure that such trusted, authoritative data is maintained, is open and accessible."* (Geospatial World, 2021). Therefore, the information provided through SDIs and NAPs is fundamental for the upcoming GKIs and needs to be prepared accordingly.

8.2. Technologies for sharing Information and information models

In GKIs, geospatial information needs to integrate with the broader digital infrastructures. For this purpose, geospatial information must be machine-discoverable, machine-accessible, and machine-readable, independently of geospatial-specific technologies. The technologies pointed at for GKIs are Semantic Web and Linked Data technologies such as the Resource Description Framework (RDF) and the Web Ontology Language (OWL) (Ivánová, et al., 2020), (Duckham, Arnold, Armstrong, McMeekin, & Mottolini, 2017).

The specifications for providing information according to the INSPIRE and ITS Directive, therefore, need to consider RDF and OWL as possible structures for information and information models. Such development will be essential for integration with the broader ecosystem of knowledge, but even more important: for integrating ITS information provided from different sources and according to distinct specifications. For example, information according to the RTTI delegated regulation provided partly by DATEX II and partly by TN-ITS can easily be integrated by applying principles from the Semantic Web. As described in section 3.3, parts of the DATEX II UML model are already adapted into the TN-ITS UML model. If both models were provided as OWL ontologies, they could be linked directly by standard RDF and OWL statements without any adaption between models. The result would be an improved harmonization of the specifications and enhanced interoperability of information.

Initial research on RDF and OWL for INSPIRE was conducted through the AR3NA project (Guidelines for the RDF encoding of spatial data (inspire-eu-rdf.github.io)). Unfortunately, the AR3NA work did not include a complete OWL ontology of the Road Transport Networks model. For TN-ITS, an experimental ontology is available on the open TN-ITS GitHub repository (ERTICO-TN-ITS/TN-ITS-Open (github.com)). Similar initiatives exist for DATEX II and Transmodel as well.

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Recommended future work for the TN-ITS specification and implementation schemas:

- The TN-ITS model should be provided in an official OWL Ontology for use in the Semantic web.
- RDF should be an alternative structure for providing information through TN-ITS, in parallel with the existing GML format.

The other standards involved in the NAPCORE project should also follow the same recommendations, making it possible to reuse model parts between specifications. However, the scope of this report from SWG 4.2 is improvements of TN-ITS.

8.3. Maintenance of schemas and code lists

The existing GML (XML) implementation schemas for TN-ITS are available at http://spec.tn-its.eu/schemas/. Besides, the schemas are also included in the CEN/TS 17268 document as the normative Annex B. The latter situation is a challenge for the maintenance and correction of the schemas. Fixing errors and other minor issues based on experiences from implementation through, for example, NAPCORE, is essential for service providers and users. Formally, errors and minor fixes cannot be made as the schemas are normative content from the TS.

Recommendation for future versions of the TN-ITS specification and implementation schemas:

- Implementation schemas, for example, GML (XML) schemas, should be excluded from the CEN document. Instead, only URIs to implementation schemas should be provided in the document.

As described in section 3.3, the TN-ITS model is very generic, with one class representing any road feature and one class representing any property for the feature. Code values from code lists maintained outside the model describe the type of feature, property, and property values. The standardized code lists are available at http://spec.tn-its.eu/codelists/. The generic model with external code lists is a very flexible approach inspired by the Open World Assumption (OWA) known from the Semantic Web. The code lists can be extended without needing to revise the CEN/TS, and providers can create specific national code values if required. At the same time, the specification has a stable set of standardized code values.

The OWA-based approach of the TN-ITS specification differs from the INSPIRE and DATEX II specifications, where more specific classes are defined with more specific properties. INSPIRE has external code lists defined in the INSPIRE Registry, while the DATEX II model even has code lists and enumerations included in the UML model. The DATEX II model can be considered according to the Closed World Assumption (CWA), making it more stable and less flexible. The INSPIRE specification with external code lists is less closed than DATEX II, while the TN-ITS specification is the most open and flexible model yet stable due to the standardized code lists.

However, the TN-ITS specification has no structured description of the relations between code lists, which may lead to confusion on what property and code values to use for each feature type value. A solution for combining a generic model with a more structured feature catalogue based on an ISO 19109 compliant UML model (such as INSPIRE) is described in (Jetlund, Onstein, & Huang, 2019) and illustrated in Figure 28. In the figure, the TN-ITS specification can be defined as a Feature Exchange Model, while a more structured set of code lists can be defined as a Feature Catalogue.

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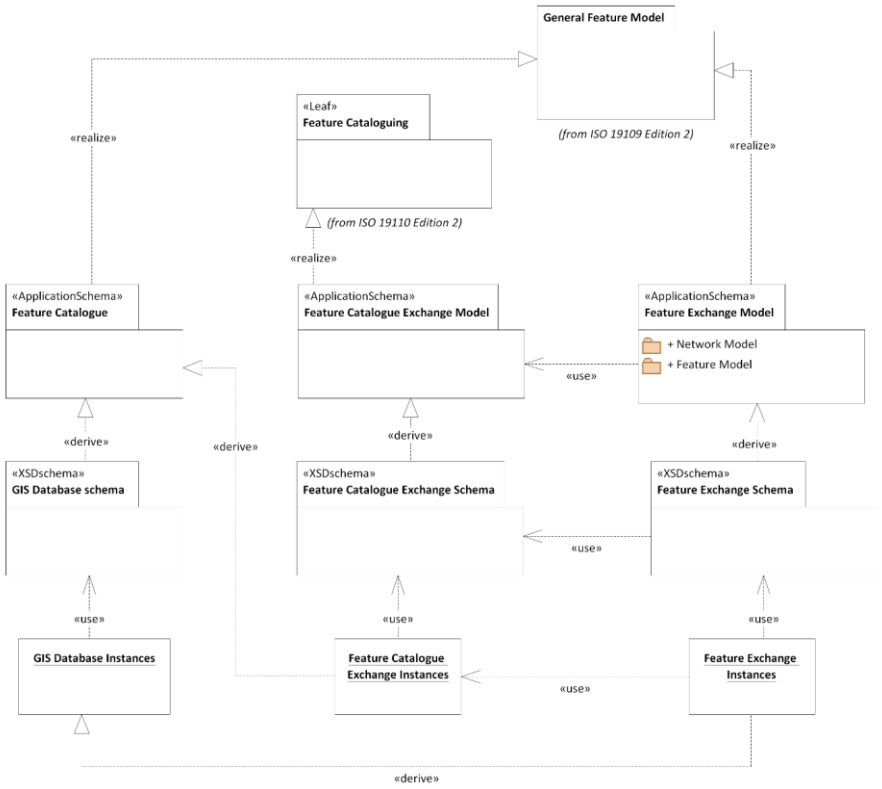

Figure 28. Feature catalogue and a generic exchange model. From (Jetlund, Onstein, & Huang, 2019).

Like the TN-ITS GML implementation schemas, the TN-ITS code list and code values are also included in the CEN/TS 17268 document in the normative Annex A. Therefore, the code lists can only be extended; they can not be changed in any other way. This approach is good for the stability of the standardized code list values but also challenging for fixing minor errors.

The external code lists for TN-ITS are described in GML Dictionaries, an XML structure based on ISO 19136. Each code value has a unique URI, which makes it fit for use in Semantic web technologies as well. However, the XML structure in GML Dictionaries is not fit for use in the Semantic Web, where code values are more likely to be described as SKOS Concepts in RDF files. The ISO/TC 211 Group on Ontology Management (GOM) is now working on a proposed structure for describing code lists and values as SKOS Concept Schemes for use in the Semantic Web. The suggested structure is similar to how INSPIRE code values are described in the INSPIRE Registry, as described in Section 3.2. and 5. For the use in GML files according to TN-ITS, the structure and serialization of the code lists are not important as long as the code values are uniquely identifiable with definitions.

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Recommended future work for the TN-ITS specification and code lists:

- Code lists should be excluded from the CEN document. Instead, only URIs to code lists or a code list registry should be provided in the document.
- Code lists should be described as SKOS Concept Schemes for use in the semantic web, based on a structure similar to the INSPIRE Registry and the suggested structure from ISO/TC 211 GOM.

The other standards involved in the NAPCORE project should also follow the same code list recommendations, making it possible to reuse code values across specifications. However, the scope of this report from SWG 4.2 is improvements of TN-ITS.

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9. Discussion

This report has investigated how the INSPIRE and TN-ITS specifications may be used to support requirements from the EU DR 2022/670 for the provision of EU-wide real-time traffic information services (RTTI). The requirements relevant to the two specifications (articles 4 and 5 in the DR and further details in points 1, 2 and 3 in the annexe of the DR) were interpreted into data requirements in section 4 and compared to the two specifications in section 5. The result of the comparison is summarized in Table 3.

Category	**RTTI Ref.**	**Required information can be provided with**	
		INSPIRE	**TN-ITS**
Infrastructure	*1*		
Network link geometry	1.a.i	Yes	Limited by using INSPIRE code values.
Road width	1.a.ii	Yes	Yes, by using INSPIRE code values and extending code lists
Number of lanes	1.a.iii	Yes	Yes
Network link gradients	1.a.iv	No, although it may be derived from geometry	Yes, by extending code lists
Network junctions	1.a.v	No	Yes, by extending code lists
Road classification	1.b	Yes, except for road number	Yes, by using INSPIRE code values and extending code lists
Tolling stations	1.c	Very limited	Yes
Service and rest areas	1.d	Yes	Yes, by using existing code values, INSPIRE code values and extending code lists
Recharging and refuelling stations	1.e 1.f 1.g	Very limited	Yes, by using existing code values and extending code lists
Delivery areas	1.h	No	Yes, by extending code lists
Crucial restrictions	*2*		
Access conditions	2.a.i 2.a.ii 2.a.iii	Yes	Yes, by using INSPIRE code values

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Category	RTTI Ref.	Required information can be provided with	
		INSPIRE	TN-ITS
Speed limits	2.a.iv	Yes	Yes
Freight delivery regulations	2.a.v	No	Yes, by using INSPIRE code values
Overtaking bans for heavy vehicles	2.a.vi	No	Yes
Vehicle weight and extent restrictions	2.a.vii	Yes	Yes. Harmonization with INSPIRE and the use of INSPIRE code values recommended
One-way streets	2.a.viii	Yes	Yes, by using INSPIRE code values
Restriction zones	2.a.ix	No	Yes
Reversible lanes	2.a.x	No	Yes, by using INSPIRE code values
Traffic circulation plans	2.b	Further analysis needed	
Other restrictions	*3*		
Traffic signs reflecting regulations and dangers	3.a.i 3.a.ii 3.a.iii 3.a.iv	No	Yes
Other traffic regulations	3.b	No	Yes
Tolling and road user charges	3.c 3.d	No	Yes. Harmonization with INSPIRE and the use of INSPIRE code values recommended

Table 3: Summarized comparison

The summarized comparison in Table 3 shows that, except for "Traffic circulation plans", all relevant RTTI requirements concerning infrastructure, regulations and restrictions can be supported by a combination of INSPIRE and TN-ITS. Furthermore, except for "Network link geometry", all remaining requirements can be fully supported by TN-ITS; Either, by the existing TN-ITS model and code lists, by using code values from the INSPIRE Registry as TN-ITS code values, or by extending the TN-ITS code lists. For the network geometry, the CEN/TS 17268 (TN-ITS) states that the data set is in the domain of INSPIRE Transport Networks. A simple representation is possible with TN-ITS, but a full topology representation is better maintained with the INSPIRE Network Model.

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Supporting the RTTI delegated regulation with INSPIRE and TN-ITS

The observation that a combination of INSPIRE and TN-ITS provides a complete solution for providing the relevant information is in line with the descriptions in the CEN/TS 17268 document. In section D.3.1 in the CEN/TS 17268 document, it is stated that *"From the public authority perspective, this document in combination with the INSPIRE Transport Network Theme-Specification provides a set of Technical Specifications that enable the provision of the data categories (road geometry as well as traffic signs) outlined in the Delegated Regulation 2015/962 (type static data) in a fully compliant way."* The quoted statement concerns the previous version of RTTI, but the summarized comparison shows that it is still valid.

Furthermore, the comparison shows an overlap between the INSPIRE model and TN-ITS for several categories, which is not surprising, given that one of the tasks for the group of experts that developed the TN-ITS specification was to harmonize with the INSPIRE Transport Networks specification. However, the overlap only concerns eight out of 22 categories since the INSPIRE model does not cover ten categories and two are covered very limitedly. INSPIRE covers one category better than TN-ITS.

Although the title of CEN/TS 17268 is 'Data exchange on changes in road attributes', the specification can also be used for exchanging complete datasets (bulk exchange). The 'Dataset' model contains the enumeration 'DatasetType', by which a dataset can be defined as a 'Snapshot' (all road features in an area, or of all occurrences of one or more specified types of road features) or 'Update' (only incremental updates for road features). Furthermore, the scope of CEN/TS 17268 states that *"Although the focus of this document is on providing information on updates, the technology described in this document in principle also enables the exchange of full data sets, either concerning the whole road network in a coverage area, including all geometry and all attributes, or a subset, concerning, for instance, all instances of one or more specific attributes."* On the other hand, the INSPIRE model is prepared for bulk exchange only.

The analysis, therefore, indicates that the TN-ITS specification with extended code lists is the best fit solution for providing relevant RTTI information concerning the infrastructure, regulations, and restrictions. However, the INSPIRE Road Transport Networks specification is recommended for the network geometry.

The INSPIRE specifications can also be further developed and extended to fit the RTTI requirements. However, the INSPIRE specifications are closely related to the INSPIRE Directive and the accompanying organizational structure. Such a development would require resources outside of the NAPCORE project. Besides, as the INSPIRE models are developed more according to a Closed World Assumption (CWA), the development would require more work than extending the TN-ITS code lists. Extending TN-ITS is in the scope of this report and is likely possible to achieve within the time and resource frames of the NAPCORE project and in time for the provision of mobility data as described in the revised RTTI Delegated Regulation 2015/92.

Commented [MI2]: Maybe mention something about timings when all requirements kicks in. I understand Napcore ends 2024, and RTTI central types data must be provided by 1/1-2025. It's in time but extending of TN-ITS can't come in last minute.

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10. Summary

This report has studied and discussed the provision of information according to requirements in the RTTI delegated regulation 2022/670, where the INSPIRE and TN-ITS (CEN/TS 17268) specifications are relevant. Information defined under article 4 (“data on infrastructure”) and article 5 (“data on regulations and restrictions”) is found to be relevant for INSPIRE and TN-ITS, as these articles refer to the two specifications. The annexe of DR 2022/670 defines the types of RTTI that shall be included in the NAPs, where points 1, 2 and 3 concern articles 4 and 5.

In the report, the requirements from the annexe are interpreted into data requirements with suggested content. The interpretation results are compared to possibilities in the INSPIRE Transport Networks and TN-ITS specifications. Possible structures for providing the required information are proposed, including suggested extensions and changes to the TN-ITS model and its code lists.

The comparison shows that all relevant and clearly defined requirements concerning the infrastructure, regulations and restrictions can be supported by a combination of the INSPIRE and TN-ITS specifications. The TN-ITS specification can support all relevant RTTI requirements by reusing INSPIRE code values and extending TN-ITS code lists. The INSPIRE Road Transport Networks specification can support only nine out of 22 categories. Therefore, TN-ITS with extensions is considered the best fit solution. However, the INSPIRE Road Transport Networks specification is recommended for the provision of the complete network geometry and topology representation.

The report also discusses technologies for sharing and extending relevant information. It is recommended that TN-ITS and INSPIRE (as well as other specifications involved in the NAPCORE project) use technologies from the Semantic Web to enable the linking of information according to the RTTI DR into a broader geospatial knowledge infrastructure.

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12. Example files

Example files for TN-ITS implementation are available on the TN-ITS open GitHub repository: TN-ITS-Open/Examples at master · ERTICO-TN-ITS/TN-ITS-Open (github.com)

One example file will be created per RTTI Data category.

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