



A Quality Framework for Road Network Topology

Report by Task 3.2: European NAPs data quality

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Abbreviations

Abbreviation	Meaning
EC	European Commission
FCD	Floating Car Data
GDF	Geographic Data File
INSPIRE	Infrastructure for Spatial Information in the European Community
GIS	Geographic Information System
ITPS	Intelligent Truck Parking Services
MMTIS	Multimodal Travel Information Services
NAP	National Access Point
NAPCORE	National Access Point Coordination Organisation for Europe



OGC	Open GIS Consortium
OSM	Open Street Map
RTTI	Real-Time Traffic Information Services
SDBMS	Spatial Database Management Systems
SRTI	Safety-Related Information Services
TN-ITS	Transport Network ITS
WG	Working Group
UVAR	Urban Vehicle Access Regulation



Table of contents

1.	INTRODUCTION	5
1.1	BACKGROUND OF THIS DOCUMENT.....	5
1.2	METHODOLOGY	5
2.	SCOPING	7
2.1	WHAT IS TOPOLOGY DATA?.....	7
2.2	ROAD (SPECIFIC) TOPOLOGY AS THE BASIS FOR SIMPLE AND COMPLEX ROAD FEATURES	8
2.3	EXAMPLES OF TOPOLOGICAL ELEMENTS OF A ROAD NETWORK	10
2.4	EXAMPLES OF ROAD TOPOLOGY RULES (CHECKS)	12
2.5	DATA SOURCES FOR ROAD NETWORK TOPOLOGY	13
3.	RELEVANT USE CASES.....	14
4.	RELEVANT DATA TYPES IMPACTING ROAD NETWORK TOPOLOGY	15
5.	RELEVANT DATA PROVIDERS.....	19
6.	APPLIED QUALITY DEFINITIONS	20
6.1	REFERENCE TO THE NAPCORE QUALITY FRAMEWORKS	20
6.2	IDENTIFICATION OF RELEVANT RULES	21
6.3	EXEMPLARY DEFINITION OF QUALITY DIMENSIONS, CRITERIA AND METRICS.....	24
6.4	ASSESSMENT OF THE EXEMPLARY DEFINITION OF QUALITY DIMENSIONS, CRITERIA AND METRICS.....	31
7.	FURTHER EVALUATIONS NEEDED	32
7.1	GENERATED INSIGHT	32
7.2	FUTURE HANDLING THE DATA QUALITY ISSUE IN THE CONTEXT OF ROAD NETWORK TOPOLOGY	32
8.	CONCLUSIONS	33
	REFERENCES	34

1. Introduction

1.1 Background of this document

The objective of this document is to inform the reader about the definition, scope and criteria for a quality framework related to data related to road network topology. It will also guide the reader on the methodology applied to come to this quality framework description. The document reflects the work and conclusions of participants in the NAPCORE task 3.2, representing experts from governmental agencies and map and service providers, as well as members of the TN-ITS ERTICO innovation platform¹.

The basic concepts behind the NAPCORE quality elaborations, including questions like “Why do we need a Quality Framework for ITS Services and ITS Data?” and “What is a Quality Framework for ITS Services and ITS Data?” have been explained in a generic report by NAPCORE Task 3.2².

This presented quality framework for data related to road topology aims to enable the quality assessment of topological features in digital maps, enabling use cases and connectivity functions to support, e.g., route planning, navigation, spatial queries etcetera. It leads to a better and common understanding of the quality related topics related to topology and its underlying data.

1.2 Methodology

The task followed a structured methodology to develop this quality framework for road network topology. The process began with an initial planning phase in which participants were introduced, and the overall approach was established. Early discussions focused on the significance of topology within the quality framework and the relevance of existing standards such as GDF, INSPIRE and TN-ITS (chapter 2). The team also identified key use cases (chapter 3) and created a priority list to ensure that efforts were directed toward the most critical aspects of road network topology quality.

Following this initial phase, the focus shifted toward clarifying definitions and developing use cases. Presentations and discussions helped refine key terminology, while a list of use cases was identified and prioritized for inclusion in the quality framework.

The next stage involved technical discussions and data exploration (chapter 4). The team evaluated existing topological checks available in commercial GIS tools and investigated their applicability to the framework. There was also an effort to study other NAPCORE Task 3.2 quality frameworks such as the FCD, UVAR, etc (as published on the NAPCORE Quality Repository³), and the NAPCORE data dictionary⁴. Further discussions explored data source identification and validation methodologies to strengthen the reliability of the framework. During this period, industry stakeholders, including HERE and TomTom, were engaged to provide input on essential aspects of road network topology, ensuring that both public and private sector perspectives were incorporated. Industry representatives provided

¹ <https://tn-its.eu/>

² https://napcore.eu/wp-content/uploads/2025/03/1_NAPCORE-M3.8-deliverable_v1_250317.pdf

³ <https://napcore.eu/quality/>

⁴ <https://napcore.eu/its-mobility-data-dictionary/>



input to identify the top five topology-related quality rules, which formed a key component of the framework.

As the project progressed, the focus shifted toward developing concrete quality criteria and validation rules (chapter 5). Iterative reviews of the draft milestone report allowed for the refinement of methodology and ensured that applicable data standards were incorporated. This iterative process continued throughout the latter half of the process for this quality framework, culminating in a structured and well-evaluated approach to road network topology quality assessment.

The final phase involved the consolidation and reporting of findings (chapter 6). The team conducted a recap of previous actions and set a plan for finalizing the framework. Internal reviews helped refine the deliverable, and preparations were made for upcoming meetings to ensure that the milestone report was fully aligned with regulatory requirements and practical industry applications.

Throughout this process, a broad range of stakeholders contributed to the discussions, including public authorities from various European countries and private sector representatives. A combination of online meetings and in-person discussions facilitated effective collaboration, ensuring that both theoretical and practical perspectives were considered. The project was structured with clear objectives, and each meeting concluded with actionable next steps to maintain progress. The iterative nature of the discussions and the continuous refinement of deliverables helped ensure that the final report addressed all critical aspects of road network topology quality. The engagement of relevant stakeholders and the structured evaluation of findings indicate a well-managed and comprehensive approach to the development of the quality framework.



2. Scoping

2.1 What is topology data?

The current report targets the development of a Quality Framework (QF) for Road Network Topology and its underlying data. The topology of a road network refers to the arrangement or structure of the network, including how roads are connected and the relationships between different segments or nodes within the network. It encompasses aspects such as the layout of roads, intersections, junctions, and the paths that vehicles can take to navigate from one point to another.

In the context of road databases, topology and geometry are two fundamental concepts that describe different aspects of spatial relationships and structures, and it is important to understand their focus. The definitions presented below reflect those which can be concluded from the most relevant international standards as GDF (ISO/FDIS 20542-1:2019), OCG and INSPIRE, starting with Geometry:

Geometry

- Definition: Geometry refers to the actual geometric shapes and coordinates that define the basic road features, such as (shape) points, lines, and polygons.
- Focus: It primarily deals with the spatial location and arrangement of individual geometric elements of a road.
- Example: In a map, geometry describes the specific coordinates of a point, the shape of a line, or the boundary of a polygon.

Turning to the main topic of this report:

Topology

- Definition: Topology describes the spatial relationships and connectivity between different geometric elements of a road.
- Focus: It is concerned with how features are related to each other, including adjacency, containment, and connectivity.
- Example: Topology would describe whether two lines representing roads intersect, whether a point is inside a polygon (area), or how polygons share common boundaries.

In essence, while geometry deals with the actual shapes and positions of spatial/road features, topology is concerned with the relationships and connectivity between these features. Both concepts are essential in spatial data analysis and geographic information systems (GIS) to accurately represent and analyse real-world spatial phenomena, such as roads. Also, both concepts support the use of digital maps for planning (vehicle routing), driving (vehicle navigation), and tactical purposes (vehicle overtaking, merging, etc.)

Understanding the topology of a road network is crucial for urban planning, traffic management, and optimizing transportation systems for efficiency, safety, and convenience (e.g., Routing and Navigation ADAS and Automated Driving). A subsequent chapter in this document addresses use cases within the scope of RTTI.

The following figure concludes the relationship between topology and geometry.



TOPOLOGY ≠ GEOMETRY

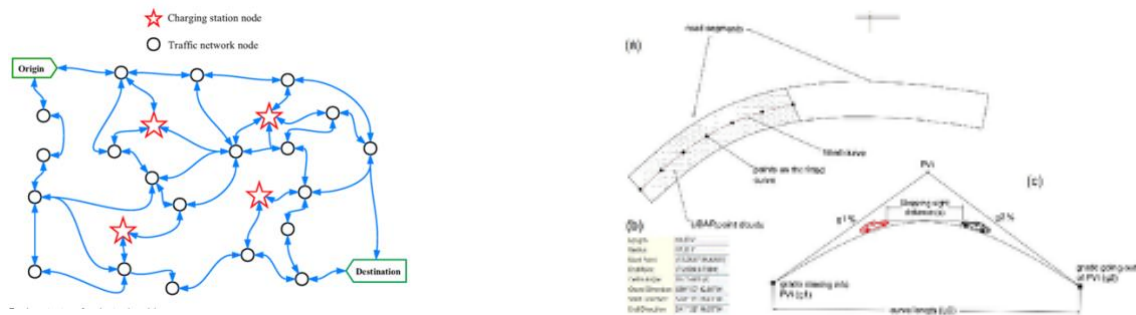


Figure 1 – Relationship between topology and geometry

2.2 Road (specific) topology as the basis for simple and complex road features

This chapter looks into the definitions of road topology in some main representations such as GDF and OSM. It also elaborates on why these levels are identified and their applications.

Having described the difference between geometry and topology in the previous chapter, it helps to understand how road databases are modelled by looking into a reference of geographic data modelling: GDF (ISO/FDIS 20542-1:2019).

In GDF, and its derived descriptions, three levels of (cartographic) representation are defined:

- **Level 0 (Topology):** This level contains elementary GIS topology components. No features overlap in any way, and neighbouring relationships are known. Everything is described by cartographic primitives as Nodes, Edges and Faces.
- **Level 1 (Features):** Level 1 contains simple features like road elements, rivers, boundaries, and signposts. Features can have attributes that are specific to the feature (for example, one way, width of the road, number of lanes). Features can also have relations, which are very important for car navigation systems. For example, relations can include “forbidden turn from road element 1 to road element 2” or “road element 1 has priority over road element 2.”
- **Level 2 (Complex Features):** At this level, the level 1 “simple features” are aggregated to a higher-level feature. For example, at level 1, all road elements of an intersection are represented. At level 2, the intersection may only be represented with a single point.

While OSM does not explicitly define “road topology” as a separate layer (as in GDF), the way its data is structured aligns with the Level 0 and Level 1 definitions from GDF:

- **Level 0 (Topology):** Represented by the node and way connectivity in OSM's raw data.
- **Level 1 (Features):** Achieved through tagging that defines roads, intersections, and other features with attributes.

Note that OSM data is used by many tools (e.g., routing engines) to build topological models of road networks for navigation, urban planning, and analysis.

The definition of these different representation levels serves several key purposes in geographic data modelling and practical applications. These purposes address the complexity, abstraction, and utility of the data for various use cases:

Abstraction and Simplification

Each level represents a higher level of abstraction:

Level 0 (Topology) is the most granular, dealing with raw geometric and topological primitives (nodes, edges, and faces) that serve as the building blocks of the map.

Level 1 (Features) abstracts these primitives into recognizable, real-world entities like roads or rivers, along with attributes and relationships.

Level 2 (Complex Features) further simplifies and aggregates detailed features into larger, conceptualized entities, like entire intersections or regions. This abstraction allows users to choose the level of detail appropriate for their needs. For example: a traffic simulation might require Level 0 or Level 1 data for detailed movement modelling. Or, a high-level navigation system might rely on Level 2 data for simplified route planning.

Data Usability and Flexibility

The levels enable the same data to serve different applications and audiences:

Technical experts (e.g., GIS analysts) might work with Level 0 data for detailed spatial analysis and engineering tasks. Mapmakers might use Level 1 data to create user-friendly visualizations. Navigation systems might focus on Level 2 data for efficient route calculation, where granular details like individual road segments or turns aren't required.

Data Optimization and Performance

Higher levels of abstraction reduce the volume of data that needs to be processed, which improves performance in systems where detailed topology isn't necessary. For instance, navigation systems use aggregated Level 2 features to quickly calculate routes without dealing with the computational complexity of individual road segments and their connections.

Standardization and Interoperability

For example, the GDF framework ensures a standard structure for geographic data, making it easier to share, integrate, and interpret data across different systems and applications. Defining these levels help clarify how the data is structured and at what level of abstraction it can be accessed or utilized.

Scalability for Different Use Cases

Different applications may require different scales or levels of detail: Level 0 is essential for precision tasks like urban planning or micro-level simulations. Level 1 strikes a balance between detail and usability for most mapping and navigation purposes. Level 2 works best for high-level planning, such as logistics or long-distance navigation, where fine details may not matter.

Examples of Purpose in Practice

Urban Planning: A city planner might use Level 0 data to analyse the connectivity of a road network and design infrastructure improvements. Car Navigation Systems: These systems primarily rely on Level 1 data (road elements and attributes) for routing and Level 2 data for simplified navigation and



user display. Cartographic Representation: When producing maps at different scales, Level 1 and Level 2 provide suitable abstractions for creating legible visualizations without cluttering the map with excessive detail.

Conclusion: related to this document subject level 0 and level 1 (road) are both considered in the road network topology framework

2.3 Examples of topological elements of a road network

This chapter gives some examples of road network topological elements.

Direction of travel (level 1)

The direction of travel on a road is a crucial aspect of road network topology. It determines the flow of traffic and influences how routes are planned and navigated within the network. In some road network representations, the direction of travel is explicitly indicated, such as one-way streets or highways with divided lanes. This information helps drivers and navigation systems determine the correct route to take to reach their destination efficiently. Additionally, understanding the direction of travel is essential for traffic management, including implementing traffic signals, signage, and lane markings to regulate the flow of vehicles and prevent accidents or congestion. So, while the physical layout of roads and their connections forms the backbone of road network topology, the directionality of travel plays a significant role in how the network operates and is organized.

Junctions (level 1)

The presence of a junction is indeed a fundamental topological element in a road network. A junction is where two or more roads intersect or meet, forming a node in the network. Junctions can vary in complexity, from simple T-intersections to complex multi-lane intersections or roundabouts. Junctions play a crucial role in determining the connectivity and structure of the road network. They define how different segments of roads are connected and how traffic can flow between them. The configuration and design of junctions influence factors such as traffic flow, safety, and efficiency within the network. In road network analysis and modelling, junctions are often represented as nodes, and the roads connecting them are represented as edges or links. Understanding the distribution and characteristics of junctions helps transportation planners and engineers assess the performance of the network, identify congestion hotspots, optimize traffic signal timings, and plan infrastructure improvements. Therefore, the presence and characteristics of junctions are integral to the topology and functioning of a road network.

Manoeuvres at intersections (level 2-out of scope of this document)

Manoeuvres at intersections are indeed a crucial aspect of road network topology. An intersection is a key point where multiple roads meet, and manoeuvres at these intersections include actions such as turning left, turning right, going straight through, or making U-turns. The design and layout of intersections greatly impact traffic flow, safety, and efficiency within the road network. Different types of intersections, such as roundabouts, T-intersections, four-way intersections, and complex multi-lane intersections, require different types of manoeuvres and have specific rules governing right-of-way and traffic flow. Understanding intersection manoeuvres is essential for drivers to navigate intersections safely and efficiently. It also influences urban planning decisions, such as the placement of traffic signals, signage, lane markings, and pedestrian crossings, to manage traffic and prioritize various modes of transportation. Moreover, modern transportation systems and navigation technologies often consider intersection manoeuvres when providing route guidance to drivers,



helping them choose the most appropriate path based on their destination and current traffic conditions. Therefore, manoeuvres at intersections are an integral part of road network topology and transportation planning.

Lane information (level 1)

Lane information in a road network can be considered an important element of road topology, especially in modern road networks and transportation systems. While traditional road network topology primarily focuses on the connectivity and layout of roads and intersections, lane information adds another layer of detail that influences traffic flow, routing decisions, and overall network performance. Here's how lane information contributes to road network topology:

- **Lane Configuration:** The number and type of lanes on a road (e.g., travel lanes, turning lanes, bus lanes, bike lanes) affect how traffic moves within the network. Lane configurations at intersections and along road segments determine permissible manoeuvres, such as turning left, turning right, or going straight through.
- **Lane Assignments:** Lane information can specify which lanes are designated for specific types of vehicles or movements. For example, some lanes may be reserved for buses, bicycles, or high-occupancy vehicles (HOV), while others are for general traffic or specific turning movements.
- **Lane Connectivity:** Lane information also includes how lanes merge, split, or transition at intersections and along road segments. This aspect influences the continuity of travel paths and the complexity of manoeuvres required at junctions.
- **Lane Markings and Signs:** Lane information encompasses lane markings, signage, and signals that provide guidance to drivers regarding lane usage, lane changes, and manoeuvring at intersections. This information is crucial for ensuring safety and efficient traffic flow within the network.
- **Lane-Based Routing:** In advanced transportation systems and navigation technologies, lane information is used for lane-based routing, where drivers are guided to specific lanes based on their destination, the type of manoeuvre required, and current traffic conditions. This enhances route accuracy and helps optimize traffic distribution across lanes.

Overall, lane information complements traditional road network topology by providing detailed insights into how traffic moves within the network and how lanes are utilized for different purposes and manoeuvres. Therefore, it can be considered an essential element of road network topology, particularly in the context of modern transportation planning and management.

Priority Regulations (level 1)

Priority regulations, such as right-of-way rules and traffic control mechanisms, are indeed an integral aspect of road network topology. While they may not be physical features like roads or intersections, they govern the behaviour of vehicles within the network and influence its structure and functioning. Here's how priority regulations contribute to road network topology:

- **Intersection Control:** Priority regulations determine which vehicles have the right-of-way at intersections, affecting how traffic flows through junctions. For example, traffic signals, stop signs, yield signs, and roundabouts allocate priority to different streams of traffic, shaping the dynamics of movement within the network.
- **Lane Assignment:** Priority regulations often dictate lane assignments based on specific conditions or vehicle types. For instance, lanes may be designated for buses, bicycles, or turning movements, with corresponding right-of-way rules to manage interactions between different types of traffic.



- **Traffic Flow:** Priority regulations help regulate the flow of traffic within the network by establishing rules for merging, yielding, overtaking, and other manoeuvres. These regulations contribute to safety, efficiency, and predictability in traffic movements.
- **Pedestrian Crossings:** Priority regulations also apply to pedestrian crossings, determining when and where pedestrians have the right-of-way to cross roads. Features like crosswalks, pedestrian signals, and traffic calming measures influence pedestrian movement within the network.
- **Special Circumstances:** Priority regulations may include provisions for special circumstances such as emergency vehicles, construction zones, school zones, and temporary traffic controls. These regulations ensure that priority is given to critical activities while maintaining the overall functionality of the network.

In summary, priority regulations are essential components of road network topology as they govern the interaction between vehicles, pedestrians, and other users within the network. By establishing rules for right-of-way and traffic control, priority regulations shape the behaviour of participants and contribute to the overall structure and efficiency of the road network.

2.4 Examples of Road Topology rules (checks)

Topological checks in road databases are important for ensuring the consistency and integrity of spatial data. These checks help verify the relationships and connectivity between geometric elements. Some common topological checks that can be made in spatial databases. For each rule, an example of importance in a road network is given.

Intersection Check:

- Verify that geometries do not intersect inappropriately, based on the data model's rules.
- Ensure that lines do not cross unless there is a proper node or intersection point.
- Prevents unrealistic crossings without connections (e.g., bridges vs intersections).

Containment Check:

- Ensure that polygons do not improperly contain other polygons. For example, a country boundary should not contain another country's boundary.
- Ensures spatial correctness, such as jurisdiction-based routing.

Adjacency Check:

- Verify the adjacency relationships between spatial features. For instance, check if polygons share common boundaries where they are expected to.
- Important for lane-level modelling or adjacent zones.

Connectivity Check:

- Ensure that network-based spatial data (such as road networks) is properly connected. Check for gaps or isolated segments that could affect routing.
- Crucial for routing algorithms; avoids disconnected roads.

Node and Edge Checks:



- Verify the correctness of nodes and edges in network data. Ensure that nodes connect to the correct edges, and edges do not have unexpected intersections.
- Prevents logical errors in graph representation.

Directionality Check:

- In cases where the direction of features matters (e.g., one-way streets), verify that features have the correct orientation.
- Essential for turn-by-turn navigation and legal movement.

Overlap Check:

- Ensure that polygons do not overlap unless they are meant to, such as in the case of administrative boundaries.
- Prevents errors in map rendering and routing (e.g. overlapping roads).

Boundary Consistency Check:

- Verify that boundaries of adjacent features align correctly. This is crucial for maintaining consistency in spatial relationships.
- Important for spatial queries and jurisdictional reporting.

Cyclic Dependency Check:

- Ensure that there are no cyclic dependencies in network data, which could lead to infinite loops in network traversals.
- Useful in network modelling and preventing infinite loops in algorithms.

Dimensionality Check:

- Verify that the dimensionality of spatial objects is consistent. For example, a point should not be represented as a polygon.
- Ensures correct elevation modelling or bridge/tunnel representation.

Planar vs. Non-planar Geometry Check:

- Ensure that geometric objects are appropriately planar or non-planar based on the spatial model being used.
- Supports realistic modelling of grade-separated roads (bridges, tunnels).

Implementing these checks can help ensure the accuracy and reliability of spatial data in databases. Many Spatial Database Management Systems (SDBMS) provide tools and functions for performing these topological checks. In the context of NAPCORE: these checks are typically done by the DBMS at the side of the road authority before the data is shared with 3rd parties.

2.5 Data sources for road network topology

Sources for such data as mentioned in previous section are manual or automated insertion in the digital map representation based upon pdf, arial picture, traffic regulation orders, floating car data (FCD), mobile mapping data (e.g., street view data), etc.



3. Relevant use cases

Digital maps have become integral to the operation and enhancement of transport services, driving innovation and improving user experiences across the globe. Within the scope of this document the topological aspects enables a number of use cases . A selection of use cases are (Non exhaustive):

- **Route planning:** Digital maps provide up-to-date road geometry and topology, turn restrictions, and traffic rules, allowing navigation systems to calculate the fastest or most efficient routes.
- **Traffic management (alternative routes):** Real-time map data, including congestion and incidents, enables traffic control centres and apps to suggest alternative routes to balance traffic loads and reduce delays.
- **Emergency service:** Accurate, routable maps help emergency responders reach incidents faster by identifying the quickest paths and considering temporary changes like closures or one-way streets.
- **ISA (Intelligent Speed Assistance):** Digital maps supply precise speed limit data that onboard systems use to warn drivers or limit vehicle speed, enhancing road safety and regulatory compliance.
- **Road works and road blocks:** Map updates reflecting temporary changes in road accessibility ensure drivers and systems are aware of closures or detours, reducing confusion and improving safety.
- **Powertrain management for trucks:** Digital maps with elevation, curvature, and traffic data enable energy-efficient route selection and adaptive engine/transmission control to reduce fuel consumption and emissions.

The relevance of topological data is depending on the use case; hence the quality rating of the topological data depends on the use case.

E.g. for the topological element 'direction of travel' with the value: 'one way street', the relevance is related to the use cases: route planning, traffic management, emergency service , ... The project team carried out a more in depth study, unfortunately no consensus was reached. This result illustrates the difficulty how to approach the topic of quality related to topology data.

4. Relevant data types impacting road network topology

Road topology itself is not directly coded in data, but it is the result of processed data in a digital map. Therefore, we look to the actual types of data that impact road topology.

In a first instance the most relevant sources are those mandated by the Delegated Regulations in the context of the ITS Directive 2010/40/EU⁵. The following tables presents the data types described in the various Delegated Regulations. For these mandated data types, priorities have been set by the commission. In the below table, the priority for availability on 1-1-2025 is put in yellow (first left column). For each mandated data type, the related Delegated Regulation has been mentioned.

Obviously, not all mandated data is relevant to road topology. The last column indicates this relevance. Some discussions are possible. Therefore, the following color code has been applied, according to the specifications of topology, previously mentioned in this document.

- Green: It is relevant for road topology
- Yellow: discussion is possible, relevance is not clear
- Red: this data has no relevance for road topology.

⁵ <https://eur-lex.europa.eu/eli/dir/2010/40/oj/eng>



Table 1 - Data types in the Delegated Regulations and their relevance to road network topology

Data types as described in various regulations of the ITS directive 2010/40/EU			
	Delegated regulation	Obligation for digitalisation for 1/1/2025	Topology related
RTTI			
(1) Kinds of infrastructure data			
(a) roads and their infrastructure data	RTTI	yes	Red
i) geometry;	RTTI	yes	
ii) Width of the road: (specification see data dictionary)	RTTI	yes	Red
iii) number of lanes	RTTI	yes	
iv) gradient	RTTI	yes	Red
v) nodes	RTTI	yes	
(b) road classification	RTTI	yes	Red
c) location of the service facilities and rest areas;	RTTI	NO	
(e) location and conditions of use of electric vehicle charging points;	RTTI	NO	Yellow
(f) location of compressed natural gas, liquefied natural gas and liquefied	RTTI	NO	
(g) location of refuelling points and refuelling stations for all other fuel types;	RTTI	NO	Yellow
(h) Location of delivery zones.			
(2) The crucial types of data on traffic regulations and restrictions:			
(a) static and dynamic traffic controls, where applicable:	RTTI	yes	Green
(i) conditions of access to tunnels;	RTTI	yes	
(ii) conditions of access to bridges;	RTTI	yes	Red
(iii) permanent access restrictions;	RTTI	yes	
(iv) speed limits;	RTTI	yes	Red
(v) rules for the supply of goods;	RTTI	yes	
(vi) prohibitions on overtaking heavy goods vehicles;	RTTI	yes	Green
(vii) restrictions based on weight/length/width/height;	RTTI	yes	
(viii) one-way streets;	RTTI	yes	Green
(ix) the zonal demarcation of restrictions, prohibitions or obligations, current access status and conditions for traffic in regulated traffic zones;			
(x) the direction of travel in reversible lanes (tidal flows);	RTTI	yes	Green
(b) traffic circulation plans;	RTTI	NO	
(3) Other types of data on traffic regulations and restrictions:			
(a) the location and identification of road signs indicating traffic regulations and hazards:			Green
(i) conditions of access to tunnels;	RTTI	yes	
(ii) conditions of access to bridges;	RTTI	yes	Green
(iii) permanent access restrictions;	RTTI	yes	
(iv) other road signs depicting traffic regulations;	RTTI	yes	Green
(b) static and dynamic traffic controls, where applicable, other than those referred to in point 2;	RTTI	yes	
(c) identification of toll roads, applicable fixed user charges and available payment methods (including retail channels and compliance methods);	RTTI	no	Yellow
(d) variable charging for road users and available payment methods, including retail channels and compliance methods.			
(a) road closures;	RTTI	no	Green
(b) lane closures;	RTTI	no	
(c) roadworks;	RTTI	no	Red
(d) temporary traffic management measures.	RTTI	no	
(a) closures of bridges;	RTTI	no	Green
(b) accidents and incidents;	RTTI	no	
(c) poor road conditions;	RTTI	no	Red
(d) weather conditions affecting road surface and visibility.	RTTI	no	
(a) the volume of traffic;	RTTI	no	Red
(b) traffic speed;	RTTI	no	
(c) the location and length of traffic jams;	RTTI	no	Red
(d) travel times;	RTTI	no	
(e) the waiting time at border crossing points;	RTTI	no	Red
(f) the availability of delivery zones;	RTTI	no	
(g) the availability of recharging points and stations for electric vehicles;	RTTI	no	Red
(h) the location of refuelling points and stations for alternative fuels;	RTTI	no	
(i) the price of ad hoc charging/refuelling.	RTTI	no	Red

	Delgated regulation	Obligation for digitalisation for 1/1/2025	Topology related
SRTI			
List of safety incidents or traffic situations			
(a) Temporarily slippery road surface	SRTI	no	
b) animals, people, obstacles and debris on the road	SRTI	no	
(c) unsecured accident site	SRTI	no	
(d) short-term roadworks	SRTI	no	
(e) reduced visibility	SRTI	no	
f) wrong-way driver	SRTI	no	
g) Unattended roadblock	SRTI	no	
(h) exceptional weather conditions	SRTI	no	
MMTIS			
The location of identified access points for all planned modes of transport, including information on the accessibility of access points and walking routes at an interchange point (e.g. presence of lifts, escalators)			
Static, historical and observed travel and traffic data			
Level of service 1			
a) Location search (place of departure/destination)			
i) address details (house number, street name, postcode)	MMTIS 2023	no	
(ii) Topographical data (municipality, town, village, district, administrative unit)	MMTIS 2023	no	
(iii) Potential poles of attraction (related to transport information) (point of interest)	MMTIS 2023	no	
(b) Route schedules		no	
(i) Operational planning, linking day types to calendar dates	MMTIS 2023	no	
c) Location search (access nodes) where relevant for regular and demand-driven services		no	
(i) Nodes		no	
(ii) geometry/location of the nodes on map	MMTIS 2023	no	
(d) Calculation of the timetable for regular demand-driven services		no	
(i) Interchange nodes	MMTIS 2023	no	
(ii) Standard intermodal transfer times at nodes	MMTIS 2023	no	
(iii) network topology and routes/lines	MMTIS 2023	no	
(iv) transport operators	MMTIS 2023	no	
(v) Timetables	MMTIS 2023	no	
(vi) Scheduled transfers between guaranteed regular services	MMTIS 2023	no	
(vii) Operating hours	MMTIS 2023	no	
(viii) facilities at junctions (e.g. information on platforms, reception/information desk, lifts/stairs, entrances and exits)	MMTIS 2023	no	
ix) vehicles incl wheelchair accessibility, low floor, and access to facilities such as toilets	MMTIS 2023	no	
x) Accessibility of nodes and routes within nodes (such as presence of elevators and escalators)	MMTIS 2023	no	
xi) Availability of assistance (e.g. remote or on-site)	MMTIS 2023	no	
(e) Calculation of road transport route (personal transport)		no	
i) road network	MMTIS 2023	no	
ii) bicycle route network (removal of cycle paths, mixed traffic, mixed pedestrian and cycle path)	MMTIS 2023	no	
(iii) pedestrian network and accessibility features	MMTIS 2023	no	
Level of service 2			
a) Location search (demand-dependent and passenger transport)			
i) Location of parking spaces (on- and/or street)	MMTIS 2023	no	
(ii) P&R	MMTIS 2023	no	
iii) Park & Drive haltes	MMTIS 2023	no	
iv) Bicycle-sharing pitches	MMTIS 2023	no	
v) Shared car stands	MMTIS 2023	no	
vi) Secure bicycle parking facilities (e.g. locked parking facilities)	MMTIS 2023	no	
(b) Provision of information		no	
i) Where and how tickets are sold for regular carriage including sales channels and methods of payment	MMTIS 2023	no	
(ii) Where and how are tickets sold for parking incl sales channels and methods of payment	MMTIS 2023	no	
(c) additional information - regular and demand-based services where relevant		no	
(i) general basic tariffs (incl tariff structure)	MMTIS 2023	no	
(ii) transport facilities such as travel class, Wi-Fi on board, accessibility to bicycles and toilets	MMTIS 2023	no	



Topology related		
Delgated regulation	Obligation for digitalisation for 1/1/2025	
Level of service 3		
(a) Detailed search of standard and special fares, regular and demand-driven transport where applicable		no
(i) passenger classes and associated conditions	MMTIS 2023	no
ii) standard travel products (access rights such as zone to zone, daily and weekly tickets, single/return, validity, etc.)	MMTIS 2023	no
iii) special offers with additional/special conditions, promotional rates, group rates, subscriptions and combined formulas such as P&R	MMTIS 2023	no
iv) basic commercial conditions (refund/exchange) and booking conditions (such as validity and mandatory length of stay)	MMTIS 2023	no
b) Provision of information on demand-driven transport		no
i) How to book a demand-driven service including sales channels and payment methods	MMTIS 2023	no
(c) Route schedules		no
i) exact characteristics of the cycle route network (quality of road surface, width, shared space, one-way traffic, etc.)	MMTIS 2023	no
(ii) Parameter required for the calculation of the environmental impact such as CO2 emissions per vehicle type, passenger-kilometre or distance walked	MMTIS 2023	no
(iii) Parameter required for the calculation of the cost of fuel (conventional and alternative)	MMTIS 2023	no
(d) Calculation of the route schedule		no
(i) estimated time per day type and time span for each mode of transport/co	MMTIS 2023	no
Level of service 4		
(a) historical journey and traffic data relating to delays and cancellations, where applicable to regulated and demand-driven transport	MMTIS 2023	no
(b) Observed data on delays in transport services		no
(i) Duration and reason for the delay in departure where it exceeds 60 minutes for users of Rail Services	MMTIS 2023	no
(ii) the duration and reason for the delay in departure where the duration of the delay exceeds 90 minutes for users of the waterway	MMTIS 2023	no
(iii) duration and length of delay in departure where it exceeds 120 minutes for users of bus services with a planned journey distance of more than 250 kilometres	MMTIS 2023	no
(iv) duration and length of delay at departure where the duration exceeds 120 minutes for air passengers	MMTIS 2023	no
(c) Observed data on outages of transport services		no
i) Failure of rail services	MMTIS 2023	no
(ii) Cancellation of waterway services	MMTIS 2023	no
(iii) cancellation of bus services with a planned travel distance of more than 250 km	MMTIS 2023	no
(iv) Failure of air services	MMTIS 2023	no
d) information regarding parking fees	MMTIS 2023	no
Dynamic travel and traffic data		
Level of service 1		
Timetable, route schedule and additional information		
(i) Disruptions such as closures and diversions with any associated reason	MMTIS 2023	no
ii) Real-time status information such as delays, failures, monitoring of connect	MMTIS 2023	no
(ii) status of the accessibility of the interchange such as dynamic platform indicators, working lifts/escalators, closed entrances and exits	MMTIS 2023	no
Level of service 2		
a) Information service on parking charges for demand-dependent and person	MMTIS 2023	no
(b) Location and availability of demand-dependent and personal transport	MMTIS 2023	no
i) location and availability of shared cars, shared bicycles, shared scooters and other modes of shared transport	MMTIS 2023	no
(ii) available parking spaces for cars, on-and/or street	MMTIS 2023	no
Level of service 3		
Information on the occupancy rate of the vehicles in the case of regular and demand-dependent transport	MMTIS 2023	no

Deligated regulation	Obligation for digitalisation for 1/1/2025	Topology related	
SSTP			
Static data on parking areas, including			
Static data on parking areas, including			
(i) Identification of the car park (name, address)	SSTP	yes	
(ii) Location of the access point in the parking zone (coordinates)	SSTP	yes	
iii) Identification of the primary path/direction (possibly multiple entrances)	SSTP	yes	
	SSTP	yes	
(iv) where applicable, identification of the exit to be taken and distance from the primary road			
(v) Total number of free parking spaces for heavy goods vehicles	SSTP	yes	
(vi) Price of parking spaces and currency	SSTP	yes	
Information on the safety and equipment of the car park			
Information on the safety and equipment of the car park			
(i) description of the security and safety equipment and services in the car park, including the national classification if used	SSTP	yes	
(ii) Number of parking spaces for refrigerated lorries	SSTP	yes	
	SSTP	yes	
(iii) information on specific equipment or services for specific trucks or other vehicles			
Contact details of the car park operator		yes	
(i) Surname and first name	SSTP	yes	
(ii) Telephone number	SSTP	yes	
iii) Email address	SSTP	yes	
(iv) the operator's consent to disclose its contact details (yes/no)	SSTP	yes	
Dynamic data on available parking spaces, including whether a parking lot is full or closed or the number of available free spaces	SSTP	no	

5. Relevant data providers

The current report, being an output of the NAPCORE project, is naturally focused on data provided through National Access Points (NAPs) – or may be provided in the future – and their data providers. In general, digital maps describing road networks are available from authoritative sources across Europe from:

- Mapping Agencies
- Road Authorities

These digital maps may be their own produce and/or may reflect maps, or elements of them, obtained from different sources, such as:

- Commercial map providers
- Community maps, e.g. OSM, Overture

6. Applied Quality Definitions

6.1 Reference to the NAPCORE Quality Frameworks

The Quality Frameworks (QFs) by NAPCORE Task 3.2 usually apply a certain nomenclature.

First, there are quality dimensions that group several quality criteria. Each quality criterion can be assessed with metrics. The acceptance of data needs to meet a certain value of each of the metrics.

An example for the usage of the nomenclature, as applied for the Quality framework for floating car data (FCD), is presented in below picture:

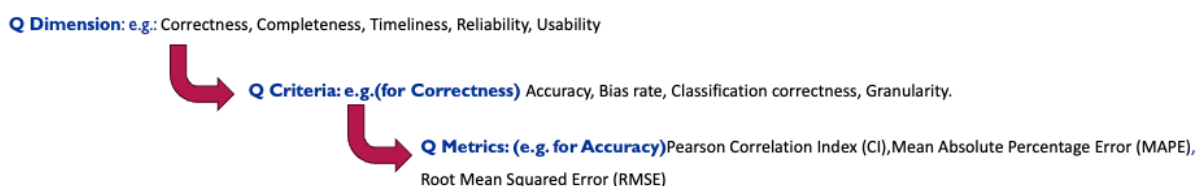


Figure 2 – Example for the nomenclature from the Quality Framework for Floating Car Data

In the QF for FCD, the applied quality dimensions are: “Correctness, Completeness, Timeliness, Reliability, Usability”

As an example, the quality criteria for the quality dimension “Correctness” are: Accuracy, Bias rate, Classification correctness, Granularity, see the following table.

Table 2 – Overview of quality dimensions and quality criteria from the FCD QF

Correctness	Completeness	Timeliness	Reliability	Usability
Accuracy – error rate	Spatial coverage	Freshness	Logical precision	Compatibility
Bias rate	Network coverage	Latency	Uniqueness	Service availability
Classification correctness	Missing values			
Granularity				

For each of the criteria one or more metrics can be defined.

In this FCD QF the possible metrics for Accuracy (error rate) can be:

- Pearson Correlation Index (CI)
- Mean Absolute Percentage Error (MAPE)
- Root Mean Squared Error (RMSE)
- Per Mile Absolute Time Error

The FCD QF and other NAPCORE QFs can be found at the NAPCORE Quality Repository⁶.

6.2 Identification of relevant Rules

Before defining quality dimensions, criteria and metrics for the topology topic, we defined relevant ‘rules’ to be applied for individual topological data, which can be applied as road network topology elements.

As an exercise, since we cannot address all related road network topology data, the team looked at selected topological data.

We consider the following exemplary topological data:

- Polygon layers (level 0 in the topology)
- Line layers (level 0 in the topology)
- Road segments (level1 in the topology)

Next, we asked digital map service providers via a small survey launched in the task, what the most relevant rules are in the process of creating topological maps. The following lists compile the top 5 rules per topological data.

Top 5 rules on the topological data “Polygon Layers” (level 0):

1. No Gaps allowed Between Polygons

Rule: Ensure that there are no gaps between adjacent polygons.

Importance: This is essential for maintaining continuous coverage of areas, such as land use or zoning maps, ensuring every part of the region is accounted for.

2. No Overlaps allowed Between Polygons

Rule: Adjacent polygons should not overlap.

Importance: Overlapping polygons can lead to inaccuracies in area calculations and misrepresentations of spatial relationships.

3. Polygons Must Be Closed

Rule: Polygons must form closed loops, meaning the start and end points of the boundary should coincide.

Importance: Open or unclosed polygons can cause errors in spatial analysis and render the data unusable.

4. Polygons Must Not Self-Intersect

⁶ <https://napcore.eu/quality/>



Rule: A single polygon should not cross over itself.

Importance: Self-intersecting polygons can create invalid geometry, leading to errors in spatial operations like buffering and overlay.

5. Must Be Single Part

Rule: Each polygon feature should be a single, contiguous part without disjoint segments.

Importance: Multi-part features can complicate spatial operations and analysis, leading to errors in data interpretation.

The metrics for these requirements is the number of infringements in a certain digital topological map

Top 5 rules for Line Layers (level 0):

1. Lines Must Not Self-Intersect

Rule: A single line feature should not cross over itself.

Importance: Preventing self-intersections ensures the accuracy of network analyses, such as determining the shortest path or flow within networks.

2. Lines Must Not Have Dangles

Rule: Lines should not have dangling ends unless they are supposed to represent a dead-end.

Importance: Dangles can indicate incomplete data or errors in digitization, leading to inaccuracies in network connectivity analysis.

3. Lines Must Be Properly Snapped

Rule: Line endpoints must be properly snapped to the endpoints of adjacent lines or to vertices of polygons when necessary.

Importance: Ensuring proper snapping prevents gaps or overshoots, which is crucial for maintaining connectivity in network analyses.

4. Lines Must Not Overlap

Rule: Line features representing the same network element should not overlap each other.

Importance: Overlapping lines can cause redundancy and inaccuracies in length calculations and network analysis.

5. Lines Must Be Single Part

Rule: Each line feature should be a single, contiguous part without disjoint segments.



Importance: Multi-part line features can complicate spatial operations and analyses, leading to errors in data interpretation.

Top 5 rules for Road Transport Networks in GIS (level1):

1. Road Segments Must Connect at Intersections

Rule: Road segments must connect at intersections, meaning the endpoints of road segments should meet precisely at junctions.

Importance: Ensuring proper connections at intersections is crucial for accurate routing and navigation. This prevents gaps or misalignments that can disrupt network continuity and affect travel time calculations.

2. No Overlapping Road Segments

Rule: Road segments representing the same stretch of road should not overlap each other.

Importance: Overlapping road segments can lead to redundancy and inaccuracies in distance and travel time calculations. Avoiding overlaps ensures a clean and accurate representation of the road network.

3. Road Segments Must Not Have Dangles (Unless Dead-Ends)

Rule: Road segments should not have dangling ends unless they are supposed to represent a dead-end or cul-de-sac.

Importance: Dangling ends can indicate incomplete or incorrect data, affecting the network's connectivity. Properly terminated road segments ensure accurate routing and network analysis.

4. Road Segments Must Be Properly Snapped

Rule: The endpoints of road segments must be snapped to the endpoints of adjacent segments or to intersection nodes.

Importance: Ensuring that road segments are properly snapped prevents gaps or overshoots, maintaining the network's integrity and ensuring accurate analysis of connectivity and traffic flow.

5. Road Segments Must Have Correct Directionality

Rule: Road segments must have the correct directionality, reflecting one-way streets and the proper flow of traffic.

Importance: Correct directionality is essential for accurate routing and navigation. Incorrect directionality can lead to routing errors and inaccurate travel time predictions, affecting traffic management and navigation systems.

6.3 Exemplary definition of quality dimensions, criteria and metrics

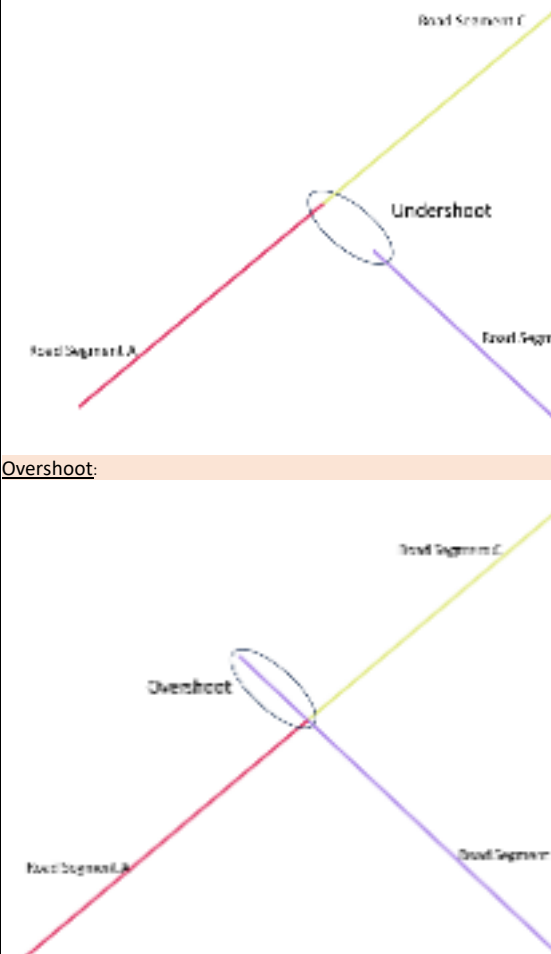
As the next step, we provided exemplary definitions of quality dimensions, criteria and metrics for the above-mentioned quality rule nr 4 for Road Transport Networks in GIS (level 1): ‘Road Segments must Be Properly Snapped’.

The following table compiles a preliminary set of such definitions, including the semantics, mathematical formulations and value ranges.



Table 3 – Definition of quality dimensions, criteria and metrics for the rule ‘Road Segments must Be Properly Snapped’

Quality dimension	Quality criterion	Criterion description	Metrics (Dimension Sub-element)	Metric description	Mathematical formulation	Possible values
Correctness	Geometry correctness (Position accuracy)	Topology QF - Precise geometry (road segments and of intersection) to ensure that the real-world is correctly represented (reflect the reality of the physical world).	Coordinate Precision	Geographic coordinates of road segments endpoints are accurate and precise with the physical world 	All road segment endpoints coordinates must be the same at the intersection. To achieve this, user should apply snapping techniques (e.g. ‘enable snapping’) during digitization or editing, to ensure that the endpoint will automatically snap precisely to the junction, avoiding any digitization errors and ensuring that the coordinates of the endpoints and the junctions are identical. Snapping Tolerance: distance tolerance between the pointer and the geometric element. If the pointer is within this distance, the snap will automatically align the pointer with the element. Possible Snapping type: Vertex Snap – This will move the pointer to the closest vertex of a polyline or polygon feature, based on the snapping tolerance. Snapping on Intersection – This will enable snapping to the intersections, even if there are no vertices at the intersection. 16.3. Editing — QGIS Documentation documentation Use snapping—ArcGIS Pro Documentation	
	Logical consistency	To ensure that the data follows the structure and rules established	Topological consistency	Quality measure: Number of Errors or Error rate (undershoots and overshoots, above a specified connectivity tolerance.) For example, 10 out of 1000 road links show an error, resulting in an error rate of 1% for topological consistency. <u>Undershoot:</u>	Topological consistency ensures that features in the dataset (i.e. road segments, intersections) conform to topological rules. In this context, it would check whether road segments meet at intersections without overshoots or undershoots.	

				 Undershoot: Overshoot:	This quality criteria calculates the number of road segments in the dataset with connection discrepancies due to undershoots, and overshoots that exceed the specified connectivity tolerance parameter. <i>* INSPIRE Data Specification on Transport Networks - Technical guidelines uses the concept of connectivity tolerance parameter which defines the acceptable threshold distance for features to be considered connected. (Mentioned in Inspire technical guide and Commission Regulation No 1089/2010 - Annex II, Section 7.9.6)</i> Example: Two road links should meet at a four-way intersection, but one road ends in a distance away than the connectivity tolerance from the intersection point. This is a topological error due to missing connectivity (undershoot). Two road links should meet at a four-way intersection, but one road ends overlapping the intersection point and the other road links. This is a topological error due to overlap connectivity (overshoot). <i>Note: QGIS has in-built topology checker mechanism, ArcGIS can validate topology with Error inspector</i> Reference : ISO 19157	
				Conceptual Consistency Error Count (count of all records in the dataset that are not aligned with the conceptual schema)	The total number of records in the dataset that do not comply with the rules of the	



					conceptual schema (example of inspire conceptual schema). Conceptual consistency ensures that the data follows the rules of the conceptual schema (i.e., the model that describes how the data should behave and be structured). This conceptual schema is usually built upon a common conceptual schema language (i.e. UML) and specifies requirements on the properties of each spatial object. Example: If the transport network conceptual schema the showing that the "A" roads must connect to "A" roads or "B" roads at intersections, and the "C" roads only allowed to connect to the "B" roads at intersections (not directly to the "A" roads), and in the dataset there is a "C" road that is incorrectly connected to a "A" road at intersection, then this is a conceptual consistency violation. If in the transport network conceptual schema, the roads are classified based on their function (e.g., highway, "A" road, "B" road) and on the dataset the road is incorrectly classified (e.g., "B" road classified as highway) this would be a conceptual inconsistency. Reference: ISO 19157	
				Geometry correctness (Intersection Information)	Include accurate information about the number of lanes, lane types (e.g., bus lanes) to correspond to an intersection (if it connects correctly with the road segments).	Connectivity index Calculate the number of road segments connected at each node.
				Geometry correctness (Intersection Information – Traffic Rules)	In relation to the route planning and travel time maybe it's important to have accurate information of the traffic rules	Attribute matching accuracy



					on the intersection (e.g no left turn, entering highway)	Calculate the percentage of matching attributes (e.g., road type, lane count) between connected segments
			Domain Consistency	Error Count	The total number of records in the dataset that do not comply with their defined value domain (e.g. domain value should be consistent as per domain of valid values in the application schemas properties requirements of the spatial object). Domain consistency ensures that attribute values fall within the predefined valid range or domain for each attribute. Example: If the transport network schema defines that speed limits should be within a specific range (e.g., 30 to 120 km/h for roads), and a road segment has a speed limit value outside of this range (e.g., 250 km/h), this would be a domain inconsistency. The data must follow the defined domain of acceptable speed limits. Another example could be in the case of road length, if in the schema defines that the maximum length of secondary road is 10 km and the dataset showing a secondary road with a length of 12 km then this is a domain consistency violation. Verify that roads are classified correctly based on their functional characteristics, such as residential, commercial, or industrial zones. Reference: ISO 19157	



			Format Consistency	Error Rate	The number of records in the dataset stored, in conflict with the required format (e.g., GML or XML). Example: If the dataset is supposed to be in a specific format (like GML), but is instead provided in a shapefile format, this would violate format consistency. Or if a road network dataset is missing an attribute such as road type that according to the schema should be present, or if extra columns are added outside the specification, then this is also a violation of format consistency. Reference: ISO 19157	
				Compatibility	Extent to which the provided information is provided in the desired format and in line with common standards (incl. location referencing). (pdf? Updates TN-ITS?) whole network	
Completeness <i>(not sure if this is relevant. This is a generic criteria for all use cases)</i>	Excess Records	Percentage of records in the dataset that are in excess to the number of records that should have been present in reality	Commission	Error Rate		
	Duplicated Records	Number of records that are duplicated with the features in the dataset	Commission	Number of Error	The total number of records in the dataset was created erroneously with a duplicate geometry.	
	Missing Records	Percentage of missing records (geometry representation).	Omission	Error Rate		
Hybrid (correctness & completeness)	Granularity	Level of detail of the information provided				
			Alignment Score (AS)	Evaluates the extent to which FCD segmentation aligns with network topology.		



		for each road segment and intersection. (Road segments connecting at an intersection should have consistent attributes, such as road type, lane count, and speed limits,	Discrepancy Index (DI) Difference Analysis?	Quantify discrepancies in key attributes.		
Timeliness (Unless there are major road works, intersections don't really change, also for road segments intersecting, timeliness is not relevant)	Freshness	Extent to which information derived from FCD is updated in a frequent basis	Average Update Frequency (AUF)	Measures the average time difference between consecutive FCD time aggregation intervals.		
	Latency	Time delay or lag between the update of an FCD record and the moment this record is made available for use through a data exchange system or platform.	Average Time Delay (ATD)	Measures the average time difference between all FCD time aggregation intervals and the moment at which the respective information is accessible to FCD users.		



6.4 Assessment of the exemplary definition of quality dimensions, criteria and metrics

Within the available time and assignment, it was impossible to work out dimensions, criteria and metrics for other mentioned road network topological data, mentioned in this document. The reader will understand that making a complete quality framework for all topological data is quite a further effort to go.

One can question if the metrics can be applied and if we can come to agreements of acceptance of the topological data quality based upon these metrics and ground 'truth' (e.g., derived from Satellite data (raster), other map data (vector), Floating Car Data...)

As a potential alternative approach to quality assessment in the topology context, we propose to look at the data that underly the creation of topological maps.

Road network topological maps and their data are the result of processing more 'raw map' data. Road network topological maps data are also considered to be more 'static data'. So, it might be obvious to look at the 'static' 'raw data' sources that lie on the basis of the topological process.

The following table identifies such 'static' 'raw data' from the data type inventory in the former table 1.

Table 4 – Identification of 'static' 'raw data' that underly the topological process.

	Delegated regulation	Obligation for data availability 1-1-2025	Topology related
Kind of infrastructure data			
v) nodes	RTTI	yes	
The crucial types of data on traffic and restriction s			
(i) conditions of access to tunnels;	RTTI	yes	
(ii) conditions of access to bridges;	RTTI	yes	
(iii) permanent access restrictions;	RTTI	yes	
(vii) restrictions based on weight/length/width/height;	RTTI	yes	
(viii) one-way streets;	RTTI	yes	
(ix) the zonal demarcation of restrictions, prohibitions or obligations, current access status and conditions for traffic in regulated traffic zones;	RTTI	yes	
(x) the direction of travel in reversible lanes (tidal flow)	RTTI	yes	
(vii) restrictions based on weight/length/width/height	RTTI	yes	
other types of data on traffic regulations and restrictions			
(a) road closures;	RTTI	no	
(b) lane closures;	RTTI	no	
(a) closures of bridges;	RTTI	no	
(h) the location of refuelling points and stations for alternative fuels	RTTI	no	
The location of identified access points for all planned modes of transport, including information on the accessibility of access points and walking routes at an interchange point (e.g. presence of lifts, escalators)	MMTIS 2023		
(i) Nodes	MMTIS 2023	no	
(iii) network topology and routes/lines	MMTIS 2023	no	
iii) Identification of the primary path/direction (possibly one-way streets)	SSTP	yes	
(iv) where applicable, identification of the exit to be taken and distance from the primary road	SSTP	yes	

7. Further evaluations needed

7.1 Generated insight

Based on the experience with the exemplary definitions of quality dimensions, criteria and metrics, based on pre-defined rules in the process of creating topological maps, we propose to establish a quality framework for 'static' 'raw data' sources that underly the topological process. Such sources include node data etc. and are listed in Table 4.

This means that the definition work for quality dimensions (e.g., correctness, completeness, ...) and related criteria and metrics needs to be rather related to such 'static' 'raw data'.

Looking to the above table of relevant required data that defines the road network topological representation in digital maps, the insight is that many of those data is again derived from the available traffic regulations and corresponding road signs. The identification and changes of those, are subject of the data exchange standard TN-ITS (becoming in the future DATEX II part 14), as referenced in the RTTI Delegated Regulation.

Quality aspects regarding traffic regulations and road signage information relate to questions such as "Are they available?", "What is the coverage?" etc. However, quality aspects about traffic regulations and road signage data were not in scope in this QF for road network topology, but should be covered in future elaborations of NAPCORE or other activities.

7.2 Future handling the data quality issue in the context of road network topology

The findings from the presented work imply two actions:

- A further study the map versus topology data relationships, maybe focussed to priority use cases as navigation.
- A focused quality elaboration on the data that build the source for the topological process, such as data related to traffic regulations and road signage.

We recommend taking on these works in the quality activity in upcoming phase of NAPCORE (starting in July 2025).

It is noted that traffic regulations and road signage data are part of the RTTI framework. A parallel approach to evaluating RTTI related data quality is the current 5-star-rating initiative from TISA⁷. This initiative aims to agree between service providers and authorities on data quality and acceptance levels. However, this process is likely to take some time, and the current scope is limited to priority data sets: speed limits, roadblocks, road closures.

⁷ https://tisa.org/wp-content/uploads/Draft-Proposal-Minimum-Quality-RTTI-Requirements-SL_RW_RC.pdf



We thus recommend to extend the work of TISA towards the relevant data types for the road network topology. In any case, the quality work in the upcoming NAPCORE phase should cooperate with the TISA initiative.

8. Conclusions

This QF for road network topology provided some basic concepts for a quality approach in the roadwork topology context. This includes an analysis on how road databases are usually modelled, on relevant use cases relying on network topology (in the scope of the RTTI), on relevant data providers, and on typical topological checks or rules in the map creation process.

However, this QF did not result in a complete finalised framework of defined and agree quality definitions (dimensions/criteria/metrics) that can be implemented right away.

The original idea of the presented Quality Framework was to create Quality Definitions Criteria and Metrics from “rules” related to typical topological checks. For example, one rule was ‘Road Segments must Be Properly Snapped’. We did define a preliminary set of definitions for this one exemplary rule, but it turned out that a comprehensive (and agreed) definition work for any kind of rules is too complex and time consuming.

In this process, it became clear that the road network data topology topic is complex in nature and in scope. The required data quality levels will depend on the envisioned use cases. But the topology is a result of a processed map. If the map data is wrong the topology data will be wrong.

The insight generated is that the quality aspect moves to the relevant data sets that define the digital maps. Thus, we identified two concrete follow-up actions:

- The relationship between the relevant map data and the resulting topology data needs to be further identified.
- Quality definitions (dimensions/criteria/metrics) have to be provided for the data that the underly the topological process. (We identified such data as of ‘static’ ‘raw data’ and listed them in Table 4.)

Further actions on that matter are recommended for the upcoming phase of NAPCORE.

References

GDF, ISO 20524-1:2020 Intelligent transport systems — Geographic Data Files (GDF) GDF5.1Part 1: Application independent map data shared between multiple sources. <https://www.iso.org/standard/68244.html>

GDF, ISO 20524-2:2020 Intelligent transport systems — Geographic Data Files (GDF) GDF5.1Part 2: Map data used in automated driving systems, Cooperative ITS, and multi-modal transport
<https://www.iso.org/standard/72494.html>

INSPIRE Data Specification on Transport Networks – Technical Guidelines. INSPIRE Infrastructure for Spatial Information in Europe D2.8.I.7 Data Specification on Transport Networks – https://knowledge-base.inspire.ec.europa.eu/publications/inspire-data-specification-transport-networks-technical-guidelines_en

Open Geospatial Consortium (OGC), Simple Features Specification: a standard that outlines how topology can be maintained in spatial datasets. URL: <https://www.ogc.org/standards/sfa>

Other NAPCORE Quality framework milestones

