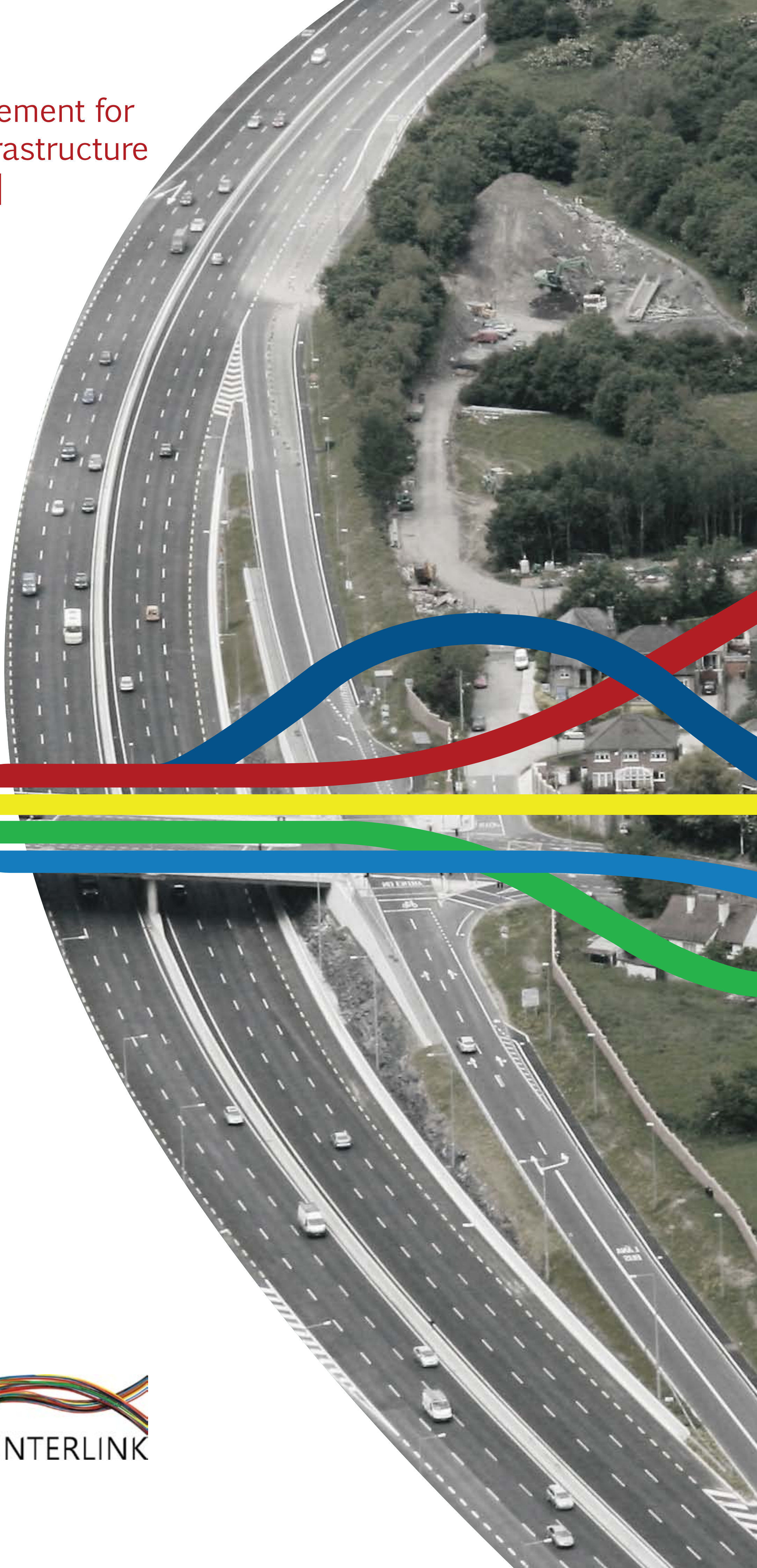
Information Management for European Road Infrastructure using Linked Data | Investigating the Requirements

Final Issue

31st March 2017



CEDR

Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

INTERLINK

INTERLINK D.2 & D.3 Combined WPA & WPB Report

Document name	INTERLINK D.2 D.3 - WPA & WPB Report.docx
Version	4.0
Date	31-3-2017
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Approval for main versions

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Proposed	1.0	Aonghus O'Keeffe	WPA Leader	23/02/2017
Reviewed	2.0	Daan Alsem	WPB Leader	24/2/2017
Authorised	3.0	Bart Luiten	Proj. Coord.	27/2/2017
Reviewed	3.1	Gerd Kellermann, Benno Koehorst	PEB Chair and Project Manager	17/3/2017
Authorised	3.2	Bart Luiten	Proj. Coord.	24/3/2017
Accepted	4.0	Gerd Kellermann, Benno Koehorst	PEB Chair and Project Manager	31/03/2017

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Acknowledgement

This document is a deliverable of the INTERLINK project, which has received funding from the CEDR Transnational Research Programme.

Executive summary

Background

Road infrastructure facilitates an important transportation mode at both a national and international level within Europe. Road networks are significant assets, which are often owned and operated by national roads authorities (NRAs). Safe and efficient operation of these networks relies on a system of numerous asset types, from the road pavement and structures to the communication systems, signs and road markings. These assets are delivered, used, operated and maintained throughout a long life with changing functional demands. Many parties are involved during this cycle of interacting processes.

From the time when the strategic need for a new road is identified through to the stage where the road is in operation, a large amount of information relevant to each of these assets is developed. The set of information about these physical assets is also an asset and European NRAs recognise that an inadequate or inaccurate information asset leads to higher capital and operational expenditure on physical assets. Likewise, NRAs are aware that effective acquisition and management of information incurs significant costs. These costs, predominantly transactional, are exacerbated by insufficient interoperability between stakeholders' information management systems. The Conference of European Directors of Roads (CEDR) seeks to improve interoperability by embedding the use of building information modelling (BIM), based on open standards, into the life-cycle processes of road infrastructure. Through its Transnational Road Research Programme, CEDR has commissioned the INTERLINK consortium to design and test an open, scalable, future-proof, basic object-type library (OTL) to facilitate improved interoperability.

The as-is condition

INTERLINK sought a clear understanding of the current condition across Europe for the management of road asset information. Two perspectives were studied in parallel; (i) the business needs for the information and (ii) the data needs to meet those business needs. A multi-faceted approach was adopted to elicit the industry's business and data needs, including: availing of the INTERLINK consortium's specialist experience; reviewing the diverse literature on the subject; conducting semi-structured interviews with over 60 senior staff from NRAs, contractors, consultants and software companies across Europe, each of whom engaged enthusiastically; and then testing a set of needs statements through an online survey of selected industry representatives.

Analysis of the primary and secondary research identified a typical as-is condition amongst European NRAs. It is predominantly document exchange-based, with silo databases and inconsistent information requirements. Some NRAs have well-established systems for predictive maintenance of structures (bridges, tunnels, gantries) and pavement assets, the two asset types that can incur the greatest liability if not managed correctly. However, in most cases NRAs rely on disparate asset management systems that have been developed over many years to suit the needs of individual teams responsible for each asset type. Even where NRAs have invested in enterprise-wide single-software systems for asset management, the data between asset types is not linked and the systems are not based on open standards, thereby compromising future value. Further, the systems are rarely integrated with internal and external project and operations systems. Due to these issues, data used is often incomplete, out-dated, inconsistent, non-uniform and not directly usable, thereby presenting extensive risks to NRAs.

The use of BIM for design and construction of roads is well advanced in various countries, including the Netherlands, Sweden, Norway and Finland. Numerous other countries are rapidly increasing their maturity in the management of information during the capital delivery phase of road assets. However, significant time and money is expended in getting relevant as-built information into asset management systems.

Nonetheless, NRAs and their partners are becoming more aware of the value of data as an asset, and that the quality and usability of the data is critical to the success of their operations. Numerous good examples of improved asset information management have been identified in various European countries. These examples form an important source of experience from which other countries should learn, and become the basis for improving asset information management.

A shift with the INTERLINK approach

The INTERLINK approach seeks to facilitate an industry shift from exchanging documents to sharing data using the European Road OTL, founded on the technologies of Linked Data and the Semantic Web. These technologies will enable CEDR to implement a software vendor-neutral system, which is applicable to the whole life-cycle of road assets, and accommodates various existing and future open data standards. Initially, the European Road OTL will facilitate a hybrid approach of linking semantically-rich data to more traditional document-based information. Ultimately, INTERLINK envisages that road asset data will remain at source, shared over the web through a system of harmonised data standards with strengths from the international, national and organisational levels, and interrogated via flexible, software-as-a-service applications. The predominant expected benefit is a reduction in transaction costs throughout the life-cycle of asset information.

Recommendations

The research enabled the INTERLINK consortium to identify various recommendations. Firstly, a set of verified business and data needs should underpin the principles for the European Road OTL, which will be developed in the next research phase (Work Package C). Secondly, various existing and forthcoming international and national data standards and initiatives should be considered for integration with the European Road OTL during Work Package C. Thirdly, the test cases for the final stage of the project should focus on use cases of business value across Europe, including the reuse of existing asset information, and the handover of information from construction to asset management.

Finally, in advance of any future implementation of a European Road OTL by CEDR, INTERLINK makes interim recommendations for NRAs and industry, including:

- that NRAs and industry contribute actively to further development of the European Road OTL and support harmonisation of the relevant standardisation initiatives;
- that NRAs develop the next step to shared information with Linked Data and other open standards and classification systems to work towards more effective collaboration with industry: i.e. using the same language, using each other’s data;
- that NRAs and industry apply open standards more extensively in their operations;
- that NRAs contractually require capital works and maintenance contractors to validate and certify as-built information, such that the subsequent trust of that information by asset managers is improved;
- that NRAs require contractors to price for engaging with asset managers during the life of a construction or maintenance project to agree and document the nature, format, testing and handover of information required for the management of assets, or for supporting the NRA in the development of ontologies for any assets which are not covered by existing relevant OTLs;
- that NRAs focus on eliciting from asset managers the most important pieces of information required for each asset type, and then ensuring that project managers limit their handover requirements to that information in an appropriate format;
- that NRAs considering developing capabilities in a certain area look at and learn from the excellent achievements in other European countries;
- that software companies develop new tools for the Linked data and Semantic Web technologies;
- that NRAs actively engage or communicate with the INTERLINK Consortium throughout this research.

Project information

Project title	INformation managemenT for European Roads using LINKed data		
Acronym - Logo	**INTERLINK**		
CEDR Topics addressed	CEDR Call 2015: Asset Information using BIM: A. Exploration of procuring asset information B. Exploration of BIM data structures C. Design for common principles for object-type library D. Design and test a basic object-type library and open BIM standards		
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	AEC3		DE
	Trimble Solutions Sandvika AS (formerly Vianova Systems)		NO
	interactive instruments (ii)		DE
	Semmtech		NL
	planen-bauen 4.0 (pb4.0)		DE
Start date **End date**	01/09/2016 31/08/2018	**Duration (in months)**	24
Project Website	http://www.RoadOTL.eu/		

1 Introduction

This report details the findings of Work Package A (WPA) and Work Package B (WPB) of the INTERLINK project. In this Section 1, an overview of INTERLINK is provided, summarising the primary aims and objectives of the project and those of this report. Section 2 describes the typical terminology used in relation to asset information management, with several examples provided to assist the reader's understanding of some of the technical terminology used throughout this report.

The methodology used to identify and analyse the condition of the industry is summarised in Section 3, with Section 4 describing key findings from the primary and secondary research. Further details and discussion on the analysis can be found in the relevant appendices. Section 5 presents the results of the research and analysis which form the basis of this report, with a focus on the current as-is condition, the application of INTERLINK approach, and the envisaged to-be condition. The industry business and data needs are discussed in Section 6 and presented in a poster in Appendix F. The final section in this report, Section 7, outlines recommendations based on the findings of this research to date. These recommendations include relevant considerations for specification, development and testing of a European Road Object-Type Library in the next phases of this project. In addition, interim recommendations to NRAs and other relevant industry stakeholders are provided.

Various appendices are provided. Certain findings documented in this report are based on a review of literature listed in an earlier INTERLINK deliverable. Hence the reader is directed to that deliverable via Appendix A for much of the cited literature.

1.1 The research need

Road infrastructure assets, from communications systems to pavement, from bridges to motorway networks, have a complex life-cycle. They are conceived, in part or in whole, to serve a strategic need within a wider transport network and economic system. They are delivered through an extended process of technical design, statutory consent, fiscal approval and construction contracts. The assets are then used, operated, maintained and rehabilitated throughout a long life with changing functional demands. Many parties are involved, directly or indirectly, during this cycle of interacting processes.

The set of information about these physical assets is also an asset. European national roads authorities (NRAs) recognise that an inadequate or inaccurate information asset leads to higher capital and operational expenditure on physical assets. Likewise, the NRAs know that effective acquisition and management of the information asset incurs significant costs. These costs, predominantly transactional, are exacerbated by insufficient interoperability between stakeholders' systems. The Conference of European Directors of Roads (CEDR) seeks to improve interoperability by embedding the use of building information modelling (BIM), based on open standards, into the life-cycle processes of road infrastructure. Through its transnational research programme, CEDR published a 2015 Research Call entitled "Asset Information using BIM", which was focussed on addressing these issues to improve interoperability between European NRAs.

This research call identified two primary objectives:

- To identify the needs among Europe's NRAs and major stakeholders regarding the exchange of Building Information in a vendor-neutral way during the assets' life cycle.
- To identify what national building/asset information knowledge can be used for implementation on a European level and for further development.

To achieve these objectives, four specific sub-themes were included in the research programme, structured in such a way as to ensure that the proposed solution would be supported by a comprehensive review and understanding of current business needs and BIM data structures. The solution would then be tested and validated using appropriate test cases. Following the evaluation of submissions, CEDR commissioned the INTERLINK consortium to carry out this research and ultimately to design and test an open, scalable, future-proof, basic object-type library (OTL) for road assets. INTERLINK stands for INformation managemenT for European Roads using LINKed data.

1.2 Overview of INTERLINK research project

The fundamental premise of the INTERLINK proposal was that the effectiveness of this European Road OTL relies on the capabilities of Linked Data and the Semantic Web. This will enable CEDR to implement a software vendor-neutral system, which is applicable to the whole life-cycle of road assets, accommodates various existing and future open data standards, and facilitates a hybrid approach of linking semantically-rich data to more traditional document-based information.

The INTERLINK consortium comprises a research institute (TNO from the Netherlands), engineering and asset management consultants (Roughan & O'Donovan from Ireland and Royal HaskoningDHV from the Netherlands), ICT consultants and software companies (AEC3 from Germany, Trimble Solutions Sandvika AS from Norway, interactive instruments from Germany, and Semmtech from the Netherlands), and a national BIM implementation body (planen-bauen 4.0 from Germany). INTERLINK is steered by, and reports to, the CEDR Programme Execution Board, which is comprised of experts in information management for road infrastructure from the NRAs participating in the 2015 Research Call.

The INTERLINK project has proposed a carefully structured work breakdown, consisting of interacting Work Packages, as shown in Figure 1.1.

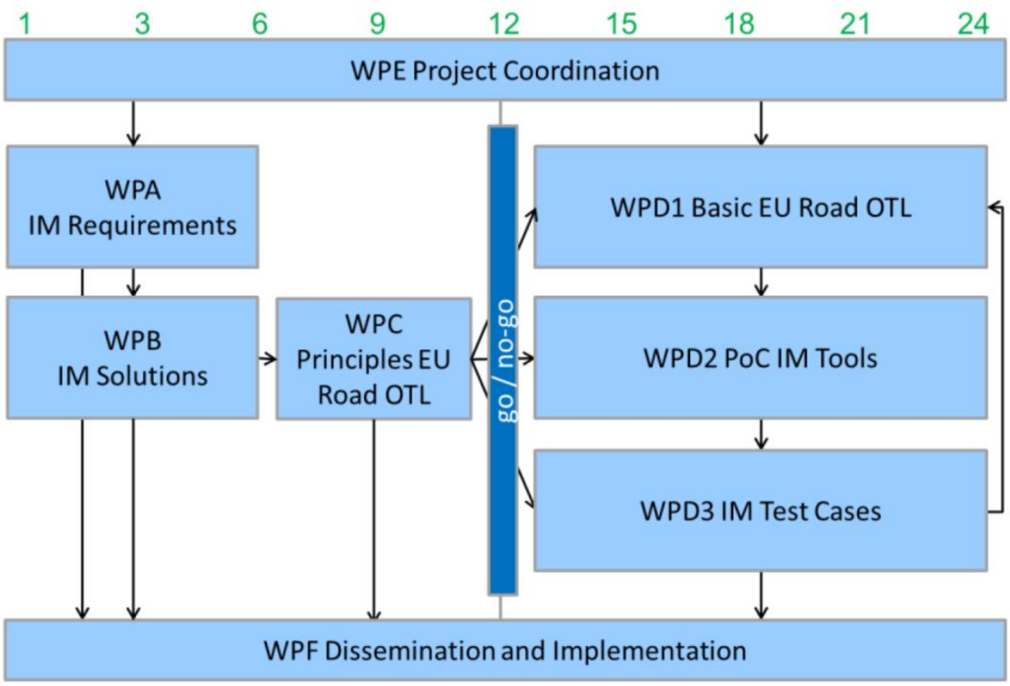


Figure 1.1 – INTERLINK work package structure

The success of this project relies on a thorough understanding of the NRAs' and their suppliers' business needs for information, supported by detailed knowledge of the technical data needs which must be met. The first two phases of the INTERLINK project, occurring in parallel over a six-month period to February 2017, were to elicit and document these business needs (WPA) and data needs (WPB), and to validate the assumption that a Linked Data approach is required to meet those needs. The next six-month phase will use those needs as a basis for establishing principles for the European Road OTL (WPC). In Year 2, the consortium will develop and test a proof-of-concept OTL, working closely with NRAs and industry to optimise implementation and to promote acceptance in practice (WPD1-D3). The final two WPs (WPE & WPF) focus on the coordination, dissemination and implementation of the project activities and aim to ensure that the project outputs are high-quality and as relevant to the needs of the industry as possible, while also ensuring that the relevant industry stakeholders are kept informed of the INTERLINK developments to maximise the potential Europe-wide adoption of the proposed solution.

1.3 Objectives of WPA and WPB

WPA and WPB were conducted in parallel and aimed to provide the INTERLINK consortium with a comprehensive understanding of the current situation across Europe in relation to asset information practices, allowing gaps or deficiencies to be identified and recommendations to be made for the development of a solution to improve on the current condition.

Both WPA and WPB aimed to elicit the current and future needs of the industry. However, the focus of these work packages, while overlapping in many cases, was separate. WPA aimed to review and identify the *business needs*, with WPB focussing on *data needs* and the associated data structures and solutions. The primary research in these work packages sought to identify the way NRAs are dealing with the exchange and sharing of asset information over the life-cycle stages, from conception through to operation and maintenance, in the current condition. The work packages also aimed to envisage the use and management of asset information in the future. The specific objectives of WPA and WPB and the approaches adopted to meet these objectives were described in the project proposal as follows:

WPA: Information Management Requirements

WPA aims to examine the current practices for the procurement, exchange and management of asset information with a focus on the business needs for information. This review of the 'As-Is' condition in Europe will facilitate the recommendation of a 'To-Be' condition in Europe.

- Literature Review: Document changes to earlier literature reviews (e.g. V-Con).
- As-Is (Functional and Information Level) Analyse and report how infrastructure asset information is currently produced, accessed and processed in various situations:
  - By European country;
  - By asset type (structure, pavement, sewerage, furniture, other relevant industries if necessary)
  - By asset life-cycle phase (design, construction, operation and maintenance);
  - By contract form (traditional, Design and Build, Public Private Partnership, service, maintenance).
- To-Be (Functional Level) Document the common needs of NRA asset managers, NRA project managers, contractors and others in the supply chain regarding how asset information will be accessed, processed and exchanged in the future.

WPB: Information Management Solutions

WPB aims to explore existing BIM data structures and to gain an insight to the current information management solutions and the existing gaps with the information management requirements at the NRAs and their supply chain. The research will focus particularly on open BIM standards and the existing systems supporting their use. The gap analysis will result in a set of data needs and related recommendations for the European Road OTL being developed in the second half of the INTERLINK project.

- Literature Review Document changes to earlier literature reviews (e.g. V-Con).
- As-Is (Functional and Information Level) Analyse and report current data standards and data-structure, internationally and by European country;
- To-Be (Functional Level) Document the common data (-standards and -structures) needs for NRA asset managers, NRA project managers, contractors and others in the supply chain regarding how asset information will be accessed, processed and exchanged in the future.

This report outlines the findings of the research carried out in WPA and WPB. Appendix F provides a graphical overview of the main result of WPA and WPB: a list of 'needs statements' which have been developed and their context of infrastructure asset management. The body of this report describes the approaches used to develop and validate these statements by combining the expertise of the INTERLINK consortium with strong stakeholder engagement. These needs statements provide an outline of how the INTERLINK consortium sees the future developments of asset information management for road infrastructure in Europe. Along with the recommendations provided in this report, the statements should serve as a guide to the industry for achieving the to-be situation. In addition, these needs statements will be used to inform and steer the development and validation of a European Road OTL which will be carried out in WPC and WPD1-WPD3 of this project.

2 Standardising Asset Information

In this section, the most common basic terms related to the use of BIM for the life-cycle of road infrastructures are defined with examples. The definitions are considered workable in the context of this report. The sources for the definitions include the experience of the INTERLINK consortium, the references in Appendix A and Wikipedia.

2.1 Object-type library

Understanding the term object-type library is essential for the reader. An object-type library (OTL) in general is an abstract, simplified view on a part of reality to be represented for some purpose. In the context of the European Road OTL, the purpose is to support a common understanding between humans and computers of information required for the design, construction, operation and maintenance of road infrastructure assets.

An OTL is a library with standardised object-types names (e.g. road, viaduct) and properties (see Section 2.2) or specifications. An object is described with its object-type data, geometry data and metadata, Metadata are data (or information) about the data of objects. Metadata are needed because each object type has its own properties. How the object types are grouped is called an ontology (see Section 2.3). The OTL can be linked to a data dictionary (see Section 2.4), with the definitions of object-types. By using an OTL assets are described with a standard language, syntax and semantics, which are required for a reliable exchange of information.

A cable-stayed bridge is an example of an object-type. An instance of this object-type would be a data object carrying relevant data about a particular bridge, for example the Millau Viaduct in France. The relevant object-type data for such a bridge would depend on who is looking for the information. For a designer, it could be the number of pylons, the number of spans, the spans lengths and the deck material. A contractor may find a web link to a construction specification. For an asset manager, the relevant data could be the expected residual life of the structure and the time to the next inspection of the bearings. For the bridge inspector, it could be the access route for inspecting the pylons.

Objects can carry or reference graphical data and non-graphical data. They can also carry metadata, i.e. data about the data. An example of metadata for the Millau Viaduct object could be when and by whom the object data was last revised. The object-type library defines the data structure and the variables to be populated at different stages of an asset's life, often in the context of associated open data standards.

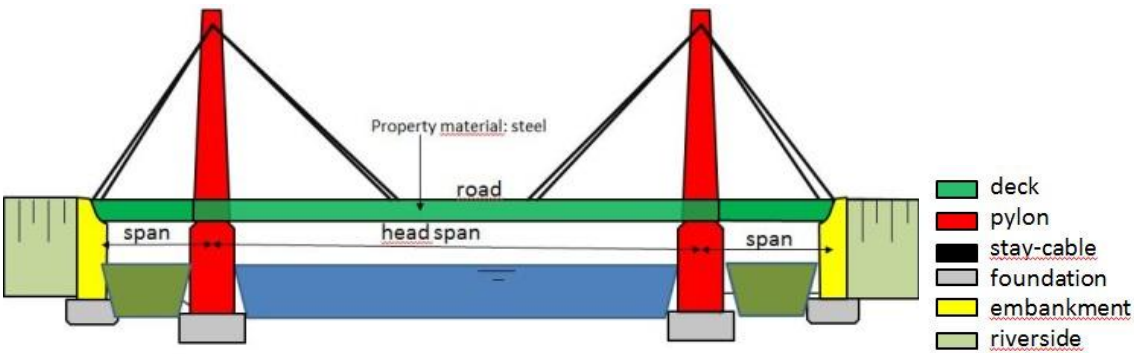


Figure 2.1 – Schematic of the object type ‘cable-stayed bridge’ showing its properties

Figure 2.2 shows the three perspectives on the use on an OTL. Together with other relevant OTLs (international, country-specific, company-specific or even project-specific ones) the European Road OTL will support the three perspectives:

- Agreement on civil infrastructure assets definition and specification by experts in the road domain;
- Giving structure to asset data for exchange and sharing between stakeholders and their software applications, along the asset's life-cycle and supply-chain; and
- Provision of a kind of 'hub' or 'entrance' to all relevant asset data and documents, (native, according to any existing open existing standard; or preferably as rich, linked 'object' data that can be directly understood and processed by software).

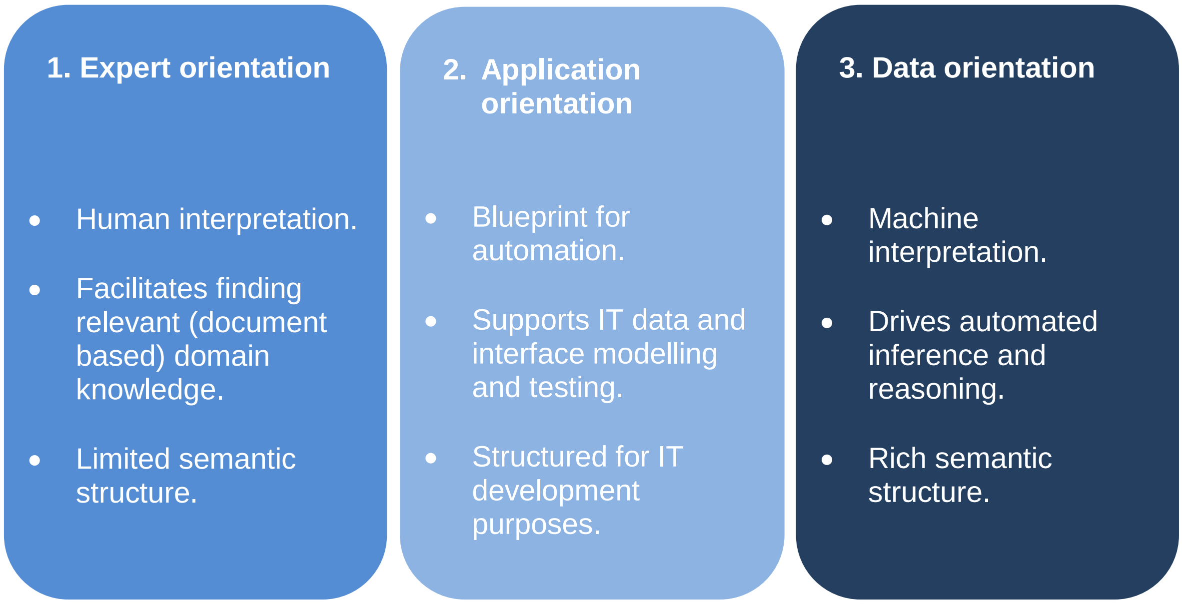


Figure 2.2 – Three perspectives on the use of an object-type library (OTL)

A common European road object-type library (the European Road OTL) is an OTL that contains that part of the object specifications of road assets upon which the NRAs in Europe agree. When agreed upon between the parties in a specific domain, the European Road OTL can be considered a 'standard' for that domain. When this standard is shared publicly, it can be considered an 'open standard'.

Figure 2.3 shows an example of how an OTL can be used in the communication between a contractor, responsible for the design and construction of an asset, and an NRA, responsible for management of the asset. The example is from Rijkswaterstaat, the Dutch NRA. It shows that the data exchanged or shared within each organisation, and the data exchanged between organisations, are structured using the OTL.

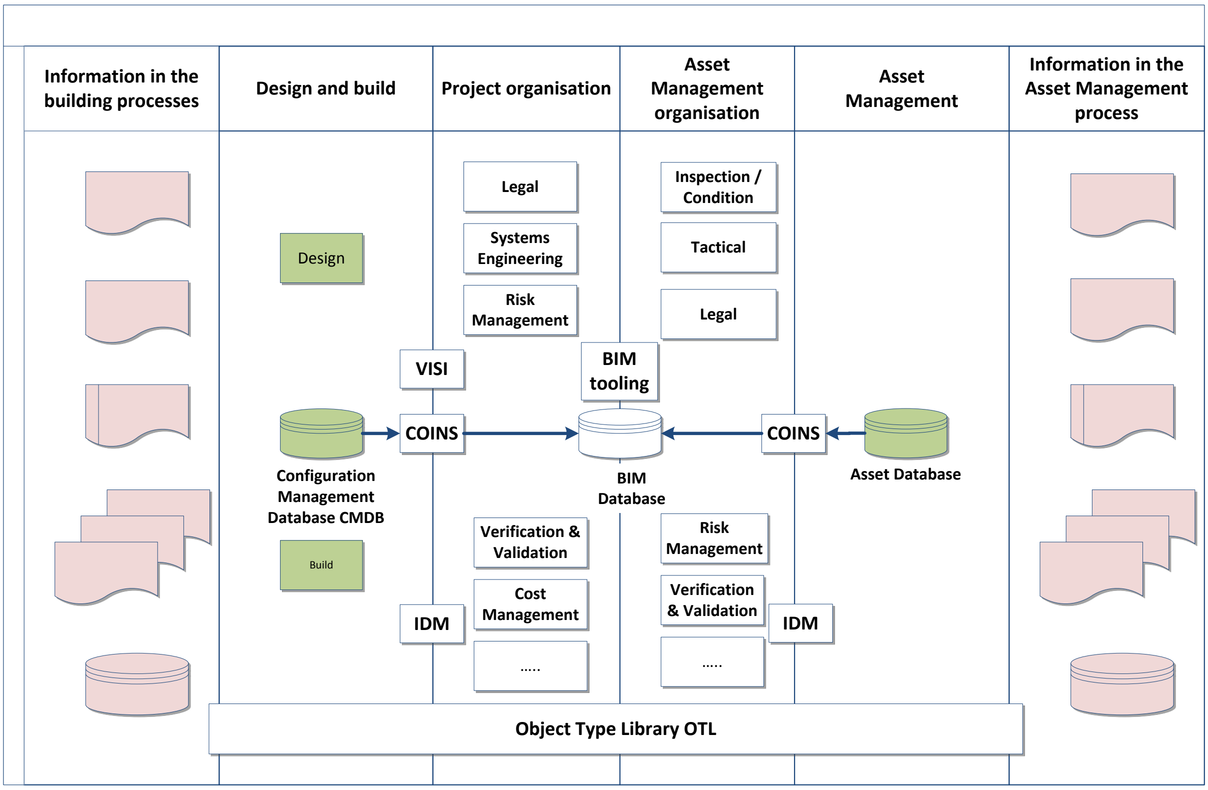


Figure 2.3 – Example of business processes with an OTL (from Rijkswaterstaat in The Netherlands)

2.2 Properties

A property is an attribute, quality, or characteristic of something. A property of the object-type cable-stayed bridge is the pylon material. Properties of the deck are the length, width and area.

2.3 Ontology

An ontology is the conceptualisation of a certain domain, which consists of concepts (elements), properties (e.g. location, material and type) and processes. The ontology defines how entities are grouped and related within a hierarchy, and subdivided according to similarities and differences. The ontology is a common breakdown structure of entities and object-types.

An ontology for a cable-stayed bridge may breakdown the bridge into entities that require inspection and maintenance, including the cables and bearings. Of course, those entities may also be shared with the ontologies for other bridge types, such as suspension bridges. An ontology may cross-reference other ontologies which provide a greater level of detail, or granularity, such as national or project-specific ontologies.Data dictionary

A data dictionary, or metadata repository, is a "centralized repository of information about data such as meaning, relationships to other data, origin, usage, and format." An OTL can be linked to one or more data dictionaries. In the UK, an Asset Data Dictionary Definition Document (AD4) defines the functions, classes and attributes for an asset type, with the intention that this applies across various infrastructure types, from road to rail. The AD4 gives the minimum level of information required at various stages throughout the procurement of an asset (Miskimmin & Dentten, 2015). An example is the information required at preliminary design stage for the embankment on the approach to a bridge, including height, slope and fill material.

2.4 Conceptual model

The aim of a conceptual model is to express the meaning of terms and concepts used by domain experts to discuss a problem, and to find the correct relationships between different concepts. An example is a conceptual model of bridges and their context, e.g. IFC Bridge.

A conceptual model clarifies the meaning of various, usually ambiguous terms, and ensures that problems with different interpretations of the terms and concepts cannot occur. Such differing interpretations could easily cause confusion amongst stakeholders, especially those responsible for designing and implementing a solution, where the conceptual model provides a key artefact of business understanding and clarity.

Once the domain concepts have been modelled, the conceptual model becomes a stable basis for subsequent development of applications in the domain. The concepts of the conceptual model can be mapped into physical design or implementation constructs using either manual or automated code generation approaches. The realization of conceptual models of many domains can be combined to a coherent platform.

2.5 Level of Development

The Level of Development (LOD) specification is a reference that enables practitioners in the architecture, engineering and construction industry to specify and articulate with a high degree of clarity the content and reliability of building information models at various stages in the design and construction process. LOD are defined from LOD100 to LOD400 in the US, as depicted in Figure 2.4.

Figure 2.4 – LOD 100 to LOD 400 level of development (BIMFORUM)

In the UK BIM standards, LOD refers to Level of Detail, and ranges from LOD 1 to LOD 7. The UK standards also apply Level of Information, from LOI1 to LOI7. Other definitions apply also. The LOD and LOI can be used for defining the asset information to be shared by different stakeholders at various stages of an assets life-cycle. For example, the load capacity of a bridge bearing is not required at conceptual design stage, but should be provided by the bridge designer at the end of detailed design.

2.6 Data Standards

A data standard is a documented set of agreements on representation, format, definition, structuring, tagging, transmission, manipulation, use and management of data. Development and formal approval of such a standard follows an agreed process.

A data standard has a scope of application, based on the organisations that publish it. This scope can be international, European, national, company- or even project-specific.

Data standards have different levels of maturity and different levels of acceptance in the industry. In some cases, the use of standards is prescribed in regulations or by the principal, in this context most often the NRA. For example, the use of Geographic Mark-up Language (GML) to describe geospatial information related to all bridges belonging to an NRA.

2.7 Semantic Web

The Semantic Web (SW) is an extension of the Web through standards by the World Wide Web Consortium (W3C). The standards promote common data formats and exchange protocols on the Web, most fundamentally the Resource Description Framework (RDF). The Semantic Web, with its key component the web ontology language (OWL), provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries.

By adding intelligence to data such that the data is computer-readable, information can easily be retrieved and interrogated by using this intelligence of data. After adding so called ‘semantic tags’ to data, it is possible to trace these data using queries. For example, by asking: “in my portfolio of all assets, search for cable-stayed bridges with a Type 123 bearing” in a situation where an asset manager is concerned about the durability of such a bearing product and wants to plan inspections.

2.8 Linked Data

Linked data, often capitalized as Linked Data (LD), is a method of publishing structured data so that it can be interlinked and become more useful through semantic queries. Data in a (relational) database are also linked data but in a closed silo. These data are not available for others beyond the boundaries of the database. However, Linked Data are openly available (subject to access permissions). Such data are shared, not exchanged. The technology builds upon standard Web technologies such as HTTP, RDF and URLs. Rather than using Web technology to serve web pages for human readers, Linked Data, when combined with Semantic Web technology, extends them to share information in a way that can be interpreted automatically by computers. This enables data from different sources and owners, like assets, documents and maps, to be connected and queried (Bizer et al., 2009). The management of Linked Data is necessary to control the consistency of the asset information.

In the cable-stayed bridge example, the use of Linked Data and Semantic Web technology could enable the asset manager to query if a group of bridges with particular bearing types was, based on their geographic location, subject to very high traffic loading over the last three years (assuming that the NRA is recording their traffic data at each site and making it available in a Linked Data format).

2.9 Classes

In object-oriented programming, a class is an extensible program-code-template for creating objects, providing initial values for state (member variables) and implementations of behaviour (member functions or methods). According to an extensional definition, classes are abstract groups, sets, or collections of objects. According to an intentional definition, classes are abstract objects that are defined by values of aspects that are constraints for being member of the class. An example of a class may be “Bridge”, the class of all bridges, or the abstract object that can be described by the criteria for being a bridge.

2.10 IFC Industry Foundation Classes

The Industry Foundation Classes (IFC) data model is intended to describe building and construction industry data, including Alignment, Road, Railway, Bridge and Tunnel data. It is a platform neutral, open data standard that is not controlled by a single vendor or group of vendors. It is an object-based data standard with a data model developed by buildingSMART, to facilitate interoperability in the architecture, engineering and construction (AEC) industry, and is a commonly used collaboration standard in BIM based projects. The IFC model specification is open and available. It is registered by ISO and is an official International Standard ISO 16739:2013.

2.11 Classification systems and data classification

Classification systems are systems with a distribution of classes created according to common relations or affinities.

A common way to organize a classification system is to use a taxonomy, where classes and/or properties are structured into a generalization/specialization hierarchy. Within the AEC industry, classification systems are commonly used to classify the processes, resources, results and properties within the realm of the built environment. A basis for such a classification system may be the standard ISO 12006-2 - Building construction — Organization of information about construction works — Part 2: Framework for classification.

A well-planned data classification system makes essential data easy to find and retrieve. Written procedures and guidelines for data classification should define what categories and criteria the organization will use to classify data and specify the roles and responsibilities of employees within the organization regarding data stewardship. Once a data-classification scheme has been created, security standards that specify appropriate handling practices for each category and storage standards that define the data's life-cycle requirements should be addressed.

An example of a classification system is the UK Uniclass 2015, a unified classification for the UK industry covering all construction sectors by the NBS, New Building Specification. Uniclass 2015 has been carefully structured to be in accordance with ISO 12006-2 Building construction – Organization of information about construction works – Part 2: Framework for classification. Uniclass 2015 is divided into a set of tables which can be used to categorise information for costing, briefing, CAD layering, etc. as well as when preparing specifications or other production documents. These tables are also suitable for buildings and other assets in use, and maintaining asset management and facilities management information.

Another example is CoClass, the new digital classification system for all of the built environment in Sweden. The new system is the result of an extensive industry-wide development projects - BSAB 2.0.

3 Methodology

The overall goal of carrying out the initial research was to gain an in-depth understanding of the NRAs' and their suppliers' business needs for information, supported by detailed knowledge of the technical data needs which must be met. This section describes the process which was followed, in the case of both WPA and WPB, to elicit these needs from stakeholders and to identify a common set of 'needs statements' which are of primary importance to the development of a common approach for the implementation of BIM processes in the asset management of roads across Europe.

In order to examine the current 'as-is' situation across Europe it was necessary to combine the expertise and opinion of the INTERLINK consortium members with detailed feedback from relevant stakeholders. This stakeholder engagement focussed on the needs of NRAs, but also considered the opinions of other relevant stakeholders including engineering consultants, construction contractors, ICT consultants and software companies. Feedback was obtained from individuals with experience in different stages of the life-cycle of road infrastructure assets as well as individuals working with different asset types.

Several different avenues were investigated to ensure that all relevant aspects were comprehensively considered as part of this process. These are represented in Figure 3.1.

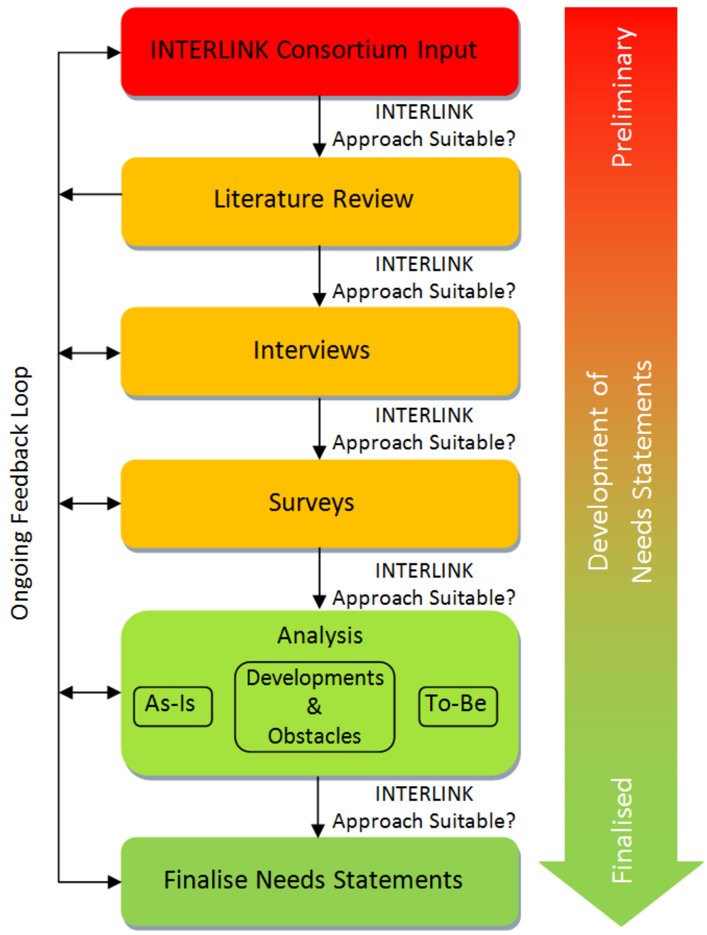


Figure 3.1 – Primary and secondary research methodology

While there was some overlap between each of these steps, for the most-part they were carried out sequentially, with the findings of one step informing the process followed in the next step. The following sections provide an overview for the methodology adopted to carry out each of these steps.

3.1 INTERLINK Consortium input

The INTERLINK consortium consists of multiple organisations all of which are well placed to understand the needs of the industry from various perspectives. The consortium comprises a research institute (TNO from the Netherlands), engineering and asset management consultants (Roughan & O'Donovan from Ireland and Royal HaskoningDHV from the Netherlands), ICT consultants and software companies (AEC3 from Germany, Trimble Solutions Sandvika AS from Norway, interactive instruments from Germany, and Semmtech from the Netherlands), and a national BIM implementation body (planen-bauen 4.0 from Germany).

At the outset of the project it was acknowledged that the project team comprised various experts who possessed vast levels of relevant experience in various aspects of the life-cycle of road infrastructure assets, and the associated the asset information practices. Therefore, the initial investigation involved engagement with the members of the INTERLINK consortium. Consortium members provided relevant information and feedback on important industry needs and identified relevant literature which was included as part of the literature review process.

This interaction between the various experts in the INTERLINK consortium initiated the process of developing a set of 'needs statements', which at this stage mainly served the purpose of identifying any major issues which warranted further investigation through a review of the literature or through engagement with industry stakeholders. While it was recognised that the inputs from the experts in the project team were valuable, it was also important to ensure that the findings of this research were not biased by the opinions of the INTERLINK consortium.

As the subsequent stages of the primary research were undertaken, interaction with the members of the project team was maintained and their opinions or suggestions for improvements considered as necessary.

3.2 Literature review

Having obtained feedback from the consortium members who provided information on the most relevant literature from their own countries or on an international level, the next step involved a review of the literature to further identify pertinent industry needs to inform the development of the INTERLINK needs statements. Independent reviews of relevant literature were carried out by both WPA (focussing on business needs) and WPB (focussing on data needs, and on information structures and solutions). Both literature reviews followed a similar process, despite their slightly different focus.

The process adopted is briefly described below with a more detailed overview of some of the findings presented in Appendix C. It is important to note that detailed literature reviews have previously been carried out (e.g. as part of the V-CON project). Therefore, the approach adopted here focussed on a more high-level examination of relevant literature and of previous literature reviews to identify any changes or developments which had become apparent since previous comprehensive literature studies had been completed.

The literature review process initially involved identifying and briefly reviewing relevant literature sources including academic research, national and international standards, guidance documents and industry reports and presentations. Each of the sources were then classified using criteria to assess relevance to the INTERLINK project and to identify the most important sources to consider in more detail as outlined below considering the relevant criteria for WPA and WPB. The relevant documentation was reviewed in more detail to identify business and data needs.

The inventory of relevant literature developed as part of this process was created at the outset of the project and has been maintained and updated as necessary. The full list of literature can be found in INTERLINK Deliverable D.1 Literature library list. The inventory also contains examples of implementation, relevant comments on various literature sources (pros and cons) and web links to further information.

The main findings and recommendations of the literature review are summarised in Appendix C and served as an initial validation of the preliminary needs statements identified by the INTERLINK consortium in the previous step. The supplemental information obtained as part of the literature review process allowed these needs statements to be further developed and refined to ensure that they remained relevant.

3.3 Interviews

To gain a deeper understanding of the current business and data needs of the industry many interviews were conducted with experienced professionals who are involved in various aspects of road infrastructure from the initial planning stages right through to the construction, operation and maintenance. The interviews were structured in such a way as to facilitate the gathering of relevant information for both WPA and WPB, with individuals in relevant roles identified to allow both the business and data aspects to be covered as part of the interview process. Table 3.1 provides an overview of the roles and organisation types which were identified as being of primary importance to ensuring the most relevant and valuable feedback.

Table 3.1 – Organisation types and roles of primary interest to INTERLINK

Organisation Types	Roles
National Roads Administrations	ICT/Information Managers
Contractors / Construction Companies	BIM Managers, Contractors
Engineering Consultancies	Project Managers and Engineering Consultants
ICT Consultancies	Project Managers and Information Consultants
Software Providers	Account Managers
Non-Governmental Organisations	Consultants, Asset Managers, Business Developers
Research Institutes	Experts

Individuals in each of the organisation types and roles outlined in Table 3.1 were identified either through contacts of the consortium members or through liaising with the relevant members of the Project Executive Board (PEB). The interviews included respondents from several CEDR countries as outlined in Appendix D. It is important to note that the interviewees were carefully selected based on their role and level of experience to ensure that the feedback from the interviews would accurately represent the needs of the industry.

It is also important to note that the selected interviewees did not necessarily require significant knowledge of BIM or asset information processes. Individuals involved in the design, construction, operation and asset management phases of roads projects, whether BIM focused or not, could all provide relevant feedback on the needs of the industry. The level of engagement and participation in the interview process was extremely encouraging, with most countries demonstrating a great deal of enthusiasm towards the INTERLINK project and the topic of asset information management for road infrastructure in general.

To make the interviews as fruitful as possible an open-ended format was adopted for the interview process. Most the interviews were carried out via Skype or teleconference, with a few the interviews conducted face-to-face. The interviews were carried out by ROD and RHDHV, with the interviews divided up between the two organisations by country. This avoided duplication of interviews with individuals with experience relevant to both WPA and

WPB. A set of relevant interview questions was drafted (see Appendix D) and these were sent, along with a brief project description, to each interviewee a few days before the interview to provide them with sufficient time to consider their answers.

To facilitate interviewees with different areas of expertise, a semi-structured approach was adopted which allowed the interviews to focus on the most relevant areas of expertise of a given individual. In most cases, where the interviewee consented, the interview was recorded and notes were taken during the interview (which could then be supplemented by the interview recordings as necessary). The use of a semi-structured approach facilitated a conversational type interview, which allowed valuable information to be obtained, perhaps outside the originally envisaged interview topics. This method proved to be extremely beneficial as interviews could be adapted to focus on the objectives of WPA or WPB as necessary and, more importantly, it allowed the topic of the interviews to move towards areas in which an individual respondent had expert knowledge. As such, this allowed originally unforeseen, but relevant, topics to be investigated.

Appendix D includes a summary of the countries that were interviewed and some details on the types of organisation and roles of the individuals that were interviewed. While there was some overlap between the interview process and the survey which was subsequently carried out, the findings of the interviews (combined with the literature review and knowledge of the INTERLINK consortium) highlighted many of the pertinent business and data needs of the industry, and allowed the needs statements to be further refined and adapted. This allowed a more detailed set of needs statements to be drafted, now informed directly by the opinions of stakeholders in the industry. The next stage in the process of developing the needs statements involved a more formalised approach of testing the needs statements which had been developed to date. This was carried out through the development of a survey as discussed in the following section.

3.4 Surveys

The primary aim of the survey was to provide a structured approach to test the preliminary needs statements which were developed during the previous phases. While the results of such a survey would not form the basis of the conclusion of this report, it facilitated a more structured means of assessing individuals' perspectives on the various needs which had been identified to date. As such, it was important that the structure of the survey was appropriate to allow the responses to be used in a meaningful way, and thereby test the level of agreement of stakeholders with these needs. It also enabled INTERLINK to identify the extent to which these needs are prioritised and implemented across various organisations in Europe.

The structure of the survey was carefully planned and an approach for conceptualising the results was developed (as described in Section 3.5). To try and maintain the attention and interest of the survey respondents it was attempted to keep the survey as brief as possible, while still including sufficient information on the needs statements developed to date to test their relevance based on feedback from industry stakeholders. The aim was to keep the survey duration below fifteen minutes, with the option for respondents to spend additional time providing text feedback at various stages throughout the survey.

The survey was structured using two primary sections:

1. <u>Introductory questions</u>

   These questions required the respondent to provide information relevant to their role, the country in which they work, the type of organisation for which they work, and with which road infrastructure assets and life cycle-phases they work. The answers provided to these questions could later be used to categorise the results.

2. <u>Testing of needs statements</u>

This section presented each of the needs statements, one at a time, with the respondent asked to answer three questions on each statement. These three questions were specifically chosen to facilitate conceptualisation of the results as described in Section 3.5:

i. What is your personal opinion on the above statement?
ii. This is a documented priority of my organisation?
iii. Stage of implementation in my organisation?

Respondents were asked, for the first two questions, their level of agreement on a Likert scale ranging from 'Strongly disagree' to 'Strongly agree'. An 'N/A' option was also provided for respondents to indicate that a specific statement may not be relevant to them. For the third question the respondents were given three options to indicate the level of development of a given statement in their organisation. Respondents were also given the option of providing written text responses to each of these questions and at the end of the survey had the option of including additional relevant statements.

At this stage, however, the number of business and data needs identified had become extensive and it was not considered feasible to include all of them within a survey which would retain sufficient interest amongst respondents to ensure that they would provide meaningful responses and avoid 'survey fatigue'. As such, it was necessary to refine the statements which would be included for testing in the survey. The process of deciding which statements to include in the survey was carried out during a one-day workshop, hosted in the Royal-HaskoningDHV offices in Amsterdam. During this workshop, a brainstorming exercise was completed to consider all relevant statements identified to date, to categorise and compare the statements, and to decide upon the most relevant statements for inclusion in the survey.

Upon completion of this process, a list of 24 statements was identified and agreed upon for inclusion in the survey. Several additional statements were not included in the survey despite being considered relevant. However, to keep the survey as concise as possible and to ensure valuable feedback some relevant statements falling into either of the following categories were not included in the survey:

- Statements which were important but obvious were not included for testing in the survey as it was agreed that there would be limited value in the likely feedback on these statements.
- To avoid too much complexity within the survey, statements which were too technical or specific to BIM processes were not tested because the survey was being sent to many stakeholders who may not have been familiar with the specific data structures and formats used in information management

The full set of survey questions, along with the needs statements included, can be found in Appendix E. Specifically identified NRA staff in each of the 26 CEDR countries and in France were invited by e-mail to participate in the survey including all the interviewees who had participated in the interview process.

3.5 Conceptualisation and analysis approach

To use the results of the survey effectively to inform the final set of ‘Needs Statements’ that should be considered within the proposed INTERLINK solution there were a few aspects to consider:

- Do people agree with a given statement?
- What is the (perceived) opinion of organisations towards a given statement?
- What is the level of implementation of a given statement within organisations?

Using a straightforward classification approach, as shown in the matrix in Figure 3.2, it was possible to classify each of the survey responses towards a given statement into one of six categories as outlined in the matrix:

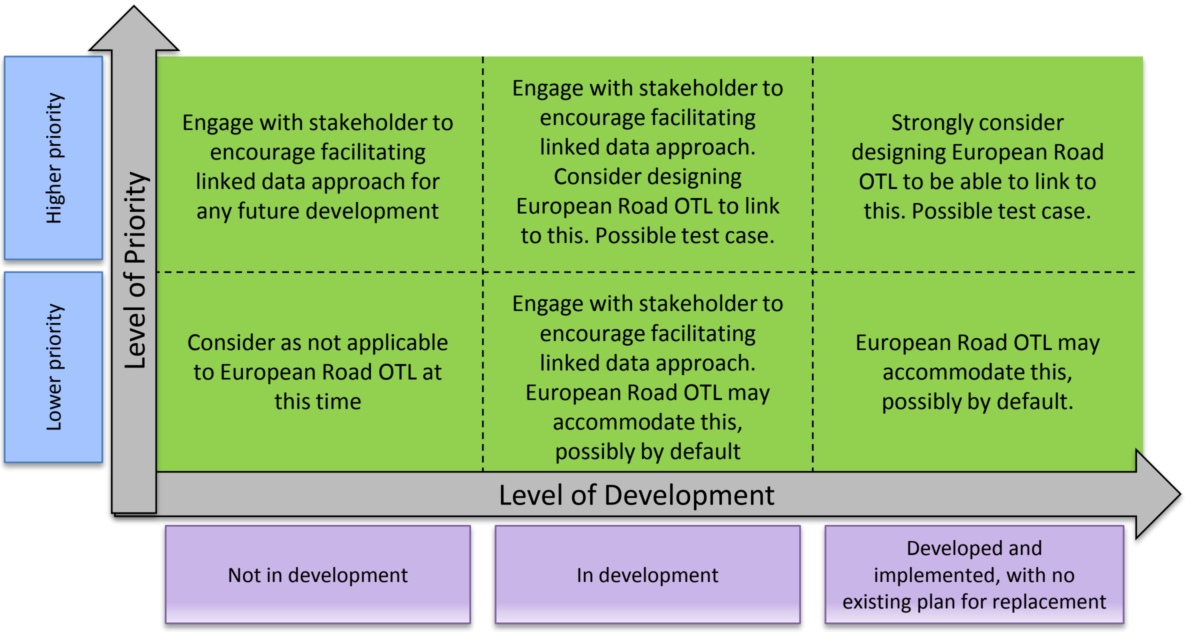


Figure 3.2 – Conceptualisation of needs statements

Using this classification approach, the level of agreement (or disagreement) of respondents and their organisations with a given statement could be assessed, and a decision made in relation to the extent to which the INTERLINK OTL solution should facilitate that statement. This high-level approach allowed the statements to be categorised appropriately and those which were of most interest or relevance to stakeholders could be easily identified.

When analysing the survey results, there were several perspectives which were of interest to gauge the level of agreement of respondents and the stage of development of different statements. The list below highlights some aspects considered in the analysis:

- Collective opinion of all respondents;
- Opinions from individuals in different roles/organisations types;
- Opinions from individuals based in different countries;
- Opinions from individuals working with different asset types;
- Opinions from individuals involved in different life-cycle phases of projects/assets.

Results were examined from the perspective of each group to understand how opinions vary from different people's perspectives. Figure 3.3 shows an example of how this was visualised:

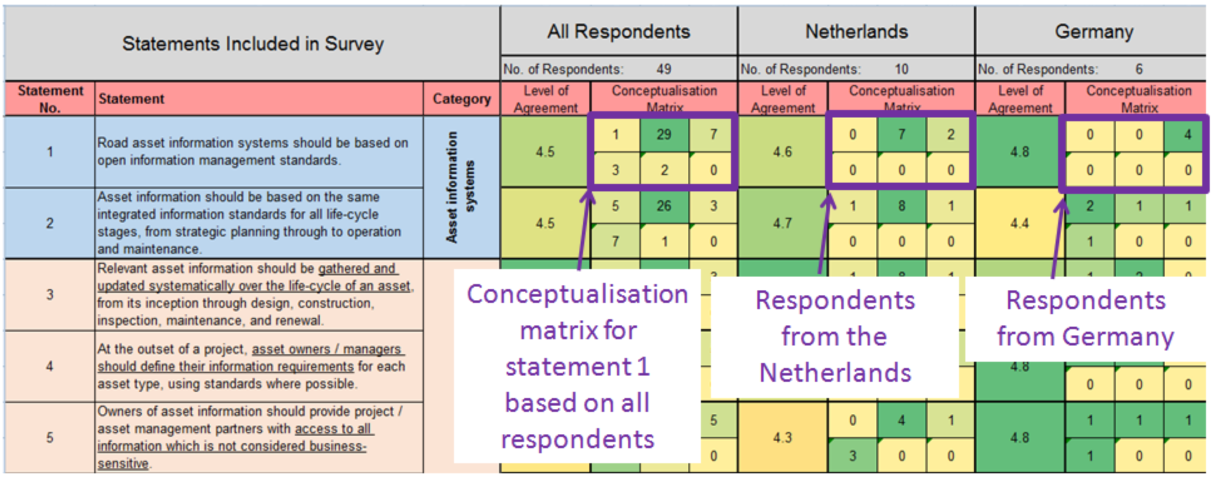


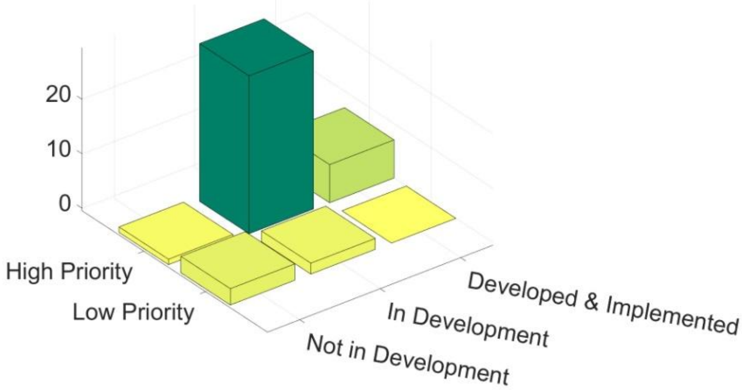
Figure 3.3 – Example of how results were visualised

Figure 3.3 demonstrates how the responses for each statement were compiled into a spreadsheet, with the results being presented in terms of the 'Level of agreement' of all respondents on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). The level of agreement was obtained by finding the average value of the respondents answer to the 'what is your personal opinion on the above statement?' question. The respondents' answers to the next two questions ('this is a documented priority for my organisation' and 'stage of development in my organisation') were then combined and each respondent's result was used to categorise their response into one of the six boxes of the conceptualisation matrix shown in Figure 3.2.

The example shown in Figure 3.3 shows the responses categorised by all respondents and by country (with the Netherlands and Germany being shown for illustration purposes). This approach allowed similarities and differences between these two countries to be identified, highlighting areas where further investigation may have been required. For example, it can be seen from Figure 3.3 in relation to the first statement that German respondents tended to be slightly more in agreement with the statement 'Road asset information systems should be based on open information management standards' than those from the Netherlands. Notably, all the German respondents indicated that this was a high priority for their organisation and that it was developed and implemented, whereas most respondents from the Netherlands indicated that this was 'in development'. It can also be seen that the total number of respondents does not always match the number of respondents on a given statement, this is typically seen where an individual indicates that the statement is not applicable (N/A) to them.

The same approach was adopted to compare opinions from individuals working in different organisation types/roles, or working with different asset types etc. The text responses that individuals provided throughout the survey were also taken into consideration when analysing and presenting the results.

Figure 3.4 shows a sample bar chart representation of the categorisation of results based on the conceptualisation approach used in the survey analysis. Similar figures to this were used to represent the conceptualisation matrix (Figure 3.2) for each statement based on the responses received in the survey.



"Road asset information systems should be based on open information management standards"

Figure 3.4 – Bar chart representation of responses to statement (all respondents)

Ranking of Statements

The final stage of the survey analysis involved ranking each of the surveyed statements to identify those which were most relevant for subsequent INTERLINK work packages. This ranking was carried out using a combination of the level of agreement to a given statement indicated by respondents and the level of prioritisation and implementation as per the conceptualisation matrix. Figure 3.5 provides an overview of how this ranking process was carried out. While the process is not scientifically based, it was used for its intuitive nature, and the results taken merely as indicative.

Approach for Ranking of Statements

Dev = Development index

Development index incorporates the level of development and the level of prioritisation

Three levels are defined:

Level	Description	Location in matrix	Weight
1	In development or implemented (high priority)	B,C	3
2	Not in development or in development & low priority	A,E,F	2
3	Not in development & low priority	D	1

A	B	C
D	E	F

Weights are assigned to the proportion of responses in each level for all of the statements

These weights are used to calculate the development index

The development index is multiplied by the level of agreement to come up with a rating for each satement

Figure 3.5 – Procedure for ranking of statements

Having carried out this ranking procedure the statements deemed to be most important for consideration during the development of the OTL were identified. These were checked against the text responses received in the survey before making a final decision on whether a specific statement should be prioritised. Each of the statements, ranked using the approach in Figure 3.5, is presented in Appendix E.

4 Analysis

To gain a true insight into the as-is situation across Europe, the methodology outlined in the previous section was followed to identify current business needs and data needs within the industry. Analysing the results of the literature review, the interviews and the surveys provided various perspectives from experienced professionals on current practices and gaps in the delivery and asset management of road infrastructure across Europe. This section provides a summary of the findings of this analysis with full details of the analysis provided in Appendices C, D and E.

4.1 Literature review key findings

Business perspective

Initially, a clear understanding of an asset is required. ISO 55000 (2014) states that:

> "An asset is an item, thing or entity that has potential or actual value to an organization. The value will vary between different organizations and their stakeholders, and can be tangible or intangible, financial or non-financial."

Clearly from this definition, the data related to physical asset is an asset in itself.

Having reviewed the literature with a focus on identifying business needs for asset information managements, it was observed that most sources inherently acknowledged the perceptions that there was value to be gained through the implementation of BIM and better information management processes throughout the life cycle of assets. However, the specific business needs, or quantification of the actual value to be gained was generally not explicitly addressed. This was likely to be primarily due to the complexity involved in such projects and the difficulty in quantifying benefits directly related to BIM processes.

It was found that high-level business needs tended to be repeated throughout the literature and while relevant were often quite general and not clearly defined in relation to specific asset types or life cycle phases of the delivery or management of road infrastructure assets. Cost savings and improved efficiency in construction and asset management were repeatedly reported. However, specific quantification of such improvements was rarely available.

Where more specific reporting of the value of BIM was discussed, savings from BIM processes were sometimes misreported. For example, capital expenditure savings of 20% were reported by HM Government (2014) on a pilot project at Cookham Wood Prison. These savings were indicated to be from the application of BIM by industry press. However, the government documentation highlighted that the reported savings were due to many factors, which included modified procurement processes, better informed clients, more collaborative contract forms and the application of BIM. These factors all formed part of the UK Government Construction Strategy (2011), which itself sought 20% capital expenditure savings. Public authorities in Sweden and Finland (CEDR, 2015) are seeking 5% savings by 2020 from the use of BIM on construction projects. The anticipated and measured savings from the use of BIM at asset management stage are not as widely reported. A UK study (Butterfield and Augusto Siguero, 2016) into the use of digital processes for asset management at Heathrow Terminal 3 Integrated Baggage showed that net annual saving of 3-7% were possible.

The business value of BIM, therefore, is hard to calculate. The perceived savings vary widely, they are difficult to measure, and the attribution of savings to BIM alone is difficult. Hence why the literature often makes broader, more qualitative references to the value of BIM, any why public and private clients should carefully manage expectations regarding future savings from upfront and ongoing investment in BIM.

The Institute of Asset Managers (2016) reported on a 2016 industry survey and compared it to an earlier one in 2012. The Institute reported that the biggest change seen over the four years was related to data management and quality. The survey results for asset management executives within the infrastructure industry identified the top two priorities for the next six to 12 month being: a) the building of a coordinated asset management strategy at corporate level; and b) improving data management and data quality. Various respondents to the survey also recognised the value of implementing best practice systems such as ISO 55000 and ISO 55001.

The differences in the implementation of BIM in various countries, from a business perspective, was interesting. Scandinavian countries seem to have a greater focus on the structure and exchange of data. Whereas, the UK has a greater focus on the processes for exchange of documents, thereby facilitating future extension into data exchange.

Beneficial cross-over between INTERLINK and other parallel work is important. The EU BIM Task Group is in its second year of operation and is due to report on initial findings soon. Mr. Philip Jackson is conducting a study on behalf of buildingSMART international on the use of BIM for asset management in infrastructure (road, rail, ports, etc.). INTERLINK has maintained linkages with these and other parallel studies and will continue to do so.

Data perspective

The total overview of key findings with respect to relevant organisations, initiatives and existing or planned results can be found in Appendix C. A general trend is application of a ‘Linked Data’ approach resulting in a variety of ontologies and OTLs already available for different purposes, contexts, scopes, life-cycle stages, aspects and disciplines, in different levels of detail. Typically, these initiatives also use different ways of modelling often determined by their history of original specifications. Some started top-down at the international level, whereas many have their origin in a certain country and some are dealt with by specific organisations or even projects.

At international level, large organisations deal with Open BIM, Open GIS and Linked Data: buildingSmart International (bSI), Open Geo-Spatial Consortium (OGC) and the World Wide Web Consortium (W3C). Typically, the International Standardization Organization (ISO) takes suitable standards from these organisations and publishes them, given the standards extra weight in an international context.

INTERLINK wants to address the European level where various European research and development projects like V-Con and the European formal standardization body CEN are also focussed.

Especially at a national level, find many initiatives involve the modelling of national infrastructure assets like CB-NL (Concepten-Bibliotheek NL) in the Netherlands, OKSTRA in Germany and BSAB (Byggandets Samordning Aktiebolag) in Sweden. All these initiatives developed their ideas and specifications quite independently and, hence, there is an enormous potential for reuse and integration.

In Figure 4.1 a key selection of the most relevant initiatives is shown. Later in this report, recommendations will be defined on how to treat (reuse and/or interconnect) them during INTERLINK and beyond.

International

- bSI LDWG ifcOWL for IFCxxx: IFC4x1 > IFC5 (incl. Road, Rail & Bridge) & bSI Modelling and Linking Guide (for IFC extensions/links) & buildingSmart Data Dictionary (bSDD)
- OGC (GML/CityGML/)InfraGML
- W3C Linked Building Data (LDB) Community Group (CG)
- ISO TC184/SC4 STEP (via bSI) & TC59/SC13/WG8 ICDD ('Information Container for Data Drop')
- NASA/TopQuadrant (TQ) Quantities, Units & Datatypes (QUDT) v2.0
- Various WWW (W3C/DCI/CC) generic semantic resources (SKOS, DC, VANN, CC REL, …)

European

- EC V-Con
- CEDR Interlink 'European Road OTL'
- EU Inspire Directives (GIS)
- CEN TC442-BIM (CEN-variants of IFC, IDM, ISO 12006-3)

National

- BASt OKSTRA/okstraOWL [DE]
- BIR CB-NL, COINS 2.0, CIB/BIR NL-SfB / Geonovum IMGeo2.0-BGT / RWS RWS-OTL [NL]
- Svensk Byggtjänst BSAB/CoClass [SE]
- Asset Data Dictionary Description Document (AD4) / Uniclass 2015 [UK]
- Inframodel 4 [FI]
- SOSI [NO]

Figure 4.1 – Selection (short-list) of the most relevant standardisation initiatives

The future harmonization of these initiatives relates not only to their results (ontologies, OTLs and interconnections between them) but also to the modelling and linking guide they implicitly or explicitly use. INTERLINK aims at playing a key role in both types of harmonization.

4.2 Interview key findings

In total, 64 individuals were interviewed from 11 European countries encompassing various roles in the delivery and management of road infrastructure. Appendix D provides a detailed breakdown of the roles and countries of interview respondents. The level of engagement and participation in the interview process was extremely encouraging, with most countries demonstrating a great deal of enthusiasm towards the INTERLINK project and the topic of asset information management for road infrastructure in general. Due to the informal, open-ended, nature of the interviews the feedback received provided a detailed overview of the current state of the art in relation to information management practices for road infrastructure assets across Europe while also identifying the most prominent deficiencies and gaps. In addition, interviewees provided very useful information on the expected future developments and potential obstacles likely to stand in the way of future development of AIM practices for road infrastructure in Europe. A brief overview of the main findings is provided below:

- Many European countries are actively incorporating digital and BIM processes in the delivery, operation and maintenance of their road infrastructure assets.
- Developments are typically more advanced for road pavements and structures as these assets tend to be higher-risk items.
- The handover of asset information from the capital delivery phase of projects through to the operation and asset management stage represents a significant area for potential improvement as this process is often inefficient and does not work well at present.
- NRAs and their supply chain partners are becoming increasingly aware of the value of asset information, focusing on the entire life cycle of assets.
- BIM means different things to different people depending on their role and their motivations.

Data standards and data exchange standards are not sufficient without associated common business processes. The use of the standards must become inherent in the daily business processes of all parties, rather than just another contractual requirement.

4.3 Survey key findings

53 individuals responded to the survey, although 4 surveys were rejected as they were significantly incomplete. A discussion on the analysis and details of the respondents' country and role can be found in Appendix E.

The responses to the survey allowed the opinions of stakeholders on each statement to be examined in detail. The opinions on each statement were considered from two perspectives:

- Based on the level of agreement, prioritisation level and implementation level indicated within the survey; and
- By examining the text responses received by respondents on each statement.

Appendix E provides a detailed overview of the responses for each statement, considering both a numerical analysis of the responses received and considering the text responses on a case-by-case basis before arriving at a conclusion on any given statement. It is noted

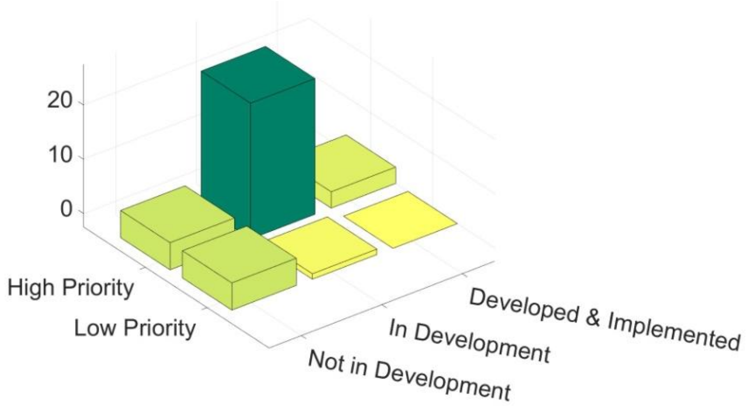
The following points provide a brief overview of the findings of this analysis:

- As expected there was a high level of agreement on almost all needs statements which had been developed through several phases of research.
- *"Relevant asset information should be gathered and updated systematically over the life-cycle of an asset, from its inception through design, construction, inspection, maintenance, and renewal"*. This statement received the highest level of agreement based on all the responses (4.8/5.0) indicating that respondents strongly agree with the fact that the collection and updating of asset information should be carried out through the whole life-cycle of an asset.
- "*Implementation of new information management standards should be focussed on major projects first, and minor projects later*". This statement received the lowest level of agreement (3.4/5.0) indicating some level of disagreement on this statement. As such, it was excluded from the final needs statements. (Implementation of new information requirements on large projects gives the incumbent contractor and their suppliers the opportunity to invest in new processes. However, it also means that feedback from the process takes a long time. NRAs should consider which approach is preferable for their needs.)

The first results were unsurprising as based on the findings of the interviews the ongoing collection and updating of asset data was recognised as a high priority and something which European NRAs consider to be an important development. As such it was already expected that this was something which the INTERLINK approach would have to accommodate in the development of a European Road OTL. The statement with the lowest level of agreement came as a surprise as some of the interviewees had clearly stated that they believed implementation on larger projects ahead of smaller projects was key to the successful development of BIM processes for road infrastructure. This statement was later examined in more detail to consider its relevance.

As outlined in Section 3.5 the conceptualisation approach adopted allowed the level of agreement with a given statement to be considered along with the level of prioritisation and development/implementation of that statement. These parameters were analysed in detail for each statement and comparisons and contrasts between different countries, organisation types, roles, life-cycle phases and asset types were examined and any significant findings documented (a detailed overview of the findings can be found in Appendix E).

Figure 4.3 shows the conceptualisation matrix for the statement "*Relevant asset information should be <u>gathered and updated systematically over the life-cycle of an asset</u>, from its inception through design, construction, inspection, maintenance, and renewal*", which despite having the highest level of agreement is only fully developed and implemented in a small number of cases. However, from Figure 4.2 it can clearly be seen that it is a high priority in the vast majority of cases and is in strongly in development. Figure 4.3 shows the conceptualisation matrix for the statement "*Implementation of new information management standards should be focussed on <u>major projects first, and minor projects later</u>*", where it can clearly be seen that there is split opinion between the prioritisation of development with many respondents indicating it as a low-priority and not in development and others indicating it as a high priority and in a small number of cases fully developed and implemented.



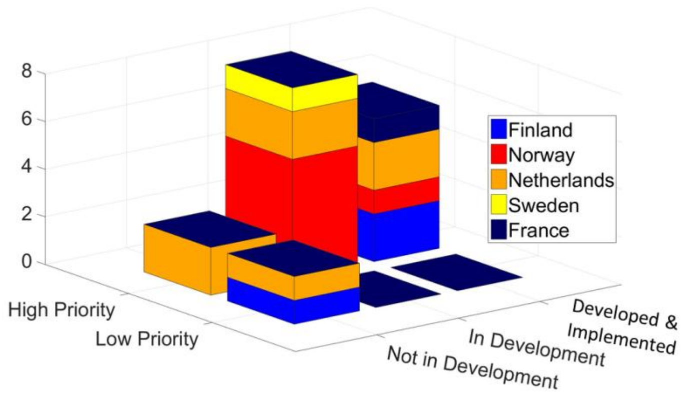
"*Relevant asset information should be <u>gathered and updated systematically over the life-cycle of an asset</u>, from its inception through design, construction, inspection, maintenance, and renewal.*"

Figure 4.2 – Conceptualisation matrix (all respondents)

"*Implementation of new information management standards should be focussed on <u>major projects first, and minor projects later</u>.***"**

Figure 4.3 – Conceptualisation matrix (all respondents)

Another interesting visualisation of the survey results can be seen in Figure 4.4 which refers to the statement *"Design checking, design approval and as-built approval should be conducted using object data with associated model data (e.g. 3D models)"*. Here the Nordic countries, the Netherlands and France all indicated a high level of prioritisation and development which can be seen in Figure 4.4, with the results for each country also visible. This approach was adopted to visually examine the situation across different categories of survey respondents.



"Design checking, design approval and as-built approval should be conducted using object data with associated model data (e.g. 3D models)."

Figure 4.4 – Conceptualisation matrix (by country)

Some survey respondents suggested additional needs statements. These were considered during the detailed analysis and, where the statements were relevant and did not duplicate other existing statements, they were adopted for the final business and data needs statements, as presented in Section 6.

5 Results

The INTERLINK consortium conducted a detailed analysis of the literature, interview results and survey results to gain a clear understanding of how information is exchanged in different countries, for various road asset types throughout the asset life-cycle. Several procurement models were considered, including traditional (design-bid-build), design-and-build, and term maintenance contracts. This enabled INTERLINK to identify a typical current (as-is) condition, presented in Section 5.1, which is subsequently used to determine the needs statements for the European Road OTL. Future anticipated developments, along with obstacles to those developments, are presented in Section 5.2. The application of the INTERLINK approach to information management is described in Section 5.3. A typical future (to-be) condition facilitated by successful implementation and adoption of the INTERLINK approach is envisioned in Section 5.4.

5.1 *Typical As-Is condition*

Interviewees were asked to describe their business processes and the flow of information from the outset of a road project through to handover and asset management, identifying high risk processes, along with processes that work well and ones that require improvement. Depending on their area of expertise, they were also asked to describe the format of exchanged information, the software systems used, and the standards followed.

Analysis of these results, in conjunction with project management and BIM guidelines from various NRAs, enabled INTERLINK to define a typical as-is condition for one scenario. Figure 5.1 represents this as-is condition using Business Process Modelling Notation (Object Management Group, 2017). Table 5.1 gives a brief overview of the notation used. The scenario assumes higher BIM-maturity countries, outsourced maintenance operations with fixed-term contracts, design-and-build construction contracts, and all assets being owned by the model NRA. Activities, data and linkages shown in green represent where information flow is well managed and uses either open data exchange formats or structured data management processes. Those shown in red represent where there is significant opportunity for improvement. Of course, the figure is a highly-simplified representation of a complex system of interacting businesses processes and stakeholders. The figure is not intended to represent any one NRA studied during this research, but merely typical conditions.

Following is a discussion of the as-is condition, highlighting why some items are red or green, and identifying selected situations where information management is more advanced. Ultimately the purpose of a road network is to carry traffic economically and safely. Hence, the discussion starts in NRA Network Operations at the top left-hand corner of Figure 5.1, and moves through funding decisions at corporate level in NRAs, to the capital project delivery process, through handover to asset management, and into maintenance.

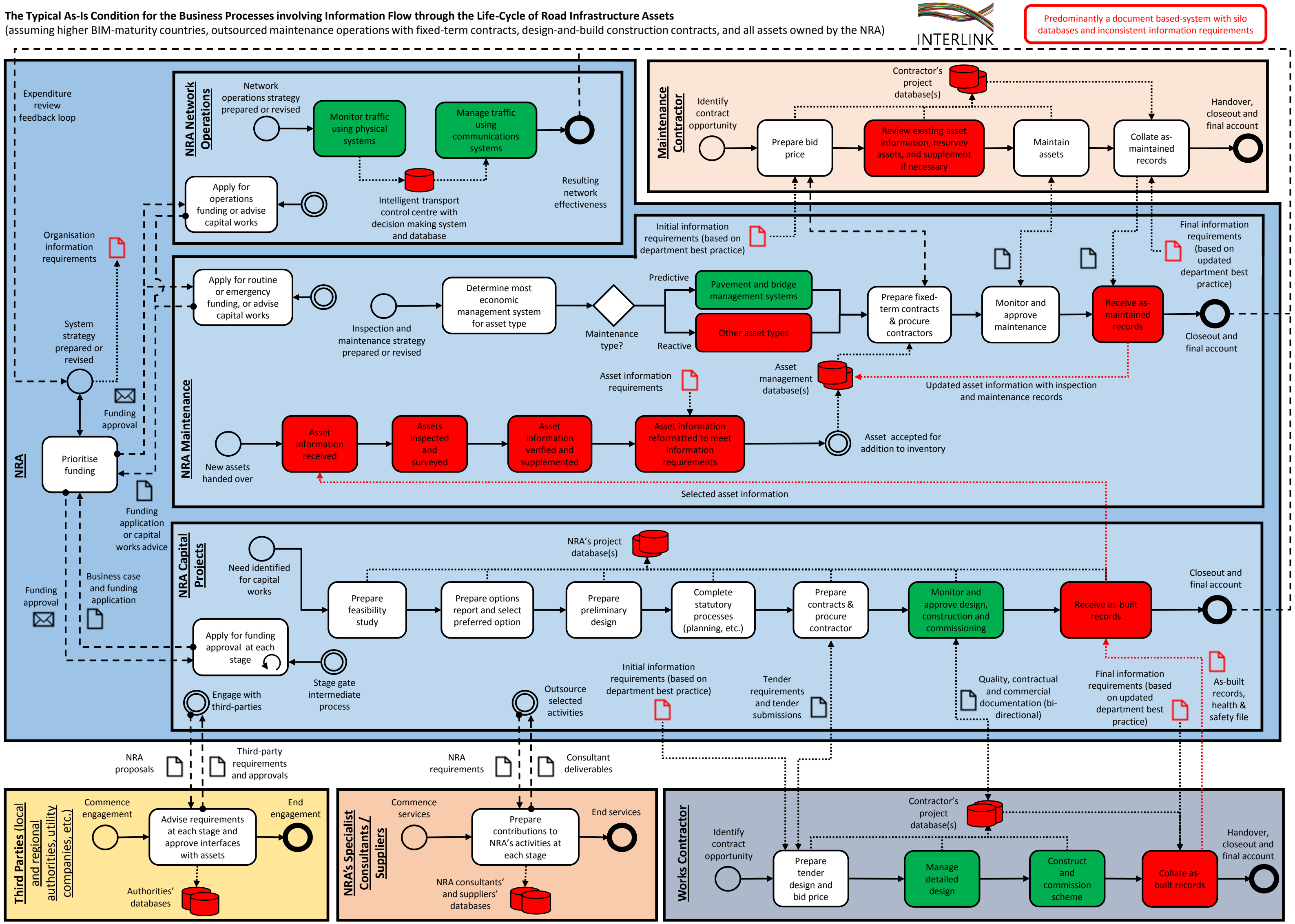


Figure 5.1 – Business process model of the typical as-is condition for information flow through the life-cycle of road infrastructure assets (link)

Table 5.1 – Selected notation used in the business process models (Object Management Group, 2017)

Notation	Description
	Data store
	Data object
	Message
	Activity
	Gateway (decision)
	Sequence flow (dashed when crossing organisational boundaries)
	Data association
	Start event
	Intermediate event
	End event

5.1.1 NRA network operations

Many NRAs, or their motorway operators, use sophisticated intelligent transport systems (ITS) to monitor traffic, with automated or manual input to control traffic flow. These systems are well developed, often using organisation- or system-specific data structures to facilitate the application of control algorithms. Hence, the activities are shown green.

However, different technological maturity is typically evident between operators, depending on when a system was procured or last updated. The multiple databases used by various operators across an NRA's road network are often not linked to each other, or to city and local authority operations databases. Also, the stored data may not be readily accessible, appropriately formatted of sufficiently complete for use by other departments within NRAs. Such information can be used to optimise maintenance strategies and budget allocations. In Ireland, for example, traffic data from weigh-in-motion sites and traffic counters has been used to examine the risk of traffic damage to bridges/pavements, in order to facilitate better decision making in relation to vehicle regulations and maintenance prioritisation.

5.1.2 NRA corporate decision making

An NRA's investment in operations, capital works, and maintenance is based on available funding and the prioritisation of needs. Feedback on investment decisions often comes years after an initial investment decision is made, by which time the original needs and assumptions may be lost. This restricts an NRA's ability to learn from previous investment decisions. Even in situations where an NRA systematically gathers feedback from capital works and maintenance projects, such as at Vejdirektoratet in Denmark, this information is typically provided in report format and cannot be interrogated easily.

Government-level support, in the form of national mandates or digitisation programmes, and organisation-level strategic initiatives within NRAs, contractors and consultants, are common features for NRAs with higher BIM maturity. Information requirements for operations, capital works and maintenance should be consistent with the elicited and documented organisation information requirements. This item is red in the figure, along with the information requirements within the departments, as many NRAs have not documented their corporate-level information requirements. As such, their department-level requirements are of varying levels of maturity and consistency.

5.1.3 NRA capital works projects

All NRAs interviewed had standardised processes for project management of major capital works projects. Generally, these processes are well established, with defined phases and approval points. They involve extensive engagement with multiple internal and external stakeholders over an extended period of years. The most advanced BIM systems are used for managing the design, procurement, approval and construction of major projects, typically in the Netherlands and Scandinavia. These are underpinned by implementation plans, published guidelines, object-type libraries and classification systems, often instituted by standardisation bodies comprising representatives of both public and private organisations.

NRA databases

Similar information is gathered on all projects, ranging from extensive planning reports in PDF format to road alignment models in a CAD format. The information is often stored in multiple databases and servers, sometimes without a standardised approach applied across projects. Valuable current or historic information can be difficult to locate and, if located, may not be trusted. Hence, the database icon in the figure is shown in red. This is of importance when projects are stopped for an extended period, perhaps due to funding restrictions.

NRA information requirements

Each life-cycle stage has different data-needs. As data standards were often developed focusing on a limited scope, different and sometimes incompatible data standards emerged. With different data needs and data standards, the re-use of historic data has become an issue. Despite Figure 5.1 showing a red symbol for information requirements due to inconsistencies of requirements across the full asset life cycle, some NRAs have made strong advances in recent years for the design and construction stages. Various NRAs require their supply chain to use particular data standards, classification systems or object-type libraries, such as OKSTRA in Germany, COINS/CB-NL/RWS-OTL in the Netherlands, SOSI in Norway, and Inframodel in Finland. In the Netherlands, the construction industry is starting to adopt Semantic Web technology for their next generation 3D information systems to incorporate CAD, BIM and GIS data.

The application of NRA information requirements results in the use of various groups of existing data standards in countries with higher BIM maturity, including:

- BIM standards, e.g. Industry Foundation Classes, Model View Definition, and Information Delivery Manual;
- GIS standards, e.g. GML, CityGML and InfraGML;
- Product life-cycle and systems engineering standards; and
- Web standards, e.g. HTML, XML, RDF, RDFS and OWL.

Third parties, NRA consultants and NRA suppliers

Throughout capital works projects, and to a similar extent maintenance projects, NRAs engage with third parties such as local authorities and utility companies. NRAs also outsource some activities to external consultants and suppliers. Again, the databases in these parts of the figure are shown in red. Efficient sharing and exchanging of information between these multiple parties is hampered by duplication of information on multiple systems, inconsistent or incomplete historic information, and the provision of information in various non-standardised formats. Information used for critical decisions regarding route selection or planning at early stages of projects may be hidden in extensive reports or various parties' databases. Further, information that may be relevant for asset management, such as the performance requirements of a particular asset, may be lost if it is not directly relevant to the next stage in the capital work delivery process. However, there are many examples of encouraging advances over the last number of years. Ordnance Survey Ireland has started to make some mapping information, such as county boundaries, publicly available in a Linked Data format (http://data.geohive.ie/). An online GIS platform in Norway (www.vegkart.no) makes road asset information publicly accessible.

Significant risk relates to existing utilities interacting with new works. Information is available from utility providers in various formats depending on the organisation, and with various levels of accuracy and quality. At the end of construction, often the quality of information provided back to the utility providers is inadequate. Some countries are actively trying to address this. Vejdirektoratet report that the Danish legislators are enacting a new law requiring utility owners to maintain digital records which can be read by a national system.

NRAs can use historic geotechnical information when designing new works or modifying existing assets. Such information is expensive to acquire and, if recorded and stored appropriately, can be a valuable asset. Geotechnical data is provided in AGS format in the UK and Ireland. This is a text-based open data format that was first established over 20 years ago. A similar open format is required in Finland, while in Norway and Sweden a single proprietary format enjoys widespread use. These files are read by various software packages, facilitating swift interrogation of ground conditions at discrete points. However, not all NRAs systematically gather this data after the completion of a scheme, thereby missing the possible future value of the data. Highways England provides a good example of systematic storing of such data within their Geotechnical Data Management System.

Design

NRAs report that early stage project activities, such as feasibility studies and route selection, have less focus on BIM and greater focus on traditional drafting and reporting. However, at later stages preliminary design and planning stages in countries with higher BIM-maturity, NRA's designers communicate their designs to the NRA using BIM models, along with drawings derived from BIM models. The models are submitted in both the proprietary software format and in open standard format where available, e.g. LandXML, GML and IFC. National BIM data formats and classification systems are also prevalent, such as InfraModel in Finland. Unfortunately, this results in multiple versions of similar design files being present in various systems. Interestingly, Trafikverket in Sweden requires their alignment designers to use an add-on for CAD which pushes design models and associated documents via the internet to a central Trafiverket database. This central database records all existing public roads greater than 50m in length and, from the designers' CAD systems, all proposed roads which have reached an appropriate stage in design development.

Most NRAs receiving and approving BIM models and associated drawings did not report that they have a standardised system for tagging the models with metadata recording the NRA's approval. Such approval is typically recorded in separate certificates. These findings also apply to the approval of contractors' design submissions on design-and-build contracts. Given that Trafikverket expect to go to tender on their first drawing-free project in early 2017, and that other NRAs have similar objectives for the future, various NRAs recognise the need to record the approval of design data as metadata.

Works contractors

The process for the procurement of works contractors is well defined, with a reasonably consistent approach across NRAs due to the application of European Union procurement directives. Despite many opportunities for improvement in the management of information at this stage, numerous countries have made strong progress in recent years. NRAs typically see the best outcomes when they publish information requirements for use on all forthcoming projects. Interviewees reported that this enables the supply chain to invest in training, software and hardware.

Private consortia that are responsible for both the delivery and operation of major roads are recognising the value of upfront investment in standardised digital processes. In response, the Norwegian Government established a public company called “New Roads” in January 2016 to design, build, operate and maintain the ten largest road projects in Norway in coming years. They aim to implement a whole life-cycle approach to decision making and to implement BIM Level 3 (taking PAS 1192-2 BIM levels).

Contractors report that at bid stage on design-and-build contracts, forecasting costs and managing risk is hampered by the widespread requirements for each component of a scheme. The requirements can be contained in various files, including environmental and planning reports, generic and project specifications, drawings, models, and standards. The same contractors note that having a system that links requirements to objects would greatly improve the cross-party management of cost and risk.

Large contractors report that they use web-based information exchange systems across their enterprise to engage and share information with the NRA, their designers, and their supply chain. Generally, they require their designers to provide information is formats that can be readily used during construction, for example in Land XML format for use in automated grading machines. Also, the workflows for design approvals, information requests, non-conformance reporting and material approvals are well established. Hence, the design and construction activities are shown green.

Earthworks comprise a significant proportion of the construction cost of major motorways. The representation of earthworks as objects present difficulties depending on who is using the information. The geometry and material properties provided by a designer may be sufficient to specify the works. However, contractors often move materials more than once depending on the sequence of operations. Therefore, earthworks objects from a designer must be discretised further to facilitate use for cost estimation and planning optimisation of operations by a contractor.

5.1.4 NRA asset management

As-built asset information

The process of handover of as-built asset information from the capital delivery stage to the asset management stage is consistently noted by NRAs and contractors as the least efficient process during the life-cycle of road infrastructure asset information. Contractor’s databases are shown in red as the information gathered, in general, is not linked to the asset to which it relates except by text within a document or file. Often, the association of output such as models, specifications and drawings with particular assets is dependent on project-specific file numbering systems. Further, the approach taken on each project is dependent on the NRAs requirements at that time and on the preferences of the project managers and their advisors. This hampers contractors in their collation of as-built records, thereby resulting in this activity being shown in red. In some cases, NRAs have extended commercial agreements with contractors to require handover of asset information in a more structured format, often due to changes in departmental requirements during the significant period from procurement to handover.

NRAs require contractors to handover as-built asset information, either directly to their asset managers or indirectly through the NRA project manager. For the handover requirements, there are two extreme perspectives:

i. The only asset information that is required for handover is that for which there is a documented business case written by the relevant asset manager; or
ii. Extensive structured and unstructured information on all assets is purchased upfront on the assumption that some of the information is of initial value to asset managers and the remaining information will provide some possible future value when the NRA has systems that can interpret it.

No NRA currently fits perfectly into either of these perspectives. Trafikverket recognises that it needs to improve the quality of the information it collects for asset managers and is aiming towards the first perspective on the basis that only a small amount of the BIM data gathered during design and construction stage is directly relevant to the asset management stage. Rijkswaterstaat in the Netherlands is aiming towards the second perspective, on the basis that publishing extensive requirements for the supply chain to follow results in higher short-term costs for an NRA but reduces costs in the medium- to long-term as the supply chain develops its capabilities, software and processes to meet the requirements.

Various NRAs incorporate into their contraction contracts detailed requirements for the handover of as-built records in a BIM or GIS format. However, often the contractual payments are related to the completion of physical works rather than the handover of asset data. As such, some NRAs report that they do not receive compliant data from contractors at the end of construction. Various NRAs, including in Finland and England, are now seeking handover of asset data in stages throughout construction such that the quality of the data can be verified and improved in advance of final handover.

Due to these issues, the activities and data exchange at handover stage between the contractor and NRA are shown red in the figure. This problem flows through to the asset managers receiving the information, as many asset managers report that they do not trust the information they receive, and often that the information is not compatible with their current asset management systems. This is a particular issue as more as-built data is received in BIM formats which cannot be read or even effectively retrieved by existing asset management systems. Various NRAs report the need to reformat asset data and to resurvey completed assets prior to adding those assets to their inventory, at significant expense. Apparently, this issue is more common in countries where construction contracts do not require a contractor to certify the accuracy and completeness of as-built records. Where such certification is required, typically in Scandinavian countries, there is greater trust in the as-built records and asset managers merely carry out spot checks.

<u>Asset inventory</u>

The asset management databases used by NRAs are shown in red in the figure for various reasons. Firstly, NRAs generally have a separate database and front-end system for each asset type, with the functionality based on the needs of each asset management team, e.g. pavement, bridges and signage. Often, the databases are not linked and the data may be duplicated or inconsistent. Even where NRAs have implemented large-scale single-software asset management systems at significant expense, NRAs report that those systems and the background data structures have not been based on open standards, and do not easily facilitate the linking of data and processes between different asset types. Secondly, information added to databases is often structured to suit the data requirements of the software which is being used to interrogate and edit the information. Often such software uses proprietary file formats, thereby limiting the future value of the data if NRAs seek to access it with other software products.

Examples of effective creation of an asset inventory during design and construction can be found in other sectors. The Crossrail project in London has attracted a lot of attention for its use of BIM during design and its implementation of a single-source of truth, object-oriented system for the collation and management of asset data. The railway construction project, with planned opening in 2018, has a detailed ontology with asset naming an equipment types in an asset breakdown structure. Significant effort was invested in the early stages of the project to define and implement a highly structured process of asset naming, IDs and labels. Each asset object has associated asset requirements, which follow the object even if the equipment is changed in the future.

<u>Asset management</u>

Various NRA interviewees advised that their organisations are considering implementing the ISO 55000 suite of standards for asset management. However, in most cases this has not yet occurred, even though NRAs often recognise the value in establishing consistent, structured processes to the management of all asset types.

Often the departments for road operations and road maintenance are different. In many cases, one or both of these functions is outsourced on term contracts. The formal and informal boundaries between these functions and organisations present difficulties for information exchange and sharing.

Generally, the most complete data sets are for bridge, tunnel and pavement assets. This is because NRAs recognise that the present value of appropriate inspection and maintenance regimes for these asset types is less than the present value of major repair works and the associated economic costs of road and lane closures. These structured data sets enable NRAs to use predictive maintenance for selected assets. Vejdirektoratet in Denmark has a structured approach to the registration of new assets and subsequent prioritisation of maintenance. They report that the approach is applied well to bridges and pavement (using automatic vehicle registration of pavement quality). Transport Infrastructure Ireland uses the EIRSPAN system to manage bridge asset data. They provide access for consultants to download selected bridge information and complete structured inspection reports.

However, many NRAs do not provide access to their asset management systems. Often, these systems rely on NRA staff updating an asset inventory following maintenance and rehabilitation operations, rather than providing direct access to the maintenance contractors or local public authorities who completed the operation. As such, historic information may be inaccurate and a lack of trust results in costly, repeated verification of information.

Assets other than bridges, tunnels and pavement are typically considered lower risk items and the associated data is less well managed. These assets are usually subject to a reactive maintenance regime, which requires less data to be stored in an asset management system.

<u>Maintenance contractors</u>

Many of the issues that are prevalent for works contractors are also prevalent for maintenance contractors. Often these contractors use their own asset management systems. An inventory is developed at the outset of a contract, perhaps with access to the NRA's database. The asset data is extended and modified over the duration of a term contract, typically five to seven years. However, in many cases at the end of the contract this asset information is not handed back to the NRA. This results in loss of valuable data, which the succeeding contractor must charge for reacquiring.

5.1.5 Summary

The as-is process is predominantly document based, with silo databases and inconsistent information requirements. As a result, data used in the business process is often incomplete, out-dated, inconsistent, non-uniform and not directly usable, thereby presenting extensive risks to NRAs. However, NRAs and their partners are becoming more aware of the value of data as an asset, and that the quality of usability of the data is critical to the success of their operations. Numerous good examples of improved asset information management have been reported in various European countries, with some initial developments towards the use of Linked Data and Semantic Web technologies. The highest ranked statement about the gradual transition of existing asset information to smart information (semantically rich information) underlines the need for the development of OTLs and the use of Linked Data and Semantic Web technologies. The well-supported statement about gathering and systematically updating over the life-cycle of an asset focuses on sharing asset information as Linked Data. These examples form an important source of experience for other countries to learn from and become the basis for improving asset information management as a whole.

5.2 Anticipated developments and associated obstacles

The research identified various likely developments over the coming years, with the following featuring prominently. Developments are grouped into people, process and technology. Interestingly, developments in software capabilities were not considered crucial, as industry experts felt that current tools have sufficient functionality.

People

1. NRAs and their supply chain partners are becoming more aware of the value of asset information, focusing on the entire life cycle of assets. The willingness to improve asset information management internally and over the supply chain is growing.

Process

2. Both domain professionals in the field and ICT experts are requesting complete, accurate, consistent, uniform and directly usable data; preferably, also data owned, maintained and managed by others.
3. The increasing need for sharing data within the organisation borders and even over organisational borders, instead of exchanging (and thereby copying) data.
4. Data standards are being developed with different target groups and scopes in mind (although reuse of lessons learnt and harmonization over a larger scope in these standardisation initiatives is not always guaranteed).
5. The ongoing development, publication and adoption of various international and national open standards (e.g. ISO standards recently adopted as Euronorms, recently published Draft International Standards (ISO/DIS 19650 parts 1 and 2), future extensions to the IFC standard such as IFC-Road, IFC-Bridge, IFC-Alignment, IFC-Railway and IFC-Tunnel and national classification systems and object-type libraries), thereby reducing industry dependency on proprietary data formats.
6. A greater focus on the collation and verification of structured data from the conception of an asset through design, construction, handover and asset management.

Technology

7. The greater prevalence of software-as-a-service (SaaS) and more dynamic, specialised mobile applications, thereby reducing the power of the larger software corporations (although those corporations will likely resist any such threats).
8. Technological advancements aimed at interoperability of systems and processes, often based on the linking of data across multiple formats, data structures and

systems, including BIM and Geographic Information Systems. In domains, not restricted to the construction industry, major steps are taken in this field, e.g. W3C Linked Data (LD) and Semantic Web (SW) technology.

Interviewees identified numerous obstacles to achieving successful development, with the following being predominant. Obstacles are grouped under people, process and technology.

People

1. Typically, NRA organisational structures separate the capital works delivery functions from the asset management functions. This can result in inconsistent approaches to information management and can hamper cohesive development if not carefully managed.
2. BIM means different things to different people depending on their role and their motivations. This presents difficulty with 'selling' the principles of BIM to senior decision makers, particularly those who see it as a technological issue with a short-term funding and resource demand, and an uncertain long-term benefit.
3. The protracted nature of roads projects means that implementation programmes for new standards and processes, often verified by pilot projects, are very long. They require continued top-down strategic support and ongoing acceptance and compliance from all involved on a day-to-day basis to achieve beneficial results.
4. Trust in historic data, even when the data is of high quality, is difficult to engender.
5. There are insufficient information technology specialists in the road construction and asset management industry.

Process

6. An NRA's supply chain will limit its investment in consistent hardware, software and training if the NRA does not communicate clear information requirements, including BIM.
7. Due to the possibility of offering advantage to certain tenderers, NRAs may be constrained in consulting BIM specialists prior to procuring a design or construction contract under relevant EU legislation.
8. Data standards and data exchange standards are not sufficient without associated common business processes. The use of the standards must become inherent in the daily business processes of all parties (including the software they use), rather than just another contractual requirement.
9. Greater use of digital data and greater sharing of data across platforms presents security risks to manipulation of data itself and the use of the data for malicious acts against critical road assets.
10. Questions remain about the ownership and use of shared and exchanged data, with limited legal precedent on which to clearly base liability.
11. Vast quantities of data are produced during road construction projects, much of which is specific to construction stage only. These quantities are likely to increase with the greater prevalence of digital modelling, laser surveying and drone technology. At handover, the information necessary for asset management can be hidden amongst this mass of unstructured and semi-structured data, or may even be missing.

Technology

12. The clock speed of information management technology, compared to that of the construction and asset management industries, means that technological requirements included in current contracts and standards may be obsolete in the medium-term.
13. The definitions of data objects for design stage, construction stage and asset management stage may be different to each other, and current open standards such as IFC are more focussed on the design and construction stages.

14. Some linear assets are difficult to discretise into separate objects of suitable granularity, e.g. earthworks and pavement.

5.3 Application of the INTERLINK approach

Clearly the delivery, maintenance and operation of a road network involves a complex interaction of systems and stakeholders, with multiple different asset life-cycles and multiple different asset information life-cycles. Industry developments in asset information management are encouraging, but their success could be hindered by wide-ranging obstacles.

The INTERLINK consortium recognises these issues and envisages a solution that can contribute to resolving the issues in a sustainable, vendor-neutral fashion for the full life-cycle of all road asset types. For the purpose of this discussion, the solution is termed 'the INTERLINK approach'. It seeks to facilitate an industry shift from exchanging documents to sharing data using the European Road OTL. The approach is founded on the technologies of Linked Data and the Semantic Web. This section presents arguments for the business value of the INTERLINK approach based on the research completed to date, and provides a brief overview of the technical solution.

5.3.1 The business value of the INTERLINK approach

The basic idea behind the Linked Data technology is, as the name suggests, that data is no longer exchanged from one organisation to the other, but shared between organisations. Data remains at the source (and often owner) of the data. This owner organisation is responsible for maintaining the data with semantically-rich content, keeping it up to date, and giving third parties access to that data via the World Wide Web, i.e. the Semantic Web technology. Figure 5.2 summarises the benefits of Linked Data and Semantic Web technology when applied to an OTL. The INTERLINK Consortium strongly believes that the European Road OTL cannot be successfully implemented unless it has a Linked Data technology at its core.

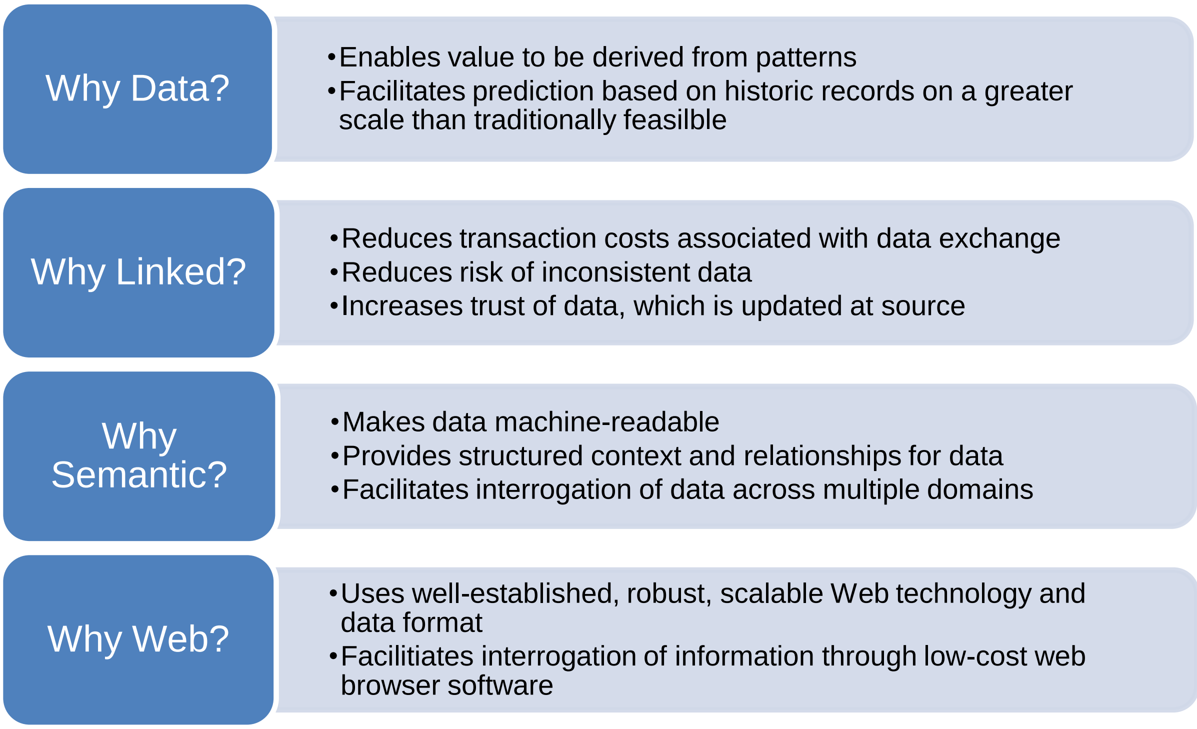


Figure 5.2 – The value of Linked Data and Semantic Web technology for the European Road OTL

Using the principles of Figure 5.2 and further to Section 2, another example of how the European Road OTL could be applied is in the interrogation of data across multiple domains during early design stages of roads. Alignment route options read through open data standards such as IFC-Alignment could be overlaid on: publicly available GIS-based Linked Data representing boundaries of environmentally sensitive areas; publicly available GIS-based Linked Data of historic geotechnical records; publicly available BIM-based Linked Data representing existing utilities and sewer networks; and publicly available Linked Data records from traffic counters on the road network.

5.3.2 Overview of the technical solution

Initially, the European Road OTL will facilitate a hybrid approach of linking semantically-rich data to more traditional document-based information. Ultimately, INTERLINK envisages that road asset data will remain at source, shared over the web through a system of harmonised data standards with strengths from the international, national and organisational levels, and interrogated via flexible, software-as-a-service applications.

To realise this for the domain of road asset information management, INTERLINK will use W3C Linked Data (LD) and Semantic Web (SW) technology. W3C stands for the World Wide Web Consortium that successfully implemented the World Wide Web. This technology will be used to implement the European Road OTL. That means that the OTL will take the form of an ‘Ontology’ represented in the standard Web Ontology Language (OWL).

Together with other relevant OTLs (International, country-specific, company-specific or even project-specific ones) the European Road OTL will enable:

- Agreement on civil infrastructure assets in the road domain, as part of the civil infrastructure sector, itself being part of the broader Architecture, Engineering, Construction / Asset Management sector.
- Instantiation of the OTL into road data sets for exchange and sharing along the life-cycle and supply-chain of the asset.
- Provision of ‘decentralised hub’ for linking (and where needed, transforming) data & documents to and from not only existing BIM, GIS and Internet of Things standards like bSI, IFC and OGC InfraGML, but also native non-standard/native legacy data sets for smooth migration. This hub of linked data and documents will indirectly also enable new software functionalities: innovation beyond mere integration (advanced calculations, simulations, decision support, big data analytics etc.).

This solution approach is based on lessons learnt from the European research project, Virtual Construction for Roads (V-Con), and is in line with the trend in many standardisation bodies towards a ‘Linked Data’ technology.

The Linked Data / Semantic Web LD/SW technology

Linked data adds a new layer to the Internet, as shown in the four-layer ‘protocol stack’ of Figure 5.3, demonstrating the evolution of the internet as a common communication infrastructure from 1) linked computers, via 2) linked documents, towards 3) linked data and even 4) knowledge about objects like road assets.

‘Linked Data (LD)’ and ‘Semantic Web (SW)’, are both World Wide Web Consortium (W3C) principles built on top of the World Wide Web (WWW), itself based on the Internet. Data on the WWW is unstructured and configured mainly for human interpretation. Linked Data is structured and therefore ‘processable’ by software. Another layer of semantics can be defined on top, with concepts, attributes and relationships forming ‘ontologies’, giving powerful meaning to the linked data utilizing Semantic Web technology. The data is now not only processable by software but also interpretable.

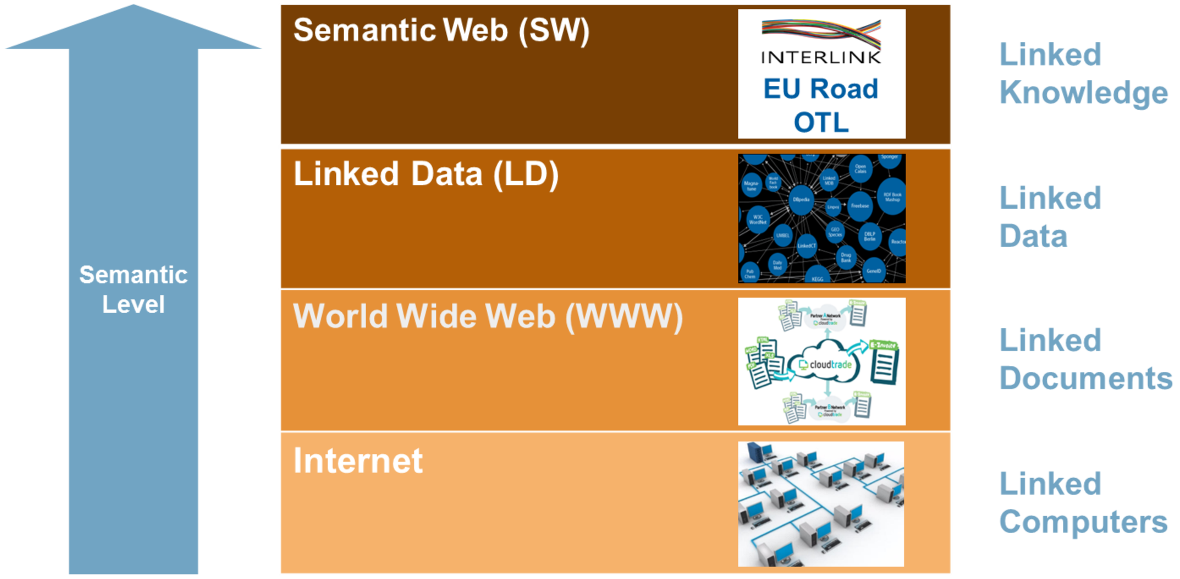


Figure 5.3 – Four-layer protocol stack

The envisioned European Road OTL will be a knowledge element at the top layer. The W3C LD/SW technology provides the means to define and utilise it. It should be noted, however, that LD/SW can do more. It provides standard formats to express the OTL-compliant linked data underneath and an also standard query language (SPARQL) to directly access both the OTL itself and its associated linked data. This situation is depicted in Figure 5.4. It is an updated and adapted simplification from the data framework that is used earlier in the European V-Con project.

Data Levels \ Data Aspects	ACCESS	FORMAT	CONTENT
LANGUAGE	SPARQL	Turtle	OWL
DATA STRUCTURE	SPARQL	Turtle	ANY ONTOLOGY
DATA SET	SPARQL	Turtle	ANY DATA SET

Figure 5.4 – Different data levels/data aspects/data covered by W3C LD/SW

The matrix shows that three levels of data modelling (data sets, data structures & languages) are supported regarding data aspects of access, format and actual content. Unlike other technologies (like the ISO Standard for the Exchange of Product model data (STEP)) there is only one consistent way for accessing and formatting all three layers of modelling (including their interrelationships).

SPARQL (a recursive acronym for Simple Protocol And RDF Query Language) is an RDF query language, that is, a semantic query language for databases, able to retrieve and manipulate data stored in Resource Description Framework (RDF) format. Turtle (Terse RDF Triple Language) is a format for expressing data in the Resource Description Framework

(RDF) data model with syntax similar to SPARQL. For Turtle as indicated format existing multiple equivalent forms but that is beyond the scope of this document.

Besides this view, three Data Kinds relevant the INTERLINK European Road OTL are distinguished in an orthogonal way:

1. Object (-type) Data (roads, bridges, tunnels, …)
2. Representation Data (like geometry)
3. Meta Data: ('data about data' including process/transaction context)

Although the focus for the European Road OTL is clearly on object-type data, both representation data (like road alignments) and meta data (creator, versions, multi-lingual labels for terms used, etc.) are also in scope.

Benefits of the LD/SW technology

- Fully web-based, reusing all existing data identification and access mechanisms already offered by the underlying WWW and Internet,
- Fully generic, independent of any specific industry sector,
- Fully international, independent of any specific country, and
- Fully functional and powerful, having a sound foundation in logic.
- **Summarized: the W3C LD/SW technology chosen for INTERLINK is 100% Future-Proof.**

This W3C Linked Data/Semantic Web technology and especially its application in INTERLINK, will be further explained and elaborated in WPC, 'Principles for the European Road OTL. The business benefits of the INTERLINK approach are envisioned in the next section.

5.4 Typical To-Be condition

Figure 5.5 shows a typical to-be condition when using the INTERLINK Linked Data approach to the fullest for the typical as-is condition, described in Section 5.1. This represents how successful implementation and industry adoption of a European Road OTL using the INTERLINK approach would enable better flow of useful, quality information throughout the life-cycle of road assets.

Business perspective

On first inspection, the typical to-be condition appears quite similar to the typical as-is condition shown in Figure 5.1. This is because improved information flow and quality would not directly facilitate the modification of well-established business processes for the operation, delivery and maintenance of road infrastructure. However, it would enable better decision making, cost estimation, and risk management, while reducing delay and rework costs. The move to sharing rather than exchange of data will significantly reduce transaction costs. Also, it will increase the trust of available information, which will be revised at source and automatically updated in all systems that link back to the source.

The to-be condition assumes that NRAs will publish organisation information requirements which recognise the value of industry adoption of a European Road OTL along with other suitable national and international initiatives. Further, it assumes that the information requirements for projects and asset management will be consistent with those of the organisation, and will be available to industry such that the supply chain, including software developers, can invest in adopting the requirements. The to-be condition also assumes that NRAs' asset managers will receive from contractors a set of valuable asset data which has been verified and certified, such that confidence in the data can be achieved prior to its addition to the NRAs inventory databases. As such, extensive resurveying, documentation and data manipulation will be avoided. The wider use of predictive maintenance is likely, beyond just for bridges and pavement assets, given that data will be of higher quality, linked, and more easily interrogated.

With regard to the stock of historical asset data, the to-be condition assumes that, over time, this will be linked to European Road OTL asset objects, thereby making the historical data more accessible and valuable. Advanced systems may then be able to mine that data to improve its value further.

A particularly important assumption of the to-be condition is that there will be much more widespread use of software-as-a-service. This will provide a more dynamic system of interacting software products that read, interpret and report on Linked Data shared by various stakeholders. This will reduce the cost of software for the industry and will provide high functionality for users. In turn, this will likely force the large software companies to provide greater integration with their proprietary file types.

Data perspective

Data structures will facilitate the sharing of data independent of industry software platforms. These data structures will be based on established open web standards. The use of flexible information management standards, based on relevant international standards will facilitate use by national organisations across the chain (national, organisational and project level). They will be built on generic standards like W3C or OGC. Functionality will provide improved interoperability with systems like GIS throughout all stages of the life-cycle, from strategic planning to operation and maintenance. The implementation of the European Road OTL will support this data structure need.

Non-graphical information (e.g. specifications, material test results) will be linked to defined objects, as necessary, in line with identified asset information management (AIM) data needs. Geotechnical data (e.g. borehole records) will be shared in a standardised open data format like SOSI and Inspire.

Data will only be used after validation to test the liability and to determine the specific data owner (metadata). Therefore, it is expected that data will be reliable, available and robust. [Inspire].

The to-be condition assumes that historic, non-semantic asset data is gradually linked to asset objects as the assets are operated, inspected, maintained, rehabilitated or replaced, and that the quality of the historic data is recorded in relevant metadata over time. As such, historic information becomes more accessible and reliable, and thereby valuable for future processes.

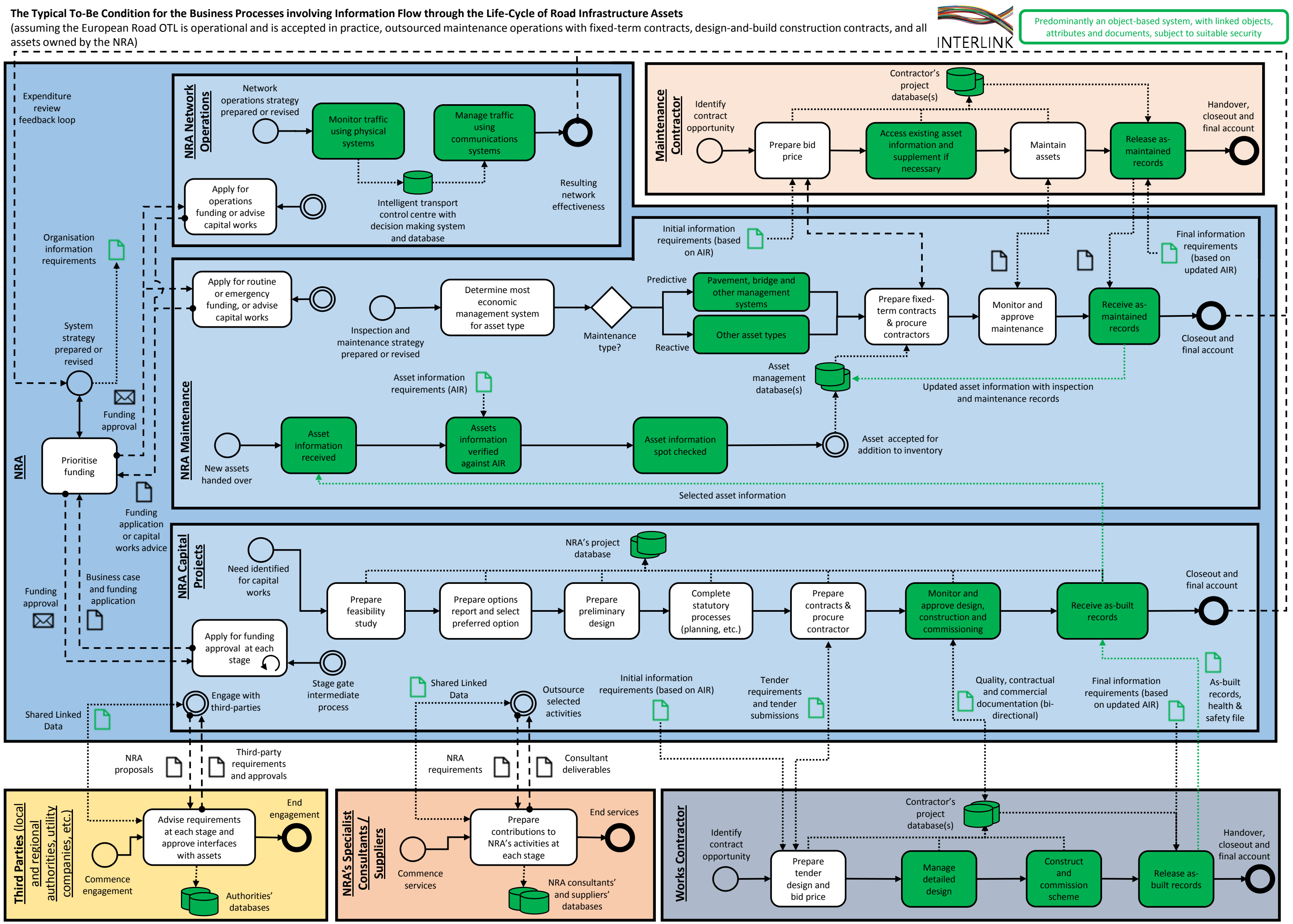


Figure 5.5 – Business process model of the typical to-be condition for information flow through the life-cycle of road infrastructure assets (link)

6 Needs Statements

The research process described in the earlier sections of this report facilitated the development of two sets of needs statements, representing the business needs of NRAs for the management of asset information, and the data needs necessary to meet those business needs. The final statements are presented in a poster in Appendix F (which is also available in high-resolution A3 format at this link). There are three origins for the statements, as follows:

i. Statements included in the December 2016 survey;
ii. Statements excluded from the December 2016 survey to reduce the survey length and as they were considered too obvious to question;
iii. Statements that were developed based on input from respondents to the December 2016 survey.

These origins are defined on the poster using tag colours. The statements are categorised into three areas:

i. Strategy, i.e. needs which relate to why information is required or data is structured in certain way;
ii. Life-cycle and supply chain, i.e. needs which relate to what the European Road OTL is aiming to achieve;
iv. Practice, i.e. needs which relate more to how the European Road OTL will be designed and implemented.

The needs statements are prioritised based on the results of the survey and the subsequent detailed analysis by the INTERLINK consortium. This prioritisation has implications for planning of subsequent works packages in this research project.

In addition to the needs statements, to provide context the poster includes various surrounding content:

- Core needs, which are commonly used single-word requirements for valuable information.
- Typical life-cycle stages (the number and naming of which depend on the country, client and procurement type).
- A list of typical stakeholders throughout the life-cycle of road assets.
- A list of typical road assets, grouped into structures, road works, environmental, and traffic and intelligent transport systems. (These groupings depend on the country, client, life-cycle stage and stakeholder perspective.)
- The intended location of the European Road OTL between international and national standards.
- The three pillars on which successful implementation of the INTERLINK solution relies, i.e. a technical specification, a standardisation body, and acceptance in practice.
- The semantic levels of web-based data.
- The granularity or hierarchy of asset objects, from areas down to materials. (Other such relationships, particularly for asset management of facilities, use complex – facility – entity – element.)

7 Recommendations

7.1 Recommendations applicable to the INTERLINK project

7.1.1 Recommendations for Work Package C

The business and data needs statements have been generated and validated through a structured process of primary and secondary research. These statements should be considered relevant to the long-term development, implementation and industry acceptance of the European Road OTL. As such, the INTERLINK consortium recommends that the statements form a basis for the functional specification for Work Package C (WPC), supplemented by requirements agreed at the commencement meeting for WPC with the Programme Execution Board.

WPC will develop the common principles for the European Road OTL, which will be applied in WPD for developing an initial European Road OTL, and testing it in test cases with proof of concept tools. These common principles should ensure that the resulting OTL could accommodate the business and data needs statements.

INTERLINK recommends that the European Road OTL is harmonized with the other most relevant standardisation initiatives, as described in Section 4.1, using the INTERLINK approach as described in Section 5.3. Harmonisation should focus on the Modelling Guide and on the OTLs (or ontologies) in a layered structure as described in Figure 7.1.

This results in an international consensus about the layered structure applied for asset information and subsequently improved asset information exchange in the whole chain.

As both the consortium partners and the PEB members are actively participating in the most relevant standardisation initiatives, INTERLINK could be the platform for facilitating this harmonisation the coming 18 months. In this way, INTERLINK could be the facilitating platform for the harmonisation of the most relevant Asset Information Management standardisation initiatives, as depicted in Figure 7.1.

INTERLINK also recommends that a minimum level of granularity is defined such that requirements of an explicit use case are met. In parallel INTERLINK also recommends that, where practicable, the principles for the European Road OTL require that each feature of the OTL has an explicit, associated use case of value at a pan-European level.

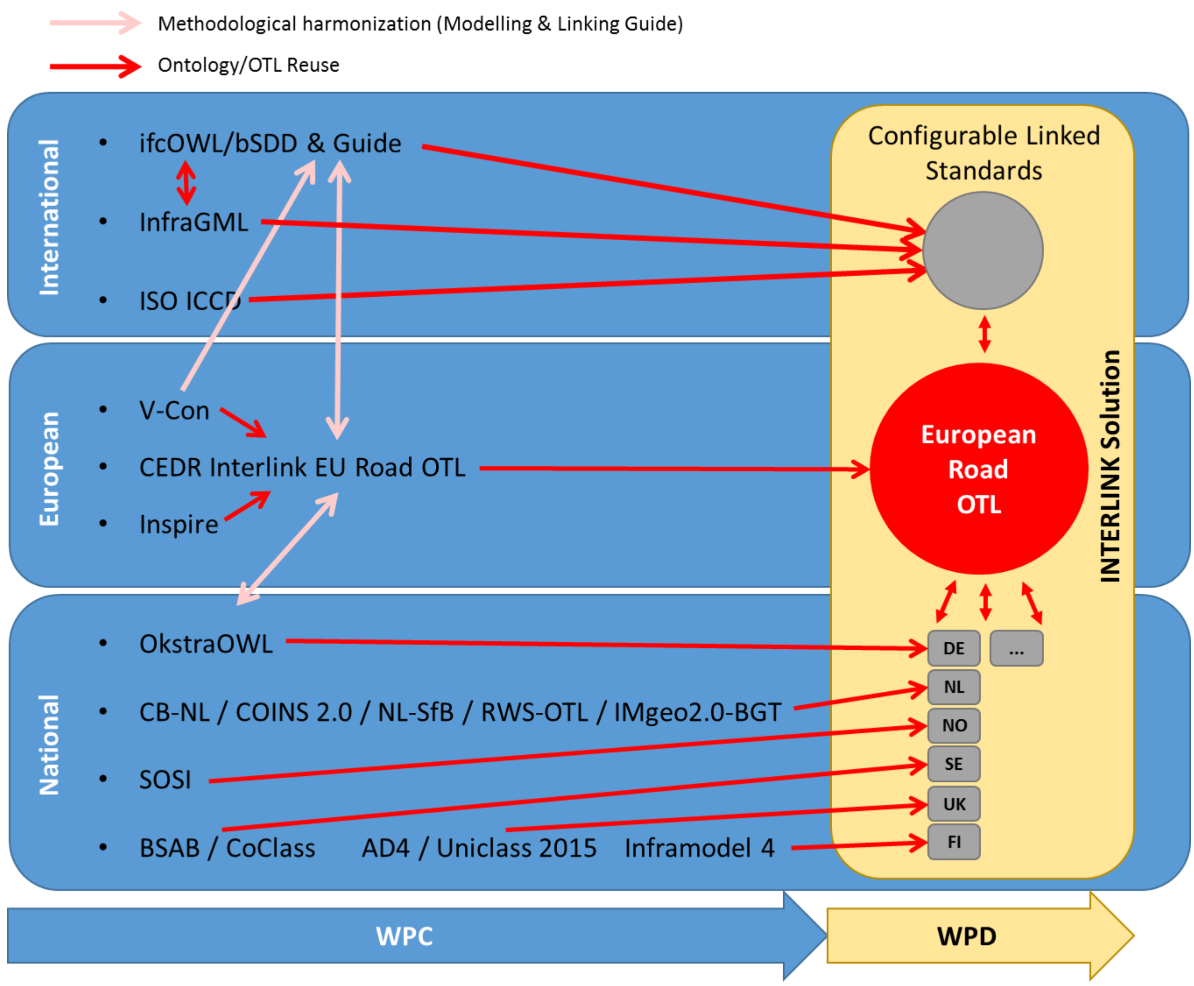


Figure 7.1 – Roadmap from most relevant standardisation initiatives to harmonisation, with INTERLINK as the facilitating platform.

7.1.2 Possible suitable test cases for WPD3

Following the development of a basic European Road OTL and proof-of-concept information management tools in WPD1 and WPD2, respectively, WPD3 involves testing of the system. This testing will aim to demonstrate realistic business processes and show that the proposed European Road OTL and associated Open BIM systems are effective and can be implemented efficiently in practice. The INTERLINK consortium suggests referring to the typical as-is process model (Section 5.1) for identifying which information exchange or sharing will be supported in the test cases. Sets of structured data will be provided for these information exchanges by NRAs and will be processed with the INTERLINK proof of concept tools.

Test cases are proposed for the following countries:

- A Nordic country;
- Germany;
- The Netherlands;
- A country with lower BIM maturity, to be agreed with the Programme Execution Board.

The to-be condition, presented in Section 5.4, identifies activities and information exchanges that are improved or redesigned using the INTERLINK approach. INTERLINK suggests addressing the following options for testing:

- The linkage of both semantically-rich asset information and document-based asset information to asset objects;
- The process of defining asset information delivery requirements and then testing asset information received at handover for compliance with those requirements;
- The linkage of BIM-based objects to GIS-based objects;
- The automatic creation of or linkage to objects conforming to the European Road OTL based on structured information from existing asset management systems.

INTERLINK recommends that the test cases are discussed at the Work Package C planning meeting in Month 7. Then, INTERLINK proposes to install small teams of NRA and INTERLINK representatives per test case to elaborate the test case scenario and guide the NRA to provide adequate structured data sets for testing. These to be finally agreed upon with the Programme Execution Board in the M12 PEB meeting. This will, to a certain extent, determine the planning for WPC, WPD1 and WPD2.

7.1.3 Validation of test cases against needs statements

To verify the technical solution provided by WPD1 and WPD2 against the elicited business and data needs of the industry, the testing plan in WPD3 will identify explicit tests for relevant needs statements from Appendix F. The needs statements which will be verified will depend on the test cases agreed with the PEB. This process will ensure that the underlying focus of a highly technical solution remains on the needs of the industry. It will assist INTERLINK and CEDR to demonstrate the value of the European Road OTL to NRAs, contractors, consultants and software companies by identifying which need statements are accommodated with the European OTL and what should be done in other areas to fully support the needs. This will optimise the likelihood of acceptance in practice.

Further, the results of the test cases should be communicated to the industry. These results should include the expected value for industry of the business processes modified by use of a European Road OTL, and the risks associated with adopting the modified processes.

7.2 Interim recommendations for NRAs and industry

In advance of the completion of the INTERLINK research project and any subsequent development of a European Road OTL, INTERLINK makes several recommendations to NRAs and industry, which should be adopted in practice over the coming 18 months.

<u>Linked Data and standardisation</u>

As described above, INTERLINK recommends that NRAs and the industry contribute actively to further development of the European Road OTL and to support harmonisation of the relevant standardisation initiatives. In the long term, this will enable the industry to grow to a state that will resemble the to-be condition sketched in Section 5.4.

By using the hybrid approach, with a gradual transition from the exchange of documents to the sharing of semantically-rich data, INTERLINK recommends that NRAs develop the next step to shared information with Linked Data and other open standards and classification systems to work towards more effective collaboration with industry: i.e. using the same language, using each other’s data.

For the short- and medium-term, INTERLINK recommends that NRAs and industry apply open standards more extensively in their business processes. When NRAs start requiring the use of open standards in their information delivery specification (Employer's Information Requirements), the industry will migrate to more structured and open data. The expectation is that having well-structured data will ease the migration to the full use of the European Road OTL. It will also ensure that the professionals involved become accustomed to working with structured data.

NRA capital works and maintenance contracts

INTERLINK recommends that NRAs contractually require capital works and maintenance contractors to validate and certify as built information, and for such certification to be attached to the as built information, to improve the subsequent trust of that information by asset managers.

Further, INTERLINK recommends that NRAs require contractors to price for engaging with asset managers during the life of a construction or maintenance project to agree and document the nature and format of information required for the management of assets and how it should be handed over and tested, or for supporting the NRA in the development of ontologies (or data dictionaries) for any assets which are not covered by existing relevant OTLs. This will help NRAs to scale their information requirements with the support of industry.

NRA project managers and asset managers

NRAs that are looking to define more explicit information requirements for handover of asset data to asset managers should first look to the practices in other countries and then consider which approach makes most sense for their business. Although there may be value in gathering all possible data, INTERLINK recommends that, in the early stages, NRAs focus on eliciting from asset managers the top five (approximately) pieces of information required for each asset type, and then ensuring that project managers limit their handover requirements to that information in an appropriate format. This will help NRAs to focus on the most valuable data first, and scale up later. Further, NRAs should then communicate those information requirements to industry, as a market driver for industry-wide development.

Learning from each other

Various countries have particular strengths in aspects of BIM for design, construction and asset management. INTERLINK recommends that NRAs that are considering developing capabilities in a certain area look at and learn from:

- The UK for standards related to document management processes, asset classification and security;
- Germany for classes and classification systems;
- The Netherlands for the early use of LD/SW technologies (and Sweden as part of V-Con);
- Norway, Sweden and Finland for developing a culture of industry-wide BIM adoption, from preparing strategies and guidelines, to implementing data standards, and using models for the full delivery of capital works projects.

Conversely, the countries listed above should be open to sharing their knowledge. This recommendation also applied to international standardisation bodies, who can learn from the significant developments in various countries.

Software companies

INTERLINK recommends that software companies develop new tools for the LD/SW approach to enable greater and more effective use of software by a wider range of industry stakeholders.

Progressive NRAs

The European Road OTL can only be successful if several NRAs are ready to adopt it once it is launched, thereby generating momentum. NRAs should actively engage or communicate with the INTERLINK Consortium throughout the research, and guide developments in their systems towards the point of being able to adopt the European Road OTL if and when it gets launched.

Appendix A – References

For most of the referencing in this report, refer to INTERLINK Deliverable D.1 – Literature Library List. This is available on the INTERLINK website (link). Additional references are provided below.

CEDR (2015). S3 Information – interim report. http://www.cedr.fr/home/fileadmin/user_upload/en/Executive_Board/EB_36_2015-06-25_Oslo/b_Documents_EB_Oslo/Anx5.2%20S3%20Information%20interim%20report%202015.pdf. Accessed on 8/02/2017.

Object Management Group (2016). http://www.omg.org/spec/BPMN/2.0/. Accessed on 1/02/2017.

Jackson, P. (2016). Quote from a presentation at the buildingSmart Summit, South Korea, September 2016.

Miskimmin, I., & Dentten, R. (2015). Infrastructure Asset Data Dictionary for the UK. http://www.bimtaskgroup.org/wp-content/uploads/2014/02/IADD4UK-presentation-V2.pdf. Accessed on 3/02/2017.

Bizer, Christian; Heath, Tom; Berners-Lee, Tim (2009). "Linked Data—The Story So Far" (PDF). International Journal on Semantic Web and Information Systems. **5** (3): 1–22. doi:10.4018/jswis.2009081901. ISSN 1552-6283. Retrieved 2010-12-18. Solving Semantic Interoperability Conflicts in Cross–Border E–Government Services.

Appendix B – Abbreviations

Abbreviation	Explanation [optional context]
AIM	Asset Information Management [INTERLINK]
BASt	Bundesanstalt für Straßenwesen [DE]
BCF	BIM Collaboration Format [bSI]
BIM	Building Information Modelling/Management
BSAB	Byggandets Samordning Aktiebolag [SE]
bSDD	buildingSmart Data Dictionary [bSI]
bSI	buildingSmart International
CAD	Computer Aided Design
CB-NL	ConceptenBibliotheek-NL (Concept Library for the Dutch construction industry) [NL]
CC	Creative Commons
CEDR	Conference of European Directors of Roads (the Platform for cooperation between National Road Authorities)
COINS	Constructieve Objecten en de INtegratie van Processen en Systemen [NL]
D.x	Deliverable x [INTERLINK]
DC(I)	Dublin Core (Initiative)
EU	Europe, European
GIS	Geo-spatial Information Systems
GML	Geography Markup Language [OGC]
ICT	Information and Communication Technology
IDM	Information Delivery Manual [bSI]
IFC	Industry Foundation Classes [bSI]
INTERLINK	INformation managemenT for European Roads using LINKed data [CEDR]
ISO	International Standardization Organization
LD	Linked Data [W3C]
MVD	Model View Definition [bSI]
NRA	National Road Authority
OGC	Open Geo-spatial Consortium
OKSTRA	Objekt katalog für das Straßen- und Verkehrswesen [DE]
OSM	Open Street Map
OTL	Object-Type Library
OWL	Web Ontology Language [W3C]
PEB	Project Executive Board [CEDR]
PLM	Product Life-cycle Management
RDF(S)	Resource Description Framework (Schema) [W3C]
SE	Systems Engineering

Abbreviation	Explanation [optional context]
SKOS	Simple Knowledge Organization System [W3C]
SW	Semantic Web [W3C]
TC	Technical Committee [ISO/CEN]
W3C	World Wide Web Consortium
WG	Working Group [ISO/CEN]
WP	Work Package [INTERLINK]
WFS	Web Feature Service [OGC]
WMS	Web Map Service [OGC]
WWW	World Wide Web [W3C]
XML	eXtensible Markup Language [W3C]

Appendix C – Literature Review

C.1 General notes on literature review

The literature review encompassed a review of relevant literature sources including academic research, national and international/European standards, guidance documents and industry reports and presentations. The approach adopted to carry out the literature review allowed the most relevant literature to be reviewed in detail with a separate focus on (i) business needs (WPA) and (ii) data needs (WPB).

It is important to note that detailed literature reviews relevant to information management for road infrastructure have previously been carried out (e.g. as part of the V-CON project). Therefore, the approach adopted here focussed on a more high-level examination of relevant literature and also of previous literature reviews in order to identify any changes or developments which had become apparent since previous comprehensive literature studies had been completed.

The review of the business needs and data needs were carried out separately, with a similar approach being adopted for both. The literature review process initially involved identifying and briefly reviewing relevant literature sources. Each of the sources were then classified using a number of criteria to assess relevance to the INTERLINK project and to identify the most important sources to consider in more detail as outlined below considering the relevant criteria for WPA and WPB.

The literature review was conducted following four steps:

1. Inventory of available literature (see INTERLINK deliverable D.1).
2. Assessment of relevance of each document to WPA and WPB:
   - Is the scope related to roads/highways?
   - Is it related to Asset Information?
   - Does it cover the exchange / sharing of information?
   - Does it cover BIM in the entire object life-cycle, connected to an object(s)?
   - Is it part of the work processes of NRAs or contractors?
   - Does it cover business needs?
   - Is it applicable to capital delivery stage (design/construction)?
   - Is it applicable to operational stage (maintenance)?
3. Review of relevant documentation in more detail to identify business and data needs.
4. Items relevant to WPB classified in a factsheet in which items are classified in terms of:
   - What it does (according to BuildingSmart methodology standards)
   - What Kind of Data is addressed (Process Data, Meta Data, Object Data or Representation Data)
   - What Data Aspects (semantics, syntax or transport)
   - What Meta Levels (language, data structure or data set)
   - Maturity level (Usable, Available, Reliable, Interoperable)
   - Solution BIM level (Level 0, 1, 2 or 3)
   - Used by (client, contractor, consultant or supply-chain)
   - Relevant countries
   - Relevant project life-cycle stages and stakeholder view

- Implementation maturity (initial, repeatable, defined, managed or optimized)
- Formalization (test phase, informal implemented, formal, industry standard or ISO)

The inventory of relevant literature developed as part of this process was created at the outset of the project and has been maintained and updated as necessary. The full list of literature can be found in INTERLINK Deliverable D.1 Literature library list. The inventory also contains examples of implementation, relevant comments on various literature sources (pros and cons) and web links to further information.

Once the most relevant literature for both WPA and WPB had been identified, these documents were then reviewed in greater detail in order to extract and examine relevant business and data needs statements. A summary of the findings of each of the literature reviews are provided in the following two sections.

C.2 Work Package A literature review

Having identified and assessed the relevance of the literature sources, the references found to be most relevant to WPA were reviewed in order to extract business needs for information management. In total, approximately 140 relevant sources were identified, before having their relevance to WPA and WPB assessed in order to identify whether or not they were to be reviewed in further detail.

It is noted that the majority of literature relevant to BIM and the application of information management processes to the delivery and management of road assets tended to be more focussed on the technical aspects and relevant data needs, exchange formats and standards with the business needs identified generally being repeated throughout most of the literature sources. Therefore it was necessary to consider a wide range of sources, not necessarily only focussed on the specifics of BIM, but also encompassing sources which examined the various stages in the delivery and management of road infrastructure assets. These sources often addressed deficiencies in specific work practices or areas in which value could be gained through the introduction of improved processes for the management and exchange of asset information.

It was observed that most sources inherently acknowledged the fact that there was value to be gained through the introduction of BIM and better information management processes throughout the life cycle of assets, however the specific business needs, or quantification of the actual value to be gained was generally not explicitly addressed, primarily due to the complexity involved in such projects and the difficulty in quantifying benefits directly related to BIM processes.

Examining these relevant literature sources resulted in the identification of a vast array of potential business needs which were then classified by considering their relevance to:

i. Different CEDR countries;
ii. Different asset types;
iii. Different life-cycle stages;
iv. Different contract types.

It was found that general high-level business needs tended to be repeated throughout the literature and were generally relevant to each of the categories outlined above, with certain more specific needs being relevant to different countries, asset types, life-cycle stages and contract types.

The following principles, which were developed based on the findings of the literature review, were shown to cover the majority of the high-level business needs for information management identified throughout the literature:

- Management of Information has great effects on cost and quality.
- Management of Information can reduce construction time.

- Management of Information can lead to more efficient management of infrastructure.
- Efficient Management of Information requires a set of common principles, criteria and requirements. Data should be well structured and appropriately structured.
- Timely and correct information enables well founded decision making and reduces risk.
- Information Management must be economically viable.
- Information Management should consider the different life-cycle phases of infrastructure.
- Information Management requires the proper procurement of information.
- Information Management facilitates reliable exchange of data between the various life-cycle stages of infrastructure and also between various stakeholders.
- Information Management requires reliable and good quality data.
- Information Management improves interoperability between NRAs and their various stakeholders, taking account of the fact that different parties may have different uses, requirements or interpretations of data for the same infrastructure components.
- Information Management should be future-proof.

While many additional business needs were identified, the principles listed above were shown to be recurring throughout the literature, with many business needs identified by the literature falling under these headings. Cost savings and improved efficiency in construction and asset management were repeatedly reported, however specific quantification of such improvements was rarely available. This is discussed further within Section 4.1 of this report.

C.3 Work Package B literature review

The most relevant earlier literature review on the subject is performed by the European V-CON project, documented in its Deliverable 3.1 – 'Inventory of available information exchange standards'. This review was conducted in April 2013. Here an updated framework is presented, as introduced earlier in the main text, to get a grip on all relevant initiatives and their standardization outcomes.

Framework for literature analysis

First, all initiatives/standards are relevant for a specific **Scope**:

- International (**INT**),
- European (**EU**), or
- National (sub-scoped / made specific per country: **UK**, **IE**, **DE**, **FR**, **NL**, **NO**, **SE**, **FI**)

Next, these initiatives/standard typically come from a certain **World of Standards**:

- Building Information Modelling/Management (**BIM**) standards (incl. CAD),
- Geo-spatial Information Systems (**GIS**) standards,
- Internet/World Wide Web (**WWW**) standards,
- Product Life-cycle Management (**PLM**) / Systems Engineering (**SE**) standards,
- Industry (**IND**) standards (building industry or software industry), or
- Other (**OTH**).

Finally three more technical 'data dimensions' are distinguished, used only for positioning of a subset (short-list) of all identified initiatives/standards. The first one is the **Data Kinds** addressed:

- Meta Data,
- Object Data, and
- Representation Data (like geometry), or

- Other, like key concepts, modelling and linking guides, supporting software tools, etc.

The second and third ones, **Data Level** and **Data Aspect** are combined in a matrix shown below.

Data Aspects / Data Levels	**ACCESS**	**FORMAT**	**CONTENT**
LANGUAGE	LANGUAGE ACCESS	LANGUAGE FORMAT	LANGUAGE CONTENT
DATA STRUCTURE	DATA STRUCTURE ACCESS	DATA STRUCTURE FORMAT	DATA STRUCTURE CONTENT
DATA SET	DATA SET ACCESS	DATA SET FORMAT	DATA SET CONTENT

Figure C.1 – Two further, more technical dimensions on the nature of data

Long-list of Initiatives/Standards

Table C.1 provides a long-list of the all the initiatives and standards mentioned by the interviewees relevant for asset information management (AIM).

Table C.1 – Overview of the initiatives/standards

Scope	Initiative/Standard	World of Standards
INT	bSI IFC (+IDM / MVD / BCF) incl ifcOWL	BIM (+PLM/SE)
	bSI IFC for Infra incl. ifcOWL	BIM
	bSI bSDD	BIM
	bSI LDWG Modelling and Linking Guide	WWW (Guide)
	OGC GML	GIS
	OGC WFS/WMS	GIS
	OGC InfraGML	GIS
	LandXML.org LandXML	GIS/IND
	W3C basic technology	WWW
	W3C XML-technology	WWW
	W3C LD/SW-technology	WWW
	W3C SKOS, SSN (IoT), …	WWW
	WWW semantic resources like DC, VANN CC REL, …	WWW
	ISO 55000	OTH (AM)
	Open Street Map (OSM)	GIS
	ESRI SHP/FGB	GIS
	Autodesk DWG/DWN	BIM (CAD)
	Autodesk RVT	BIM
	IETF Comma-seperated Values (CSV)	WWW
	ISO TC184/SC4 - 10303 (STEP)	BIM
	ISO TC211	GIS
	ISO 12006-3	BIM
	ISO/TC59/SC13 ISO DIS 19650-1 & 19650-2	BIM
	ISO/TC59/SC13/WG8 ICDD	BIM
	gbXML.org gbXML	BIM/IND
	NASA/TQ QUDT v2.0	WWW/IND
EU	CEN TC287	GIS
	Inspire (2005-2008)	GIS
	V-Con	WWW (Guide)
UK	BS & PAS 1192 suite of standards and specifications	BIM
	Highways England IAN 182 and IAN 184	BIM
	Uniclass 2015	BIM
	NBS BIM Toolkit	BIM (infra)
	IADD4UK	BIM
IE	Ordnance Survey Ireland Linked Data Platform	GIS / LD
DE	BASt OKSTRA / okstraOWL	BIM
	BauDataWeb	WWW
	ISYBAU (drainage)	BIM
	AFIS-ALKIS-ATKIS (“AAA-model”)	GIS
FR	XP P07-150	BIM

Scope	Initiative/Standard	World of Standards
NL	BIR VISI	PLM/SE
	BIR COINS	BIM
	BIR NLCS	BIM (2D CAD infra)
	BIR GB-CAS	BIM (2D CAD buildings)
	BIR CBNL	BIM
	BIR/UNETO-VNI ETIM/UOB	BIM (installations)
	CIB BIM Loket/STABU/BNA NL/SfB	BIM
	Geonovum IMgeo2.0-BGT	GIS
	RWS-OTL	BIM
NO	SN/TS 3489 (use of IFC Library/bSDD in IFC)	BIM
	ProductXchange (bSDD-based)	BIM
	SOSI (Inspire-based)	GIS
	Public Roads V770 Handbook	BIM
	NVDB Feature cat. for road DB	GIS
SE	BSAB 96 >2.0>CoClass (OTL)	BIM
DK	LandXML	BIM
FI	Inframodel data exchange	BIM
	InfraBIM Nimikkeisto (classification system)	BIM
	Common InfraBIM Requirements (buildingSMART Finland)	BIM
	BIM Guidelines for Bridges	BIM

Description of some identified items

Note: Selected short-listed initiatives/standards are textually described at the short-list to avoid double descriptions.

IAN 182 & 184

Major Schemes enabling Handover into Operation and Maintenance resp. Highways England Data & CAD Standard Instructions on naming conventions, file types and data structures for the delivery and transfer of CAD / BIM files to Highways England and its supply chain.

LandXML.org LandXML(DK)

Launched January 2000, LandXML.org is committed to providing a non-proprietary data standard (LandXML), driven by an industry consortium of partners.

ISO 12006-3

Defines a framework for the development of built environment classification systems. Used by bSDD within bSI at the moment. Actually a meta-schem in EXPRESS.

W3C basic technology, XML-technology, LD/SW-technology and semantic resources

The World Wide Web Consortium (W3C) is not just giving us the World Wide Web (WWW) as we know it and all new Linked Data (LD) and Semantic Web (SW) technology, it also has a so-called Community Group for Linked Building Data (LBD) that stimulates the uptake of linked data and semantic web technologies in the building domain as a kind of generic variant of the bSI Linked Data Working Group (i.e. more IFC-independent). This results in many useful “Best Practises” on modelling and ontology alignment and also the identification and discussion of specific ontologies/OTL available. A good example are the Semantic

Sensor Network (SSN) ontology for the monitoring domain (currently extended to also cover 'actuation' control aspects). Another example is SKOS being an area of work within W3C developing specifications and standards to support the use of knowledge organization systems such as thesauri, classification schemes, subject heading systems and taxonomies within the framework of the Semantic Web. Kind of OWL-light where the knowledge is modelled as meta-data under the SKOS ontology.

All these results feature as basic standards for many other initiatives selected later for short-listing in INTERLINK.

DCI Dublin Core (DC) & VANN

The Dublin Core Initiative published ontologies describing meta-data that are often reused. Examples are: dc:Creator. This is another vocabulary for annotating vocabulary descriptions with examples and usage notes created by Ian Davis.

CC REL

The Creative Commons (CC) Rights Expression Language (CC REL) lets you describe copyright licenses in RDF.

BauDataWeb (DE)

This is a (they call it) European Building and Construction Materials Database for the Semantic Web.

NBS Uniclass2015 (UK)

A unified classification for the UK, based on the requirements of ISO 12006-2.

NBS COBie (UK)

Developed in the UK and is available as BS1192-4.

XP P07-150

French BIM standard including a dictionary.

YIV 2015 (FI)

InfraBIM requirements buildingSMART Finland

PAS 1192-2, -3, -5

A British Standards:Specification for information management for the capital/delivery phase of construction projects using building information modelling.

BIR VISI

Dutch standard for the definition of transactions in construction (esp. civil engineering) incl. meta-level data elements. Two-level approach: framework and actual data structure involving promotion/demotion of meta-data. Defined in an appendix of ISO 29481 Information Delivery Manual (IDM) originating from bSI.

BIR NLCS & GB-CAS

Dutch 2D drawing open standards for respectively infra (NL: GWW sector) and buildings (NL: B&U sector).

BIR ETIM

Standard data structure developed and maintained by UNETO-VNI (Dutch umbrella organisation for electro-technical and mechanical installations) for installation components/product. The actual product instantiations from vendors are maintained by the 2ba organisation. Currently they are working on a Uniforme Objecten Bibliotheek (UOB) variant of ETIM or in English, a Uniform Object Library applying also LD technology.

ISO TC211

An ISO standardization group providing basic/conceptual GIS standards.

ISO 55000

ISO 55000 is an international standard that specifies the requirements for the development, implementation, maintenance and improvement of a management system for asset management.

IETF Comma-separated Values (CSV)

CSV is a common data exchange format that is widely supported by consumer, business, and scientific applications. Among its most common uses is moving tabular data between programs that natively operate on incompatible (often proprietary and/or undocumented) formats. This often works despite lack of strict adherence to RFC 4180 because so many programs support variations on the CSV format for data import.

Short-list of Initiatives and standards

This section gives a brief description of the most relevant items found. Further details are provided in the fact sheets.

International

- bSI LDWG ifcOWL for IFCxxx: IFC4x1 > IFC5 (incl. Road, Rail & Bridge) & bSI Modelling and Linking Guide (for IFC extensions/links) & buildingSmart Data Dictionary (bSDD)
- OGC (GML/CityGML/)InfraGML
- W3C Linked Building Data (LDB) Community Group (CG)
- ISO TC184/SC4 STEP (via bSI) & TC59/SC13/WG8 ICDD ('Information Container for Data Drop')
- NASA/TopQuadrant (TQ) Quantities, Units & Datatypes (QUDT) v2.0
- Various WWW (W3C/DCI/CC) generic semantic resources (SKOS, DC, VANN, CC REL, …)

European

- EC V-Con
- CEDR Interlink 'European Road OTL'
- EU Inspire Directives (GIS)
- CEN TC442-BIM (CEN-variants of IFC, IDM, ISO 12006-3)

National

- BASt OKSTRA/okstraOWL [DE]
- BIR CB-NL, COINS 2.0, CIB/BIR NL-SfB / Geonovum IMGeo2.0-BGT / RWS RWS-OTL [NL]
- Svensk Byggtjänst BSAB/CoClass [SE]
- Asset Data Dictionary Description Document (AD4) / Uniclass 2015 [UK]
- Inframodel 4 [FI]
- SOSI [NO]

Figure C.2 – Short-list of initiatives/standards directly relevant to INTERLINK

Textual description of all selected items

bSI LDWG ifcOWL, Modelling and Linking Guide & bSDD (primarily on underlying ISO TC184/SC4 - 10303 – 'STEP' technology)

The current Industry Foundation Classes (IFC) specification is IFC4ADD2 (for the modelling of buildings but also often 'misused' for the modelling of civil infrastructures). The bSI Infrastructure Room recently released a follow-up or extension schema: IFC4x1 (Release Candidate (RC) 3, incl. '3D alignments' as explicit shape representations for roads etc., conceptually harmonized with OGC InfraGML developments). The future is towards IFC5 adding road, rail and bridge semantics. All these existing and new data structures will also become available as ifcOWL (s ontology/OTL) supported by the Linked Data Working Group (LDWG) with the bSI Technical Room.

In this LDWG also a Modelling and Linking Guide (MLG) is currently being written, defining a vision and strategy for W3C LD/SW application in bSI including tutorial material on RDF, RDFS and OWL but also many guidelines for application of all this new technologies in the bSI rooms. Special attention is towards the Product Room dealing with buildingSmart Data Dictionary (bSDD) which could also benefit from the MLG since it is a essentially a network of interconnected sub-ontologies/OTLs.

The currently available IFC Alignment entities in IFC4x1 are a common source for the future IFC Roads, Rails, Bridges and (and later maybe also) Tunnels:

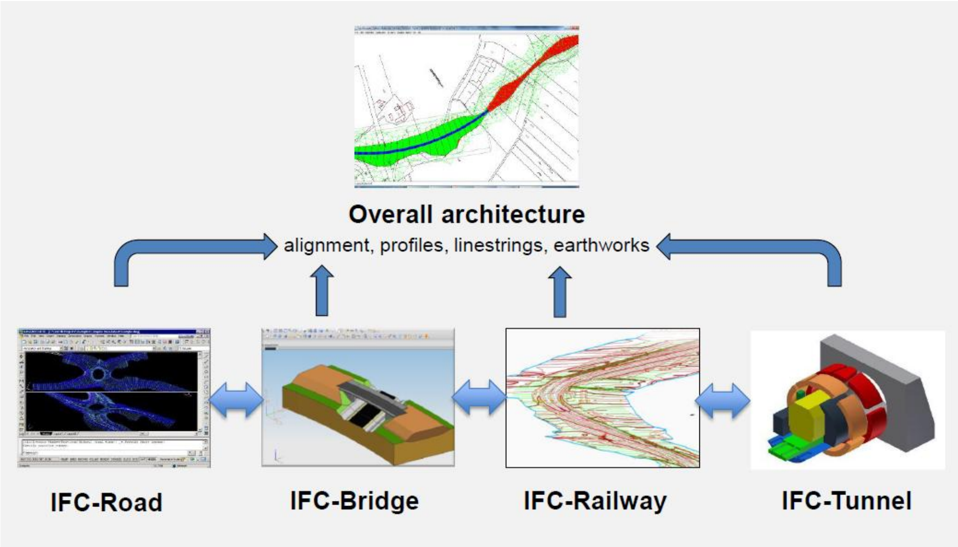


Figure C.3 – "IFC for Infra" components (buildingSmart)

Using basic standards from product modelling standard ISO 10303 - Standard for the Exchange of Product model data (STEP): EXPRESS, EXPRESS-G, SPFF and SDAI). Used in bSI for IFC as primary definition.

<u>Positioning</u>

Data Kinds:

- Meta Data: IDM/MVD specifications and BCF for design changes and limited meta-info in IFC
- Object Data: primary scope of IFC: Buildings and recently Civil Infrastructures
- Representation Data: 70% of IFC deals with explicit shape representation: bounding boxes, extruded solids, BREPs, etc.

Data Levels:

- Language: EXPRESS, secondary XSD for ifcXML and OWL for ifcOWL
- Data Structure: IFC, ifcXML, ifcOWL

Data Aspects:

- Content: IFC, ifcXML, ifcOWL
- Format: EXPRESS for IFC, SPFF for IFC-DATA in case of IFC; XSD/XML in case of ifcXML, RDF/RDFS/OWL in case of ifcOWL
- Access: SDAI for IFC, XPATH/XQUERY etc. in case of ifcXML, SPARQL in case of ifcOWL

OGC (GML/CityGML/)InfraGML

The OGC (Open Geospatial Consortium) is an international not for profit organization committed to making quality open standards for the global geospatial community. Standards based on ISO19xxx as implemented by OGC GML, CityGML, InfraGML etc.

This GIS standard defines concepts for land and civil engineering infrastructure. Based on a subset of LandXML (from LandXML.org) functionality. It is consistent with the OGC standards, implemented with GML and supported by a UML (Unified Modelling Language) conceptual model. The model standardizes a single set of consistent, implementation-independent concepts for the identified subject areas. Subject areas include facilities, projects, alignment, road, rail, survey, land features, land division, and wet infrastructure. It forms the basis for (a.o.) InfraGML which will be the replacement of LandXML. GML provides a feature model and geometry support but will leave smart detailed modelling to IFC (for Infra) and InfraGML.

InfraGML is currently out for comments (replacing LandXML) based on the OGC® Land and Infrastructure Conceptual Model Standard (2016). The candidate InfraGML specification has been conceptually harmonized (w.r.t. alignments) with bSI and is now out for public feedback.

Positioning

Data Kinds:

- Object Data: primary scope of CityGML/InfraGML: Land use & Civil Infrastructures
- Representation Data: 70% of IFC deals with explicit shape representation: GML.

Data Levels:

- Language: XSD
- Data Structure: GML, CityGML, InfraGML

Data Aspects:

- Content: GML, CityGML, InfraGML
- Format: XSD for GML/CityGML/InfraGML. XML for data sets.
- Access: Object-based Web Feature Service (WFS) and model-based Web Map Service (WMS)

W3C Linked Building Data Community (LBD) Group (CG)

This meets often to discuss LD/SW based topics and best practices relevant for the construction sector. Semantic resources are identified and also presented like for building topology and energy efficiency. It can be seen as the more generic, IFC-independent counterpart of the bSI LDWG.

Positioning

Data Kinds: ALL (but relevant for construction and LD/SW-based)

Data Levels:

- Language: RDF/RDFS/OWL &rule/query languages
- Data Structure: all kinds of semantic resources that could be reused

Data Aspects:

- Content: all kinds of semantic resources that could be reused
- Format: All LD/SW serializations (Turtle, RDF/XML, etc.)
- Access: SPARQL and maybe higher level interfaces for construction: IFCQL, BIMQL etc.

ISO TC59/SC13/WG8 Information Container for Data Drop (ICDD) & CEN TC442/WG2-BIM

ICDD deals with specific data access aspects involving 'containers' that group sets of data according to some view. The topic is also dealt with in on a European level in CEN TC442/WG2. Several initiatives bring their ideas and results to the ISO/CEN working groups that are intended to be harmonized (DRUM (FI), Mephisto Multi-Model Containers (MMC) (DE), bSI BCF2.0 (INT), COINS (NL).

Positioning

Data Kinds:

- Meta Data: containers for, typically heterogeneous, data sets

Data Levels:

- Language: under investigation, several options, like W3C Linked Data protocol (LDP)
- Data Structure: under investigation, several options, depending on language choice also

Data Aspects:

- Access: under investigation, several options heavily depending on language and data structures chosen

NASA/TopQuadrant (TQ) Quantities, Units & Datatypes (QUDT) v2.0

Many approaches exist worldwide for modelling quantities and units. One of the most worked out ontologies for this is Quantity, Units (of measure), Dimensions and data Types (QUDT) version 2.0. It influences the way in which end-user properties are modelled in ontologies. In QUDT, quantity kinds like "Length" are modelled as individuals (instances) of the meta-class qudt:QuantityKind" and so are user defined specializations of it like ":buildingHeight". At the time of writing this document, the partial/modular specifications for QUDT2.0 are gradually published.

Positioning

Data Kinds:

- Meta Data: lots of related meta data ON quantity kinds, units etc. (definitions, abbreviations, symbols, etc.)
- Object Data: describing how to model quantities and unit for objects

Data Levels:

- Language: OWL
- Data Structure: QUDT2.0

Data Aspects:

- Content: QUDT2.0
- Format: Turtle
- Access: SPARQL

EU V-CON project

The V-Con research project with key partners (RWS, TrafikVerket, Triona, CSTB and TNO) will result in an environment that enables data exchange/sharing (by conversion or linking) according different standardisation initiatives like BIM (bSI ifcOWL) and GIS (OGC CityGML). The resulting semantic models may be used in a hybrid configuration respecting the use of bSI and OGC standards like IFC and CityGML. These other initiatives will also continue their separate developments, with a link to a future proof, more dynamic, environment. One of the (by-) products of the research project is a common international ontology (COMMON_INT). It provides an upper ontology where national (supposedly more specific) ontologies can be attached as shown in Figure C.4. It provides a neutral and common place to make standard linking and/or conversion of data possible.

The V-CON project has finalized its Modelling and Linking guide which material is now brought to bSI's Linked Data Working Group where it recently became a new work item, lead by TNO. This guide is currently used by software vendors to implement precompetitive semantic asset management software (TopQuadrant and Arcadis/Semmtech).

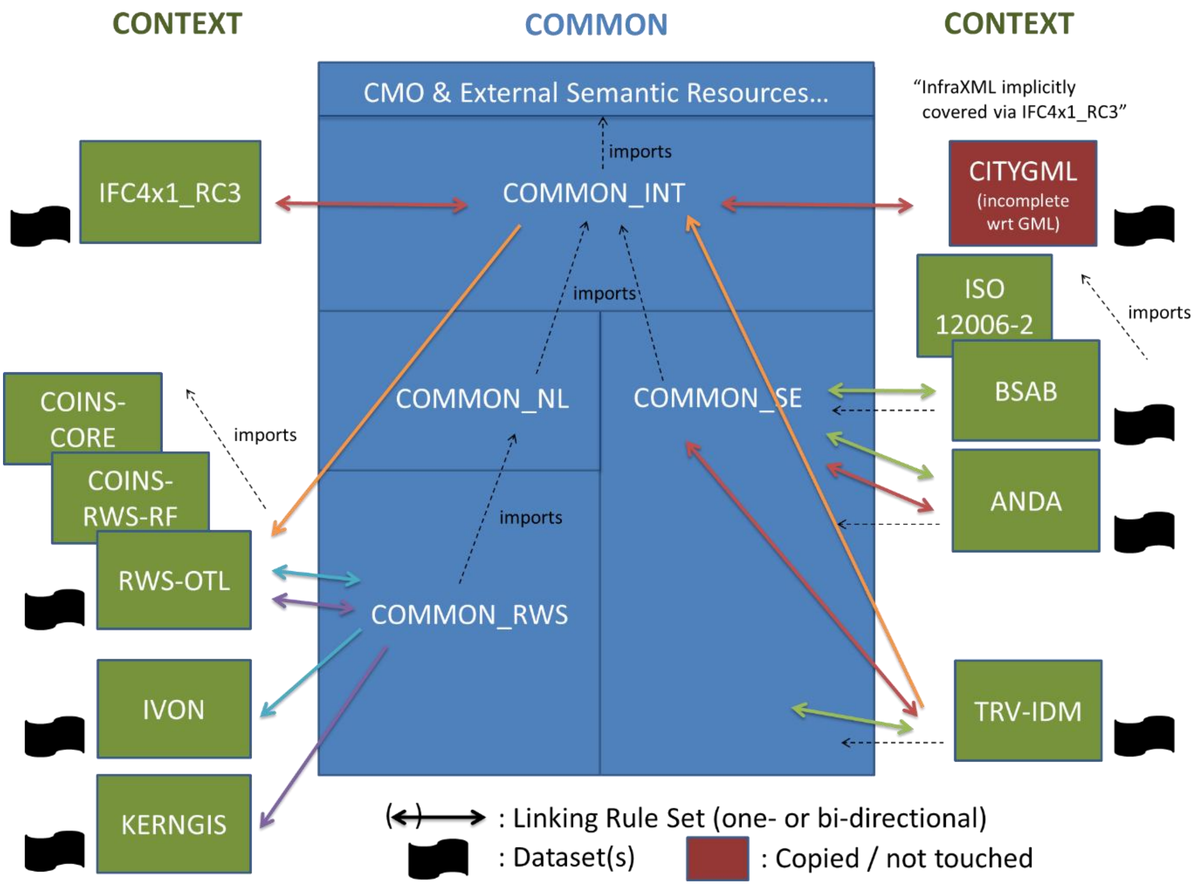


Figure C.4 – COMMON_INT for linking standards and libraries

<u>Positioning</u>

Data Kinds:

- Object Data: main roads network, several context/common ontologies and linking rule sets (LRSs)
- Representation Data: first application of IFC4x1 3D alignments, CityGML geometry

Data Levels:

- Language: hybrid: BIM/GIS/WWW-variants: integrated by W3C LD/SW so RDF/RDFS/OWL
- Data Structure: many, see Figure C.4, but as examples to test approach, special CMO ontology covering basic product modelling capabilities like typical decomposition and quantities & units

Data Aspects:

- Content: various
- Format: OWL+SPIN for conversion rule sets, Turtle serialization preference for data sets. Experiments with CWA constraints in SHACL.
- Access: SPARQL

EU Inspire Directives

This is an EU initiative to establish an infrastructure for spatial information in Europe that is geared to help to make spatial or geographical information more accessible and interoperable for a wide range of purposes supporting sustainable development". The INSPIRE Directive requires that additional legislation or common Implementing Rules (IR) are adopted for a number of specific areas (metadata, interoperability of spatial data sets and services, network services, data and service sharing and monitoring and reporting). Inspire is a standard that can provide useful data for the Asset Management process. For 34 themes data models are available like transport network, soil, hydrography, cadastre, height, topography and plans.

The standards for exchange data is follow OGC standard (GML, WFS, …) and for finding the data and network services each country has a catalogue service where data sets can be found because of proper metadata (based on ISO 19115 standard). Some countries like NL and Norway use some Inspire data models/data sets.

Positioning: same as OGC but extended with specific guidelines/directives/code lists etc.

BASt OKSTRA/okstraOWL [DE]

Objekt katalog für das Straßen- und Verkehrswesen (BASt) is a German Data Structure for modelling roads and traffic related civil infra objects over their whole life-cycle. Currently they are investigating how to derive an ontology ('okstraOWL') for it, having a close look on the generation on ifcOWL from IFC. UML, EXPRESS and XSD are used as languages to model OKSTRA. More info at: http://www.okstra.de/schema.html.

Positioning

Data Kinds:

- Object Data: OKSTRA, road and traffic related civil infra objects as GML application schema
- Representation Data: GML3.2.1

Data Levels:

- Language: UML, EXPRESS, XSD and investigations towards OWL
- Data Structure: OKSTRA, okstraOWL (future)

Data Aspects:

- Content: OKSTRA
- Format: UML, EXPRESS, SPFF and XMI/XSD for structure, XML for data
- Access: unclear but assumed OGC's WFS/WMS, also via i.e. FME Plug-in (programming via OKLABI, the OKSTRA class library in C++,C# and Java)

BIR CB-NL, Concept Library for construction in the Netherlands [NL]

The CB-NL is a concept library, with an ontology of object-types and sub-types with definitions, aiming at the integration and mapping of several local and international structured vocabularies. As described on the public website "The CB-NL's aim is the unambiguous description of built environment concepts. The contents of the CB-NL apply to the entire lifecycle of a project and include all sub-sectors in construction. Its contents also apply to all groundwork, road and hydraulic engineering as well as the spatial (geo-) environment. It's available free of charge through the Internet and API's are provided. Its focus is the Dutch construction industry but it offers all functionalities for a wider adoption and is an example of a common ontology for linking data.

Positioning

Data Kinds:

- Object Data: Construction taxonomy (properties also modelled as classes)
  - Just used for linking, not instantiable

Data Levels:

- Language: RDF/RDFS/OWL
- Data Structure: CB-NL

Data Aspects:

- Content: CB-NL
- Format: RDF/RDFS/OWL
- Access: own particular APIs

BIR COINS [COINS]

COINS (Construction Objects and the INtegration of Processes and Systems) is a Dutch standard for the exchange of BIM information. It provides a data exchange format by means of a container for BIM related data/information. COINS supports the exchange of digital information between different IT platforms from parties involved in construction and building. The standard is an answer to the need of practice in which information deliveries often consists of combinations of various data structures. It enables data drop as one coherent information package with multiple data formats, e.g. comprising functions, requirements, objects, GIS-data, 2D drawings, 3D models, IFC models, and object-type libraries. It's a well maintained and supported open-standard that is free to use. Recently the 2.0 version was released that better aligns with OWL as W3C standard (i.e. model catalogue parts modelled as classes instead of. individuals).

Positioning

Data Kinds:

- Meta Data: links to geometry and/or other descriptive documents
- Object Data: physical objects, spaces (geometry via linked IFC/GML) in COINS container

Data Levels:

- Language: RDF/RDFS/OWL
- Data Structure: COINS BIM (CBIM) version 2.0

Data Aspects:

- Content: CBIM2.0
- Format: RDF/XML
- Access: SPARQL

CIB/BIR NL/SfB [NL]

Dutch construction classification originating from CIB and digitized by BIR. Often used in practice.

Positioning

Data Kinds:

- Object Data: classification (‘taxonomy of terms’) of construction objects

Data Levels:

- Language: primarily textual, Excel sheets are available
- Data Structure: NL classification of construction objects

Data Aspects:

- Content: NL classification of construction objects
- Format: Textual
- Access: n.a.

Geonovum IMGeo2.0-BGT [NL]

This is a key Dutch GIS standard. IMgeo2.0 gives the data structure for open GIS data. The BGT for 'Basisregistratie Grootschalige Topografie' (Eng.: Basic Map for Large-scale Topography) is the reference GIS data set for the Netherlands. The map contains buildings, roads, rails, water, green etc. The data structure and data is arranged by law since 1. January 2016 and maintained by the Dutch Kadaster. The data structure is implicitly an ontology/OTL based on three subclassing-layers: entitytype, objecttype and classification with a link to geometrytypes.

Technically the IMgeo2.0 standard is defined as an application schema on top of OGC's GML/CityGML. The BGT becomes (reference) XML data accordingly.

More info can be found at: https://www.kadaster.nl/bgt

IMGeo2.0 is an OGC ‘application schema’ on top of CityGML specialized for the Netherlands. The Basisregistratie Grootschalige Topografie (BGT) is a IMGeo2.0 data set is a topological NL map.

Positioning

Data Kinds:

- Object Data: same primary scope oas CityGML specialized for NL
- Representation Data: 70% of IMGeo2.0 deals with explicit shape representation: GML.

Data Levels:

- Language: XSD
- Data Structure: IMGeo2.0
- Data Set: BGT

Data Aspects:

- Content: IMGeo2.0
- Format: XSD for IMGeo2.0. XML for data set BGT
- Access: Object-based Web Feature Service (WFS) and model-based Web Map Service (WMS)

RWS RWS-OTL [NL]

The RWS-OTL is an fairly large (30 MB) Object-Type Library (or ontology) reflecting the object data needs of RWS organization. It is a specialization of the COINS (CBIM version 2.0) ontology (itself extended first with a RWS-specific 'reference framework').

Positioning

Data Kinds:

- Object Data: The RWS-OTL focuses on semantic objects

Data Levels:

- Language: OWL
- Data Structure: RWS-OTL

Data Aspects:

- Content: RWS-OTL
- Format: RDF/XML
- Access: SPARQL

Svensk Byggtjänst BSAB [SE]

BSAB 96 developed to 2.0 and will further evaluate into an OTL referred to as CoClass. BSAB is based on the ISO 12006-3 standard. BSAB is a classification system for buildings, civil engineering works and its constituents and identifies, divides and sorts information for all construction and real estate operations. BSAB is owned by the Swedish Building Centre, a company owned by 32 Swedish construction and FM organizations.

Positioning

Data Kinds:

- Object Data: classification covering ISO 12006-3, no geometry

Data Levels:

- Data Structure: BSAB classification

Data Aspects:

- Content: BSAB classification
- Format: textual tables, CoClass will be OTL-like

IADD4UK Asset Data Dictionary (ADD) Definition Document [UK]

The aim of the IADD4UK group is to provide a common asset data dictionary suitable for all UK infrastructure assets (road, rail, power and water). It is a mixed group of owners, contractors, operators and specialist groups, whose aim is to create a complete asset data dictionary that will deliver the details needed to populate Uniclass/COBie for the Concept, Design, Construction and Maintenance data drops. Result is an ADD Definition Document (AD4). Goals are to make decisions in relation to requirements, surveys and constraints to assure the client has the right data for the outline solution; for the contractor and supply chain to deliver and/or construct the asset; needed to operate and maintain the asset.

Positioning

Data Kinds:

- Object Data: minimum data set in four stages of procurement

Data Levels:

- Data Structure: AD4 textual description

Data Aspects:

- Content: AD4 textual description
- Format: text only ("AD4 will not dictate how informaton is transmi5ed, only in what that informaton is)
- Access: n.a.

Inframodel 4 (2016) [FI]

Inframodel is the Finnish national application specification for a subset of LandXML schema, the current version Inframodel 4 is based on LandXML version 1.2. Detailed implementation guidance and agreements have been documented in the defined scope for prioritised exchange cases between design tasks and design to construction. Inframodel 4 (4.02) covers the following topics:

- Contextual information: exchange data set (file author, date...), project, coordinate systems, units, coding/classification systems in use;
- Source data (surfaces, breaklines, data points): geometric data and type codings (classifications);
- General roads, waterways and railways planning/design: alignment and surface model geometry and type codings;
- Road/street, railway and waterway design: design parameters, cross section, properties;
- Areal planning: landscaping, noise barriers, geo-structures;
- Water supply and sewerage: pipe networks with pipes, structures, connections and equipment;
- Planimetric features: fences, guard rails, light pole or signage footings.

The latest documentation can be found at: http://cic.vtt.fi/inframodel/.

Positioning

Data Kinds:

- Object Data: Inframodel (based on the LandXML schema v1.2)
- Representation Data: according to LandXML

Data Levels:

- Language: XSD
- Data Structure: Inframodel

Data Aspects:

- Content: Inframodel
- Format: XSD for Inframodel and XML for its data
- Access: unknown

SOSI [NO]

SOSI is a much used geospatial vector data format for predominantly used for exchange of geographical information in Norway.

SOSI is short for Samordnet Opplegg for Stedfestet Informasjon (literally "Coordinated Approach for Spatial Information", but more commonly expanded in English to Systematic Organization of Spatial Information).

The standard includes standardized definitions for geometry and topology, data quality, coordinate systems, attributes and metadata.

The open standard was developed by the Norwegian Mapping and Cadastre Authority. It was first published in 1987 (version 1.0). It is continuously being revised and further developed. The long term development points towards international standards (ISO 19100). This work is being done by ISO/TC211, currently chaired by Olaf Østensen with the Norwegian Mapping and Cadastre Authority.

The Norwegian SOSI-standard (general feature catalogue), is finally translated to English (mostly UK English) in version 4.0. It still have some names and definitions in Norwegian.

<u>Positioning</u>

Data Kinds:

- Object Data: SOSI models: many UMLs with concepts, properties and code lists on airports, buildings, roads, railways etc. (status: seems not yet finalized; many question marks in documents).
- Representation Data: geographical vector data, seems GML based but unclear in English version

Data Levels:

- Language: UML
- Data Structure: SOSI models

Data Aspects:

- Content: SOSI models
- Format: UML

Appendix D – Interview Details

D.1 Interview questionnaire

Following is the interview questionnaire circulated to interviewees a minimum of one day in advance of the scheduled interview.

General Notes

The interview did not last more than 1hr 30mins.

Introduction/Background

- In order to allow us to obtain as much information as possible from the interview we would like to record the conversation. Would you be willing to give us permission to record this interview?
- It is possible that we may use direct quotes from the interview in some of our reports or publications. Information from this interview may be used; however any such information or direct quotation taken from this interview will not be attributed to you.
- What is your (or your organisation's) scope in relation to road infrastructure?
- What is your background? (get a brief summary of the interviewee's areas of experience/expertise)
- What is the current status of BIM related to Asset Information in your country?
- What is the current status of BIM related to Asset Information in your organization?
- What type of organisations do you typically collaborate with on infrastructure projects?
- Which national or international standards for tools, information models or exchange formats do you use?

Open-Ended Questions (allowing for interaction/ discussion with interviewers)

- In your opinion, where is the most time/money wasted on issues related to data management?
- Walk us through a typical project, from inception/pre-planning stage right through to handover.
- What information is typically gathered at each stage?
- Can you describe the typical format of this information; is it in a 'digital' format which is BIM friendly? (Well structured, semantically rich?)
- If the information is computer readable:
- Is there a particular ontology used (Object-Type Library)?
- Is there a particular taxonomy used?
- What data exchange standards are used?
- What software is used?

- What is the level of detail?
- What is the level of information?
- What type of information is actually needed at each stage? Is there anything that is often difficult to obtain, which would be beneficial to and made more easily available through more rigorous information management processes?
- How do the information requirements change depending on the contract type used?
- How project-specific is this information? Do information requirements vary a lot depending on the nature of the project? If yes, could you provide some further detail?
- Are you aware of any notable similarities or differences in information requirements in different countries?
- Is there any standard used in your country which defines the information (and format of this information) that is required to be provided at handover stage of a road project.
- Do you envisage BIM approaches being accepted in practice? What can be done to ensure acceptance in practice?
- Could you suggest any relevant literature or sources of information which may be beneficial to our research?
- Any other comments or questions?

<u>Future Developments</u>

- Are there any plans for BIM in relation to Asset Information within the next 12 months?
- What is your (or your organisation's) vision for the next 5 years?
- Do you see any relevant developments in Information technology?
- Do you see any trends in Asset Management/BIM etc. that influence the information solutions?
- Do you have any additions to the questions asked or other remarks for INTERLINK to consider?

D.1 Interviewees

Refer to Table D.1 for a breakdown on the interviewees by country and by organisation type.

Table D.1 – Interviewee country and organisation type

Organisation Country	Consultant	Contractor	NRA	Software	Total
Austria	1				1
Belgium – Flanders			4		4
Denmark		1	2		3
Finland	1		4		5
France	1	1			2
Germany	3		2	1	6
Ireland	4		2		6
Netherlands	6	2	3	3	14
Norway	1		4	1	6
Sweden		3	7		10
UK	3	2	2		7
Total	**20**	**9**	**30**	**5**	**64**

Appendix E – Survey Details

E.1 Survey questionnaire

The survey questionnaire was divided into two sections. The first section consisted of five questions which relate to the identification of the surveyed parties, their roles/responsibilities and the organisation in which they work. The second section outlines 24 needs statements regarding information management during the life-cycle of road infrastructure. The survey questionnaire required that three questions are answered for each statement and the same questions, i.e. the same three questions were repeated for all 24 statements. An optional comments field is available for each statement and additional space is provided at the end of the survey to insert further relevant statements if necessary.

Introductory questions

The initial questions in the survey relate the role and organisation of the surveyed party. Questions 1 requires contact information to be insert and the following 4 questions have multiple choice answers including an option to select "other" with text entry to specify the appropriate answer. Each question included in the first section and their respective answers are as follows;

Could you please provide us with the following information?

- Name
- Company
- Address
- Address 2
- City/Town
- State/Province
- ZIP/Postal Code
- Country
- Email Address
- Phone Number

What type of organisation do you work for?

- Government body/Transport administration
- Contractor
- NGO
- Consultancy
- ICT
- Other (please specify)

Which of the following best describes your role?

- Consultant
- Contractor
- Asset Manager
- Project Manager
- ICT/Information Manager
- Business Developer
- Other (please specify)

During what asset life-cycle stages do you mostly work?

- Planning
- Design
- Construction
- Operation
- Maintenance
- Other (please specify)

With which asset types do you mostly work?

- Structures (e.g. bridge, tunnels, retaining walls, gantries etc.)
- Road Works (alignment, pavement, drainage, utilities, signage & road markings etc.
- Traffic & Intelligent Transport Systems (traffic controls, variable message signs, traffic counters etc.)
- Geotechnical
- Other (please specify)

<u>Repeated questions regarding each needs statement</u>

The survey required that three questions were answered for each statement. The three questions to be answered were the same for each statement and an addition text entry field is provided for further comments. The questions asked are as follows;

iv. What is your personal opinion on the above statement?
v. This is a documented priority of my organisation?
vi. Stage of implementation in my organisation?

Please provide examples and/or comments, especially if you do not agree with?

<u>Needs statements</u>

Listed below are the needs statements and their respective categories used in the survey.

Asset information systems

- Road asset information systems should be based on open information management standards.
- Asset information should be based on the same integrated information standards for all life-cycle stages, from strategic planning through to operation and maintenance.

Workflows

- Relevant asset information should be gathered and updated systematically over the life-cycle of an asset, from its inception through design, construction, inspection, maintenance, and renewal.
- At the outset of a project, asset owners / managers should define their information requirements for each asset type, using standards where possible.
- Owners of asset information should provide project / asset management partners with access to all information which is not considered business-sensitive.
- Asset information management should facilitate sharing of information on the internet.
- Owners of asset information should be able to provide write access selectively to project / asset management partners.
- Design checking, design approval and as-built approval should be conducted using object data with associated model data (e.g. 3D models).
- During a project, the compliance of exchanged data with the client's required data structures and data exchange standards should be checked using automated systems.
- Contractors should be required to handover to the asset owner a set of quality assured, certified as-built graphical and non-graphical information.

- Asset information should be specified for handover to asset owners / managers only where there is a clearly defined asset management value for such information.
- Asset information systems should enable access to information through GIS (geographical information systems)

Asset Attributes

- When exchanging asset data, the level of development and contractual status of the data should be clearly stated and defined.
- Non-graphical information (e.g. specifications, material test results) should be linked to defined objects
- An asset object should record the asset's performance, expected time to replacement, physical condition and maintenance history.
- Relevant cost information should be linked to asset information throughout an asset's life-cycle.
- Relevant risk management information should be linked to asset information throughout an asset's life-cycle.
- Road asset objects should include information about construction tolerance and as-built deviation.

Development of new standards

- Asset information standards should be flexible so they can be used at the national, organisation and project level.
- Standards for exchange and sharing of asset information should be built on established open web standards.
- Common European standards for information management of road infrastructure assets should be based in English, with the possibility to translate to other languages.

Implementation of new standards

- Asset information management should facilitate a gradual transition of existing asset information to smart information (semantically rich information)
- Implementation of new information management standards should be focussed on major projects first, and minor projects later.
- Implementation of new standards for road asset information management should be supported by change management processes, e.g. communication, training, guidance.

E.2 Overview of responses

Following the issue of the survey via email to 92 individuals, who were also asked to forward the survey to any of their contacts who they considered suitably experienced to contribute, a total of 53 responses were received. Upon closer examination, it was found that a small number of these responses were invalid as respondents had not proceeded beyond the first page and had not provided any answers to the survey questions of interest. After removing these responses, it was found that there were 49 valid responses which could be used in the analysis.

Of these 49 responses, it was found that 10 of the respondents did not complete the survey in full. However, their responses were retained for the portion of the survey which they had completed.

The information provided by respondents was examined in detail and a few minor amendments, outlined below, were made to allow the results to be appropriately analysed:

- Countries of respondents all changed to correct English spelling;
- Respondents in England and Northern Ireland categorised under the UK;
- Respondents from Belgium-Flanders and Germany-Saxony categorised under Belgium and Germany respectively;
- Where respondents from the same organisation chose different categories under their organisation type these were amended for consistency.

It was also noted that in several cases respondents had chosen multiple options when describing their role and organisation type. These were reviewed and left unchanged as they were all considered to appropriately fall under the headings chosen. Table E.1 provides an overview of the survey respondents.

Table E.1 – Overview of survey responses

Overview by Country		Overview by Organisation Type		Overview by Role	
Country	**No. of Responses**	**Organisation Type**	**No. of Responses**	**Role**	**No. of Responses**
Belgium	4	Gov Body / Transport Administration	30	Consultant	16
Denmark	2	Contractor	4	Project Manager	13
Finland	3	NGO	3	Asset Manager	15
Germany	6	Consultancy	15	ICT Information Manager	11
Ireland	2	ICT	6	Business Developer	4
The Netherlands	10			ICT Consultant	4
Norway	7			Contractor	4
Sweden	3				
UK	4				
Other	8				
Total	**49**	**Total**	**58***	**Total**	**67***

*Note that respondents were given the option of choosing multiple categories so these totals may exceed the total number of respondents.

E.3 Survey limitations

While the use of a survey provided a structured approach to test the validity of some of the business and data needs statements it is noted that there are a few limitations to the survey which should be considered when attempting to interpret the findings.

- Categorising the level of development into three discrete categories does not necessarily provide a full understanding of the level of development (e.g. many items may be considered 'in development' however these may not be developed to the same extent).

- Many countries had only one or two respondents making it difficult to confidently conclude that the responses from these countries were truly representative of the national situation rather than the specific opinion of the respondent(s) on a given statement.
- While it could be argued that the limitation of having very few respondents within certain categories may not provide statistically significant results, survey respondents were carefully identified based on their high levels of relevant experience and understanding of the delivery and asset management of road infrastructure. Hence, their opinions are highly regarded and are considered to constitute an accurate representation of the current situation.
- Many of the survey respondents selected multiple asset types when asked to indicate which assets they work with. This made it difficult to compare/contrast the relevance of statements across different asset types as the results tended not to vary a great deal.
- It is noted that the aim of the survey analysis was not to carry out a detailed statistical analysis of the responses, rather the use of the survey facilitated a structured approach to understanding the opinions of relevant stakeholders across Europe and to allow the statements to be prioritised based on their perceived relevance within the industry.
- While the numerical analysis of survey responses did not specifically allow respondents' views or opinions to be directly considered, the text responses provided by respondents were reviewed and closely considered alongside the numerical analysis of responses before drawing any conclusions.
- While every effort was made to reduce the length of the survey and to retain the attention of survey respondents, it is likely that the repetitive nature of answering the same questions on each successive statement may have led to survey fatigue or repetitive answers from respondents who lost concentration or did not consider the statements in great depth as the survey progressed. Reviewing the responses received did not show that this was an obvious trend, however it is noted that there may have been some influence of survey fatigue on the findings.

E.3 Survey statement ranking

Table E.2 provides a list of the 24 needs statements which were included in the survey along with a summary of the level of agreement and the conceptualisation matrix for each statement indicating the level of prioritisation and development as described in Section 3.5. The statements have been ranked using the approach also described in Section 3.5 with the rankings being shown in the second column. The final column in Table E.2 outlines the category under which each statement was grouped based on the ranking procedure. The relevance of the three categories, labelled A, B and C are outlined below:

A. Highly Relevant - Strongly Consider During Development of OTL
B. Stakeholder Engagement Required to Ensure Relevance
C. Consider and Justify Value/Relevance for OTL

The numbering shown in the first column of Table E.2 refers to the original order in which the statements were included in the survey. This numbering corresponds to the numbering of the statements in Section E.4 which provides a more detailed summary of the survey findings for each statement. It is noted however that this numbering does not correspond to that of the finalised needs statements provided in Appendix F which also include statements which were not incorporated in the survey. The numbering used herein has been retained in this appendix for ease of reference when comparing the numerical findings shown in Table E.2 to the discussion on each survey statement in Section E.4.

Table E.2 – Summary results of survey analysis, including ranking results

No.	Rank	Statement	Level of Agreement	Conceptualisation Matrix			Category
1	1	Road asset information systems should be based on open information management standards.	4.5	1	29	7	A
				3	2	0	
4	2	At the outset of a project, asset owners / managers should define their information requirements for each asset type, using standards where possible.	4.7	6	23	5	A
				3	1	0	
12	3	Asset information systems should enable access to information through GIS (geographical information systems)	4.5	2	22	10	A
				2	2	0	
3	4	Relevant asset information should be gathered and updated systematically over the life-cycle of an asset, from its inception through design, construction, inspection, maintenance, and renewal.	4.8	5	25	3	A
				5	1	0	
10	5	Contractors should be required to handover to the asset owner a set of quality assured, certified as-built graphical and non-graphical information.	4.6	4	21	6	A
				6	0	0	

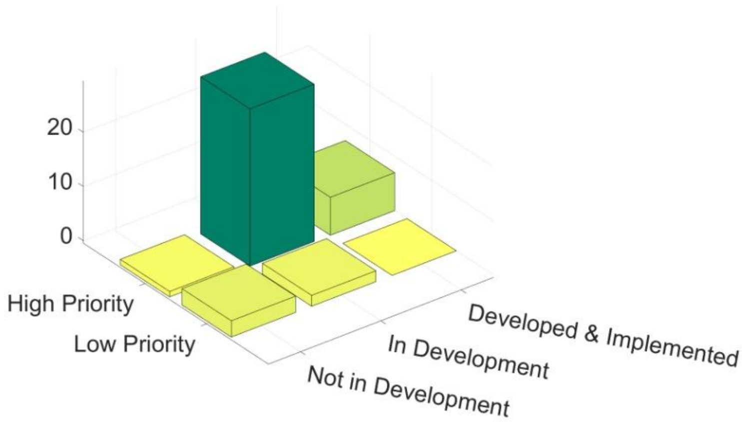
<table>
<tr><th>No.</th><th>Rank</th><th>Statement</th><th>Level of Agreement</th><th colspan="3">Conceptualisation Matrix</th><th>Category</th></tr>
<tr><td rowspan="2">14</td><td rowspan="2">6</td><td rowspan="2">Non-graphical information (e.g. specifications, material test results) should be linked to defined objects</td><td rowspan="2">4.5</td><td>1</td><td>22</td><td>6</td><td rowspan="2">A</td></tr>
<tr><td>8</td><td>0</td><td>0</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">7</td><td rowspan="2">Asset information should be based on the same integrated information standards for all life-cycle stages, from strategic planning through to operation and maintenance.</td><td rowspan="2">4.5</td><td>5</td><td>26</td><td>3</td><td rowspan="2">A</td></tr>
<tr><td>7</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">15</td><td rowspan="2">8</td><td rowspan="2">An asset object should record the asset's performance, expected time to replacement, physical condition and maintenance history.</td><td rowspan="2">4.4</td><td>3</td><td>18</td><td>4</td><td rowspan="2">A</td></tr>
<tr><td>8</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">13</td><td rowspan="2">9</td><td rowspan="2">When exchanging asset data, the level of development and contractual status of the data should be clearly stated and defined.</td><td rowspan="2">4.4</td><td>6</td><td>17</td><td>3</td><td rowspan="2">A</td></tr>
<tr><td>7</td><td>2</td><td>0</td></tr>
<tr><td rowspan="2">8</td><td rowspan="2">10</td><td rowspan="2">Design checking, design approval and as-built approval should be conducted using object data with associated model data (e.g. 3D models).</td><td rowspan="2">4.4</td><td>6</td><td>14</td><td>6</td><td rowspan="2">A</td></tr>
<tr><td>8</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">9</td><td rowspan="2">11</td><td rowspan="2">During a project, the compliance of exchanged data with the client's required data structures and data exchange standards should be checked using automated systems.</td><td rowspan="2">4.3</td><td>4</td><td>15</td><td>8</td><td rowspan="2">A</td></tr>
<tr><td>8</td><td>2</td><td>0</td></tr>
<tr><td rowspan="2">24</td><td rowspan="2">12</td><td rowspan="2">Implementation of new standards for road asset information management should be supported by change management processes, e.g. communication, training, guidance.</td><td rowspan="2">4.4</td><td>5</td><td>15</td><td>5</td><td rowspan="2">A</td></tr>
<tr><td>9</td><td>0</td><td>0</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">13</td><td rowspan="2">Owners of asset information should provide project / asset management partners with access to all information which is not considered business-sensitive.</td><td rowspan="2">4.4</td><td>2</td><td>16</td><td>5</td><td rowspan="2">B</td></tr>
<tr><td>10</td><td>2</td><td>0</td></tr>
<tr><td rowspan="2">20</td><td rowspan="2">14</td><td rowspan="2">Standards for exchange and sharing of asset information should be built on established open web standards.</td><td rowspan="2">4.3</td><td>3</td><td>16</td><td>3</td><td rowspan="2">B</td></tr>
<tr><td>9</td><td>0</td><td>0</td></tr>
<tr><td rowspan="2">19</td><td rowspan="2">15</td><td rowspan="2">Asset information standards should be flexible so they can be used at the national, organisation and project level.</td><td rowspan="2">4.5</td><td>5</td><td>15</td><td>2</td><td rowspan="2">B</td></tr>
<tr><td>10</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">7</td><td rowspan="2">16</td><td rowspan="2">Owners of asset information should be able to provide write access selectively to project / asset management partners.</td><td rowspan="2">4.1</td><td>2</td><td>15</td><td>2</td><td rowspan="2">B</td></tr>
<tr><td>14</td><td>1</td><td>0</td></tr>
</table>

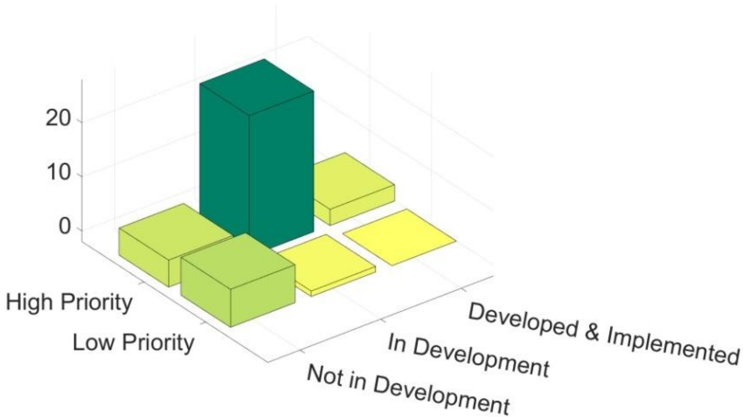
No.	Rank	Statement	Level of Agreement	Conceptualisation Matrix			Category
22	17	Asset information management should facilitate a gradual transition of existing asset information to smart information (semantically rich information)	4.2	3	14	0	B
				13	0	0	
6	18	Asset information management should facilitate sharing of information on the internet.	4.0	3	13	4	B
				13	2	0	
21	19	Common European standards for information management of road infrastructure assets should be based in English, with the possibility to translate to other languages.	4.2	5	9	2	B
				14	0	0	
16	20	Relevant cost information should be linked to asset information throughout an asset's life-cycle.	4.2	5	11	1	C
				16	1	0	
11*	21*	Asset information should be specified for handover to asset owners / managers only where there is a clearly defined asset management value for such information.	3.6	2	16	2	C
				13	0	0	
18	22	Road asset objects should include information about construction tolerance and as-built deviation.	4.0	5	10	2	C
				16	0	0	
17	23	Relevant risk management information should be linked to asset information throughout an asset's life-cycle.	4.0	8	7	2	C
				15	1	0	
23	24	Implementation of new information management standards should be focussed on major projects first, and minor projects later.	3.4	4	14	2	C
				12	0	0	

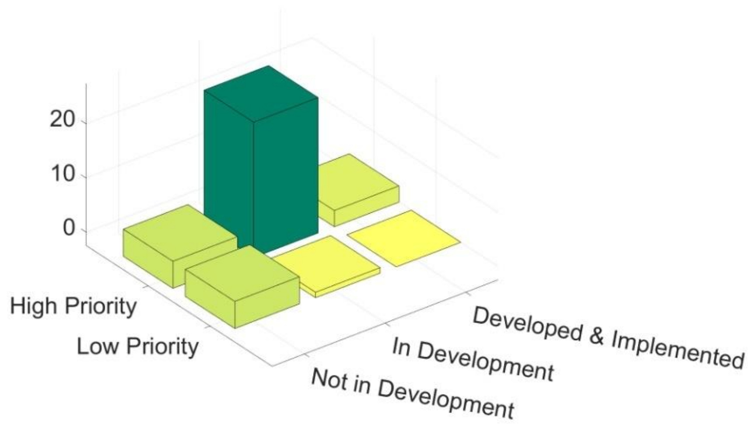
* Comment No. 11 (Rank 21) received a low level of agreement relative to other statements. It also received numerous comments from the survey respondents varying from strong support to strong disagreement. Based on the feedback and on further consideration by INTERLINK, the final statement was modified to:

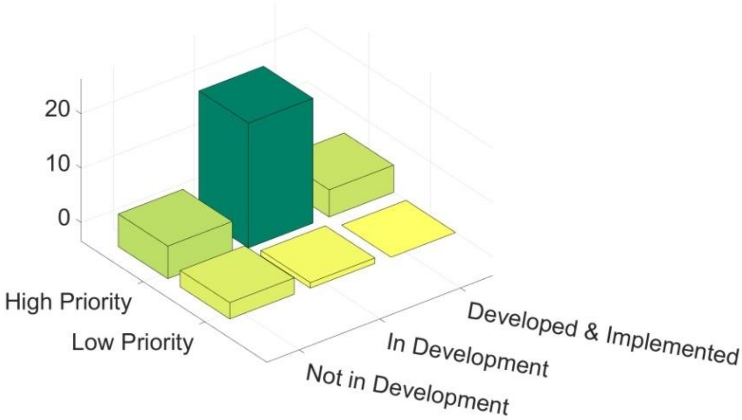
> *"Although the value of some as-built unstructured construction quality documentation (e.g. material test results, method statements) may not be apparent to asset managers at the time of handover, such data may present value in the future and should be linked through standardised objects."*

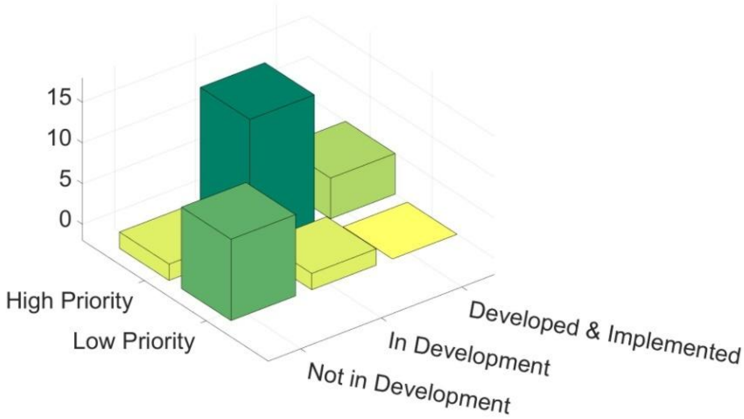
E.4 Discussion on each survey statement

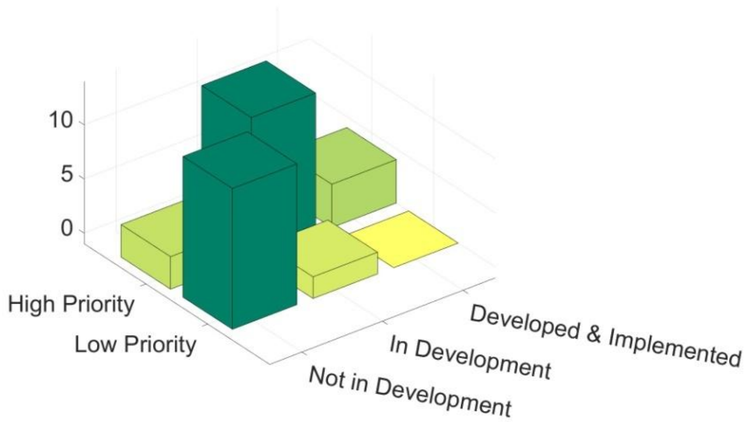
1.	**Road asset information systems should be based on open information management standards.**
Numerical Analysis	There is a high level of agreement amongst respondents (4.5) In the majority of cases it is either developed & implemented or else in development. Nothing of major interest to report across different categories of respondents/countries
Text Responses	In general, the text comments agree with this statement but it is noted that open standards do not necessarily need to mean free software. It is noted (Latvia) that the main obstacle is the administrative side associated with making asset management 'manageable'. There is mention of the use/implementation of standards: Germany: Use of OKLABI library to implement OKSTRA. Norway: Adoption of SOSI. Netherlands: Castor Asset Management system is based on open standards.
Figures	
Summary	There is a high level of agreement (4.5) and implementation.

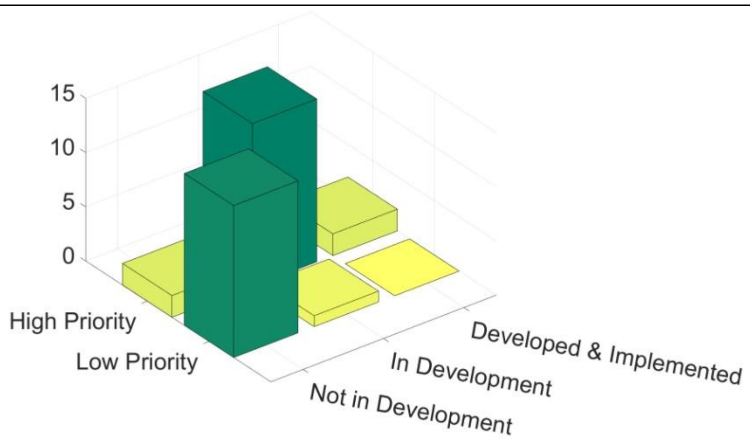
2.	**Asset information should be based on the same integrated information standards for all life-cycle stages, from strategic planning through to operation and maintenance.**
Numerical Analysis	There is a high level of agreement amongst respondents (4.5) In many cases, it is either developed & implemented or else in development. There are some cases where it is a low priority and not developed. Finnish respondents show much lower level of agreement than any other country or respondent (3.3 - based on 3 respondents), mainly influenced by one individual respondent who ranked it as a 2. Nothing else of particular interest to report.
Text Responses	It is noted that it may be necessary to use different standards at different stages as different levels of details will be required for different assets. Reference again in Latvia to administrative lack of targets, and in Norway (and the Netherlands) it is mentioned that organisational issues may stand in the way of making this feasible. Currently in Germany there are different object models used in the planning stage to the Asset Management stage and at present therefore the planning information cannot be carried through to Asset Management.
Figures	
Summary	High level of agreement (4.5) and implementation but some obstacles to implementation have been identified.

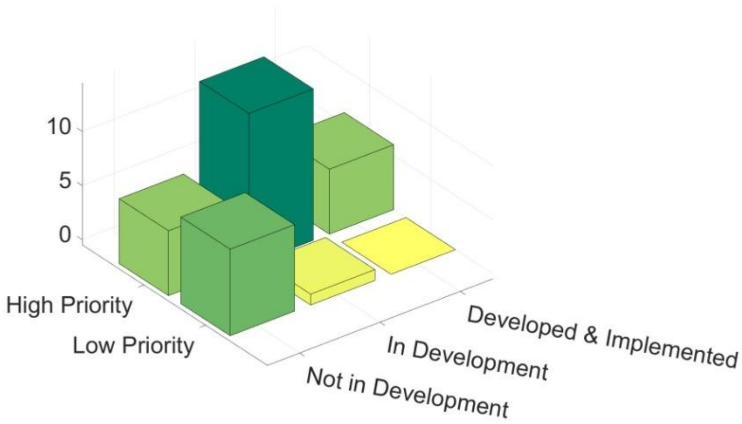
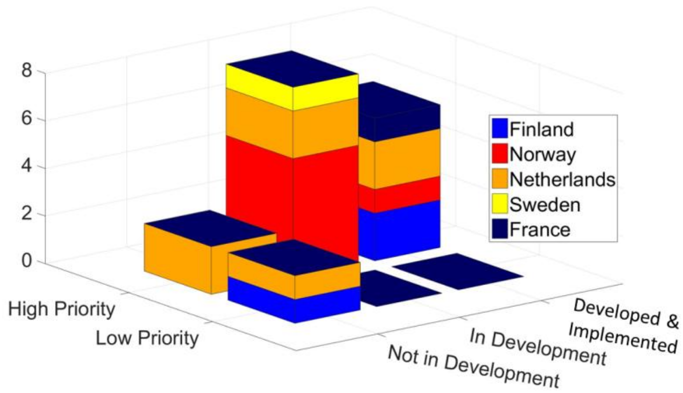
3.	**Relevant asset information should be <u>gathered and updated systematically over the life-cycle of an asset</u>, from its inception through design, construction, inspection, maintenance, and renewal.**
Numerical Analysis	General high level of agreement (4.8) with most respondents ranking it as a high priority (and in most cases, it is under development), in a number of cases it is not in development (but often still a high priority) Nothing else of major interest to report.
Text Responses	Not too many text comments on this statement but there is general agreement. It is highlighted that difficulties often arise when procuring new designers at different stages of design development (UK). It is noted that the Bridge Management System in Finland provides a mechanism for storing and using information from various phases (but the planning phase is not included at present).
Figures	
Summary	Very high level of agreement (4.8) and typically in development.

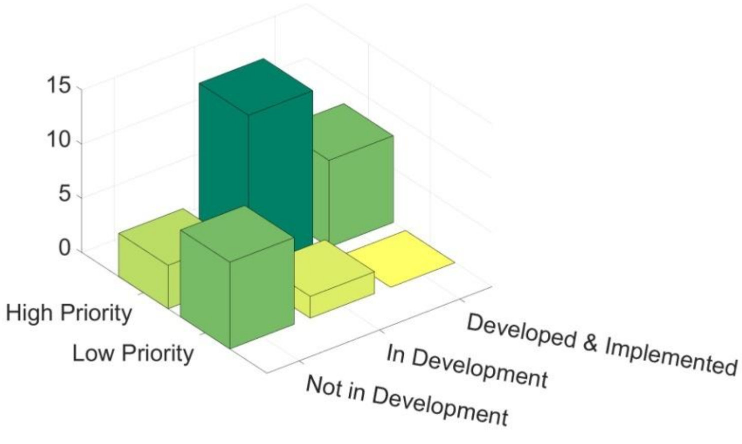
4.	**At the outset of a project, <u>asset owners / managers should define their information requirements</u> for each asset type, using standards where possible.**
Numerical Analysis	General high level of agreement (4.7) with most respondents ranking it as a high priority (in most cases it is under development or developed), in a number of cases it is not in development (but often still a high priority) Appears to be better developed for construction, maintenance and operation phases than for planning and design. Most developed in Finland, Netherlands & UK. Nothing else of major interest to report.
Text Responses	Not too many text comments on this statement but it is noted that "It is very important for asset owners/managers to manage and/or facilitate and support the process of establishing these standards in an efficient and effective way" It is noted that in Austria these requirements are well defined for structures and pavement and are in development for electromechanical equipment.
Figures	
Summary	High level of agreement (4.7) with reasonably high implementation/priority level. Probably most developed for structures and pavements (as these tend to be higher risk items for NRAs).

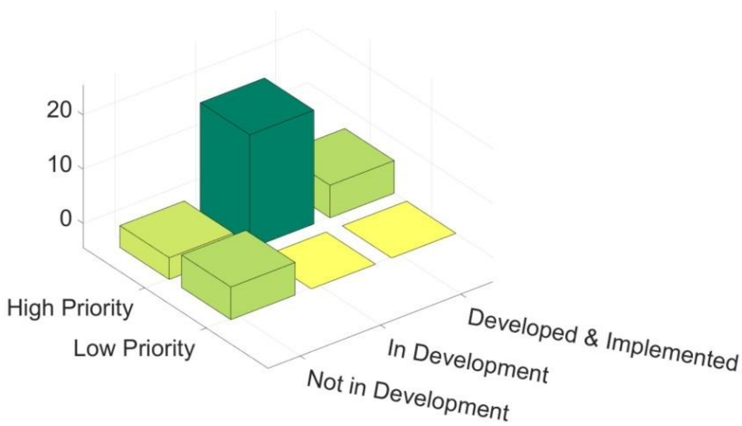
5.	**Owners of asset information should provide project / asset management partners with <u>access to all information which is not considered business-sensitive</u>.**
Numerical Analysis	General high level of agreement (4.4). Interesting to note large amount of low priority (& not developed) responses. Lower level of agreement (3.5) and prioritisation in the UK. Austrian respondent not in agreement (2).
Text Responses	The text comments on this statement express conflicting views with some respondents indicating that it is better to be open and provide access, whereas in other cases it is stated that "partners should only get the information needed for fulfilling their contract" It is noted that in Norway the NPRA have implemented a thin web client with direct access to the national road database. Entrepreneurs (Contractors?) have access to their road projects where they can deliver geodata and validate their deliverance during the road project. In Finland consultants are given limited access to the Bridge Management System.
Figures	
Summary	High level of agreement (4.4) but some conflicting views in the responses. There appears to be a split in the opinions of respondents and in the level of prioritisation/implementation.

6.	**Asset information management should facilitate <u>sharing of information on the internet</u>.**
Numerical Analysis	Reasonably high level of agreement (4.0). Austrian respondent not in agreement (2). Nothing major to report between different categories/countries, possible some indifference or lack of understanding of this statement.
Text Responses	There may have been some confusion around this statement. It is mentioned that the relevance of this statement depends on the scale and nature of the information. There appears to be general agreement in relation to sharing of information (to parties who require the information) but there are several concerns in relation to security and whether the internet is the best way to facilitate such data sharing. There is a Norwegian online database available "NVDB API - www.vegkart.no" Concern is raised in relation to the fact that there is (military-wise) sensitive information in relation to infrastructure assets and this should not be "totally free for all access" Others mention (Germany) that they are currently developing internet based asset management systems and a respondent from Finland states "The question of data securing is not completely solved. I'm not sure if I understood the question. On line access with passwords etc. is implemented and mobile versions of management systems is under development"
Figures	
Summary	Reasonably high level of agreement (4.0) but some conflicting views in the responses. People appear to be worried about security issues, and some of the respondents may have interpreted the statement as being related to open-access data on the internet (which some of the responses agree with). The level of implementation/prioritisation is also split (perhaps influenced by some misinterpretation of the statement).

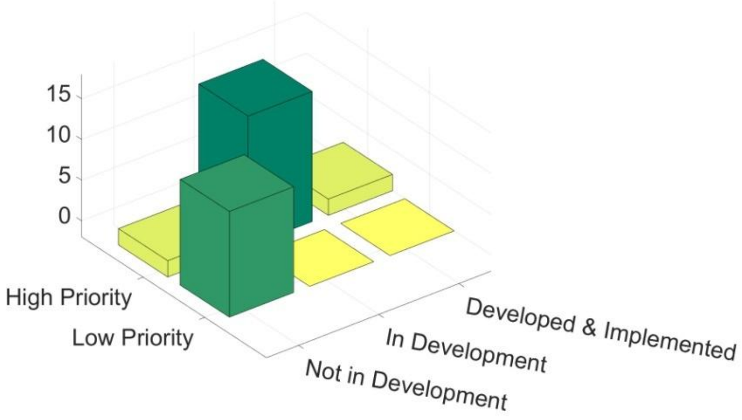
7.	**Owners of asset information should be able to <u>provide write access selectively</u> to project / asset management partners.**
Numerical Analysis	Reasonably high level of agreement (4.1). Austrian respondent not in agreement (2). In Germany (3.3), France (3.0) and Ireland (3.5) it is not much of a priority and less developed. The Irish example is interesting to note (i.e. This is developed in Eirspan, but neither of the Irish respondents were NRA staff so this statement was not developed in their own organisations).
Text Responses	It appears that it is a good idea "When working together in BIM environment this seems to be a prerequisite", however there is concern expressed in relation to quality assurance of data when providing write access. "Our systems have complex structures. I doubt that the quality of the data can be assured with external access." "Clear policy on data ownership needs to be in place with the ability to delegate and the controls required to enable this. (i.e. verification and validation)" "quality assurance is necessary, comprehensibility is necessary" "If no validation/control of data takes place asset information will be inadequate, because asset management partners have other objectives." It is noted that in Finland "Trained consultants and inspectors have write-access to our systems. Systems are of course backed up"
Figures	
Summary	Reasonably high level of agreement (4.1) but implementation appears not to be majorly advanced. Concerns raised over security and quality assurance.

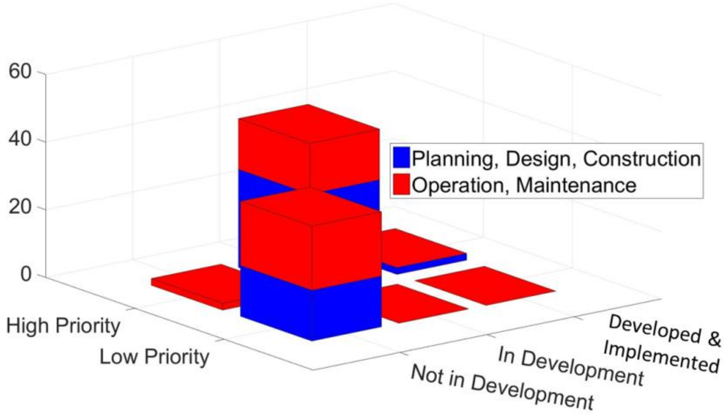
8.	**Design checking, design approval and as-built approval should be conducted using object data with associated model data (e.g. 3D models).**
Numerical Analysis	General high (4.4) level of agreement There is a good spread in the level of development in relation to this statement, in general it is a high priority. High level of development in Nordic countries, Netherlands and France (see figure).
Text Responses	There are not too many text comments but the comments provided do appear to provide general agreement with some respondents indicating that this is partially in development. One respondent from the Netherlands states that "Design check is of primary responsibility by contractor". A German respondent indicates "Our main focus are georeferenced road links and junctions. There is no need for a 3D-visualisation". It is noted that in Finland "The approval is still made on paper documents".
Figures	  <u>**Countries with higher level of implementation**</u>
Summary	High level of agreement (4.4) and prioritisation, with many examples of advanced implementation.

9.	**During a project, the <u>compliance</u> of exchanged data with the client's required data structures and data exchange standards should be <u>checked</u> using <u>automated</u> systems.**
Numerical Analysis	General high level of agreement (4.3). Typically, a high priority with a high level of development Lower levels of agreement (3-3.5) combined with low development in Cyprus, Ireland and Denmark (few respondents though). Contractors show lower level of agreement (3.3) than NRAs, Consultancies, NGOs, & ICT organisations (all 4.3 - 4.5).
Text Responses	The text responses indicate that there is agreement with this statement, and that in many cases it is already done (although some respondents indicate that this checking is often not done as it is such a time-consuming task). Some of the comments highlight the fact that quality assurance of data is still an issue that needs to be considered. "One issue is also check what is needed to be able to say if the design is good or bad. Technical validation of data is one corner of the overall design checking process and alone it's not enough." Germany: OKSTRA tools have been developed to do this. A Norwegian respondent states "We have a Client that automatically validates road data deliveries from entrepreneurs. This is done according to our feature catalogue in National road database. It saves a lot of time in the communication with the entrepreneurs during the Project phase. No more emails with file attachments back and forth". A Finnish respondent indicates that this is already done in road design.
Figures	
Summary	High level of agreement (4.3) and typically a high priority (with a few exceptions). There is a reasonably high level of development/implementation.

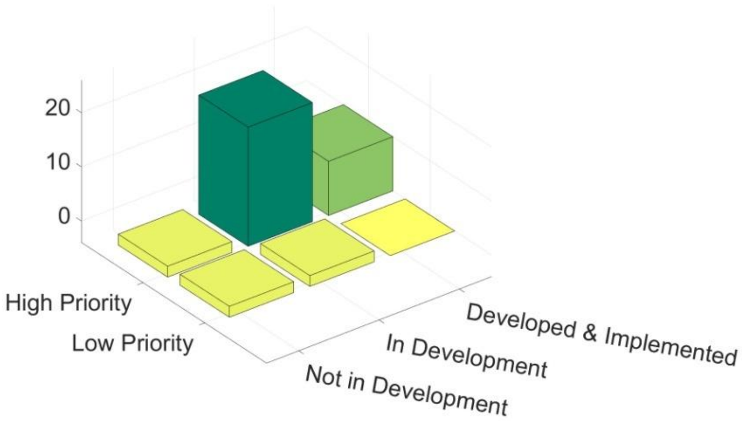
10.	**Contractors should be required to handover to the asset owner a set of <u>quality assured</u>, <u>certified</u> as-built graphical and non-graphical information.**
Numerical Analysis	There is a high level of agreement amongst respondents (4.6) and it is typically a high priority, with most either in development or developed and implemented. Danish respondent (3.0) shows lower level of agreement than others. Also, the level of agreement appears to be lowest amongst contractors (3.3).
Text Responses	Not too many text responses but it is noted that the certification aspect is questioned by the Netherlands respondents "Certification is not in the scope of development yet" & "Questionable whether it has to be certified." Interesting view from the Contractor's perspective (Netherlands) "I think at the start of each project the asset owners are supposed to handover quality assured, certified object information within the scope of the project first. If this information is not available yet, then only if it is assured that each contractor delivers the same (minimum) data/information quality the system can work. Another approach is to take the aspect of delivering the required quality of data/information out of the scope of competition".
Figures	
Summary	High level of agreement (4.6) with high priority/implementation level. Questions over the certification aspect (in the Netherlands) and Contractors agree least with this statement.

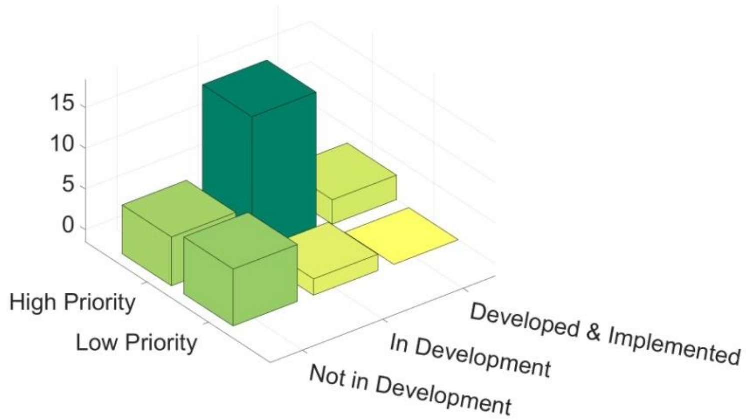
11.	**Asset information should be specified for handover to asset owners / managers only where there is a <u>clearly defined asset management value</u> for such information.**
Numerical Analysis	Relatively low level of agreement (3.6) compared to other statements, although it is still high priority in most cases, tending to be mostly in development. The Netherlands (3.2), Germany (2.8), Austria (2.0), Estonia (3.0) and Finland (2.0) show lowest levels of agreement. It is interesting to note the low level of agreement in the Netherlands even though two-thirds of the respondents indicated that it was a high priority and in development (or developed & implemented). It is interesting to note that the stage of implementation appears to be higher in the design/construction phases than for the operation and maintenance phases (see figure), with these phases also showing slightly higher levels of agreement.
Text Responses	There are conflicting views on this statement with some indicating that all information is valuable and that the value of some information is not known until a long time after it has been collected (and possibly analysed for trends). In general, the text responses indicate disagreement with this statement and there are some interesting points made (although in some cases the responses agree with the statement) "I disagree, the asset owner should get asset info, even if it is not specified" (research institute). "At present the future is unclear and thus the relevance of data and information often only becomes visible in time. Better safe than sorry." (research institute). "In practise lot of information is sent over without a clear view on where it is needed for. Therefore, relevant information is missed / cannot be found. Needle in the haystack problem". "How do you define the value of information?" "There are times where the value of information emerges over time - particularly in trend analysis and defect prediction. However, data should only be taken on by an organisation if there is a reasonable likelihood that it will deliver benefits." "All well-structured, consistent and reliable data/information may be specified for handover in my opinion." "I believe in uniform system of required minimum data. Extras should be required project-wise and room to store not formalized data for possible future use (point clouds, films etc.)"

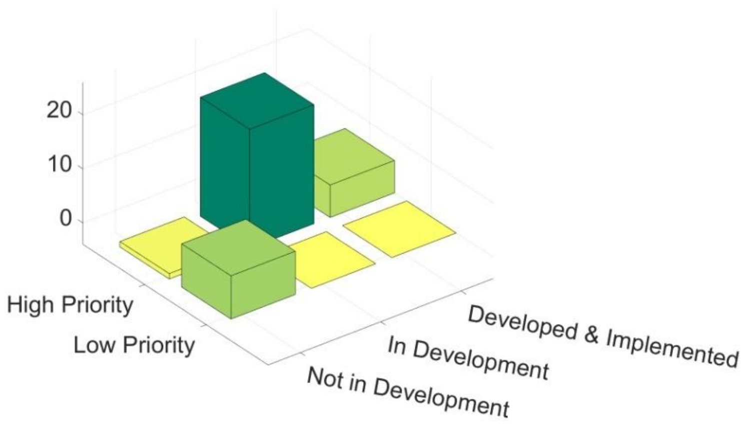
<table>
<tr><td>Figures</td><td>

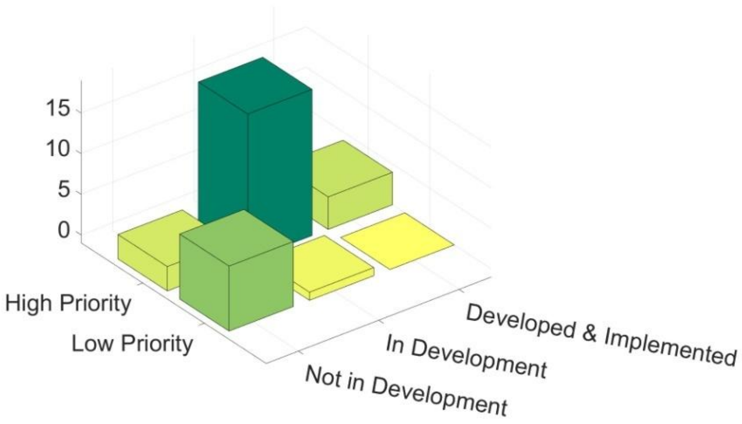


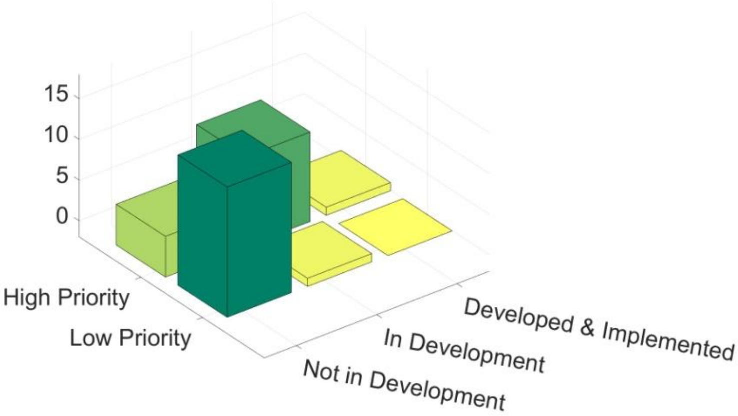
<u>Project Phases (Planning-Construction & Operation + Maintenance)</u></td></tr>
<tr><td>Summary</td><td>Relatively low level of agreement (3.6) compared to other statements, although it is still high priority in most cases, tending to be mostly in development. Some conflicting views on this statement, with many indicating that the value of information is often not known until after it has been collected.</td></tr>
</table>

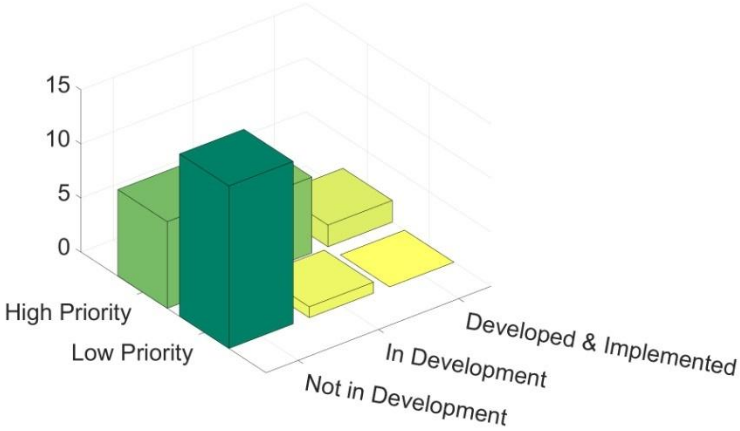
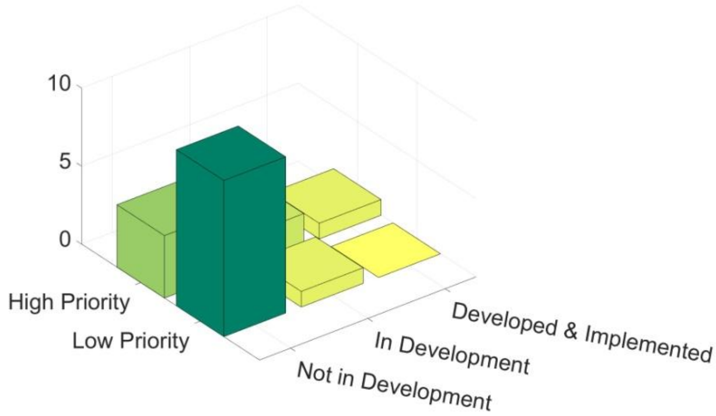
12.	**Asset information systems should enable <u>access to information through GIS</u> (geographical information systems).**
Numerical Analysis	General high (4.5) level of agreement and extremely high level of prioritisation and implementation.
Text Responses	Very few text responses on this statement, reference is made to the fact that "If the information doesn't have GIS data, it is no information at all." and the Norwegian (GIS based) database is again mentioned "www.vegkart.no".
Figures	
Summary	General high (4.5) level of agreement and extremely high level of prioritisation and implementation.

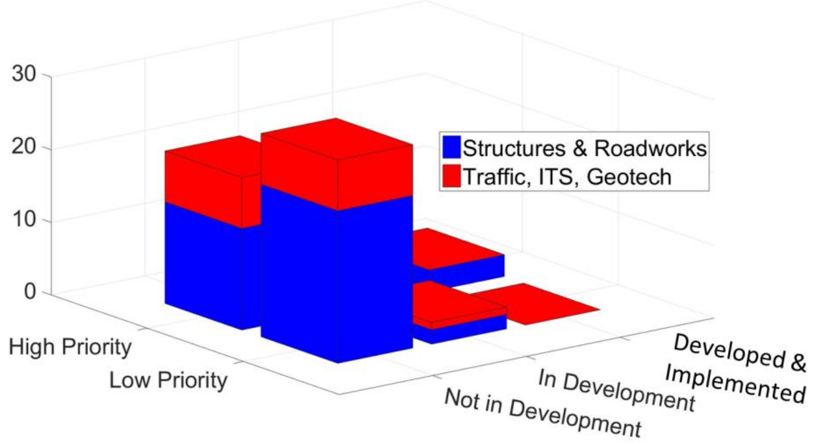
13.	**When exchanging asset data, the <u>level of development and contractual status of the data</u> should be clearly stated and defined.**
Numerical Analysis	General high (4.4) level of agreement, generally a high priority (but not always) and level of implementation is typically 'in development' but in more cases, it is not in development rather than developed and implemented. Lowest level of agreement/development (unsurprisingly) by NGO respondents.
Text Responses	Very few text responses on this. One respondent indicates that this is more important for construction projects rather than at the asset management stage, with another respondent highlighting that "This is a problem also with paper documents. The data used is not always correct (not the latest version etc.)"
Figures	
Summary	General high (4.4) level of agreement, generally a high priority (but not always). Level of implementation varies.

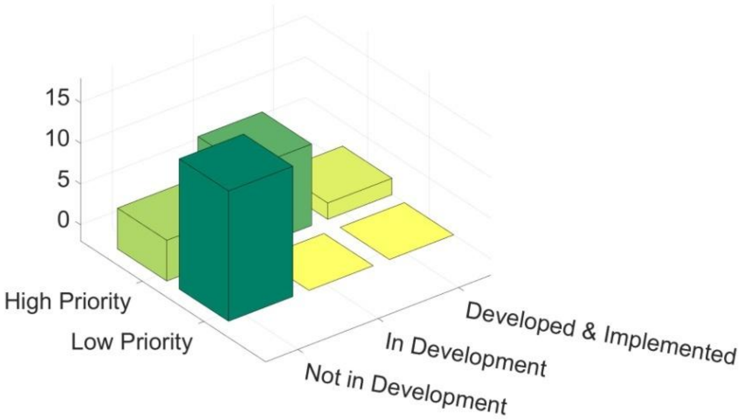
14.	**Non-graphical information (e.g. specifications, material test results) should be linked to defined objects.**
Numerical Analysis	There is a high level of agreement amongst respondents (4.5) with a reasonably high level of implementation. Ireland (3.5) shows the lowest level of agreement & prioritisation/implementation.
Text Responses	Very few text responses on this statement with one respondent from Norway indicating that this is already (technically) developed in Norway, but that the level of use varies.
Figures	
Summary	There is a high level of agreement amongst respondents (4.5) with a reasonably high level of implementation.

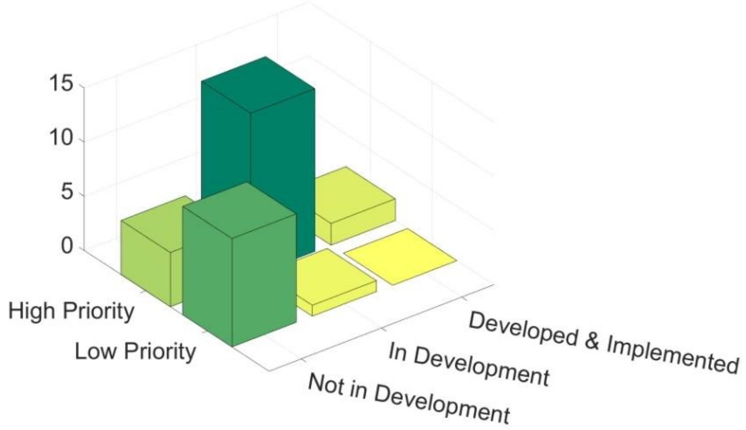
15.	**An asset object should record the asset's <u>performance, expected time to replacement, physical condition and maintenance history</u>.**
Numerical Analysis	There is a high level of agreement amongst respondents (4.4) and it is typically a high priority, generally being in development but in some cases implemented. Lowest level of agreement in Sweden (3.0) (only based on 1 No. respondent) despite being a high priority and in development.
Text Responses	Very few text responses on this statement with one respondent from Norway indicating that this is already (technically) developed in Norway, but that the level of use varies. There is general agreement with some indication that this is already used for bridges and that it is crucial for life-cycle assessment. One respondent notes that "There are a huge number of variables that will input into performance."
Figures	
Summary	There is a high level of agreement amongst respondents (4.4) and it is typically a high priority, generally being in development but in some cases implemented.

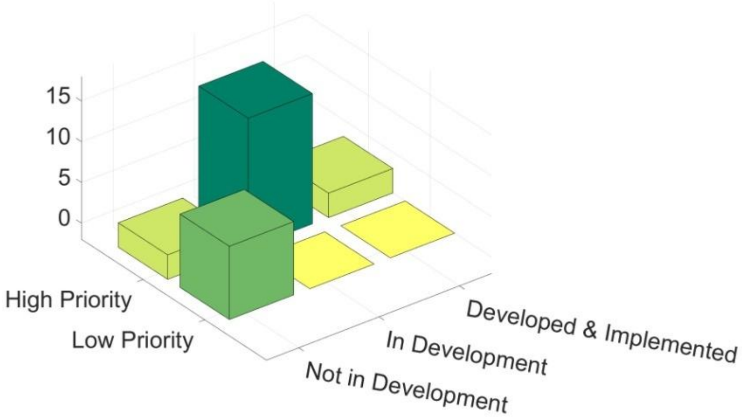
16.	**Relevant <u>cost information should be linked</u> to asset information throughout an asset's life-cycle.**
Numerical Analysis	Reasonably high level of agreement (4.2) but in most cases it is low priority and not in development. When it is a high priority, it is often still not in development, but in several cases, it is in development. No significant differences to report across categories.
Text Responses	The text responses to this statement tend to disagree with the statement, indicating that cost information is too dynamic, often unknown and generally dictated by items not directly related (traffic management, user delay, etc.). One respondent indicates that "Cost information should not be accessible by all asset related business processes."
Figures	
Summary	Reasonably high level of agreement (4.2) but in most cases, it is low priority and not in development.

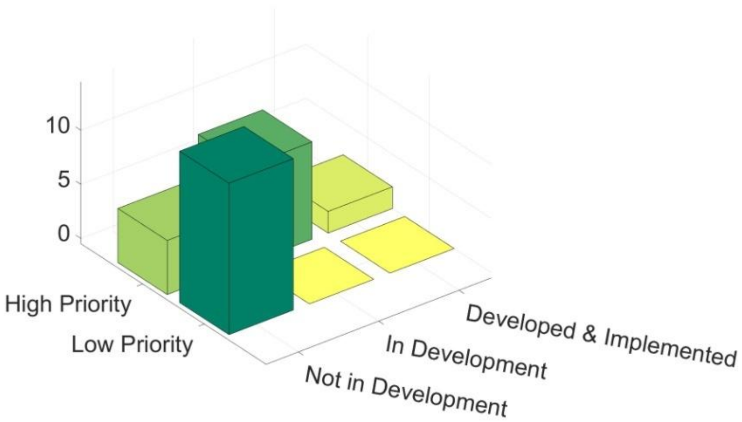
17.	**Relevant risk management information should be linked to asset information throughout an asset's life-cycle.**
Numerical Analysis	Reasonably high level of agreement (4.0) although it tends to not be in development (and in many cases not a high priority). Interesting to note that the level of development & prioritisation is low amongst NRAs (who you would expect to be most interested in the risk) - see figure. Interesting to note the relatively low (3.7) level of agreement by asset managers, who show the lowest agreement of all roles despite generally being a priority. It appears that this is more developed in relation to structures and roadworks than Intelligent Transportation Systems & Geotech (see figure).
Text Responses	Not too much input from text responses on this one. It is indicated that this information should be included in life cycle planning and it is also noted that this requires high level inputs throughout all stages. One respondent highlights the fact that "Risk management info is not needed for many business processes."
Figures	  **Government Body/Transport Administration**

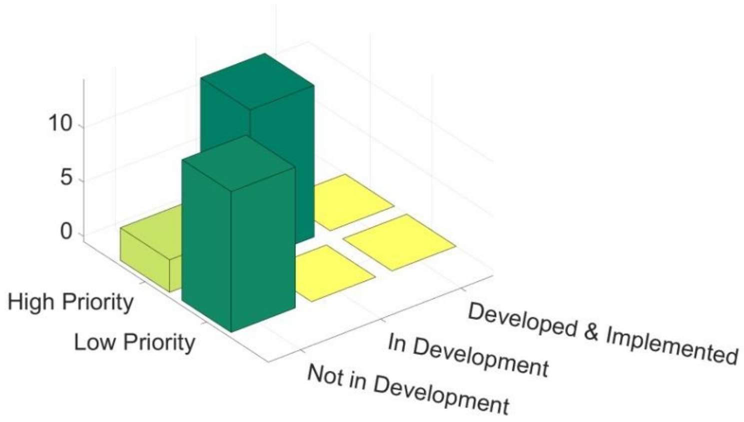
	 **<u>Asset Types: Structures & Roadworks vs. Traffic, Intelligent Transportation Systems & Geotech</u>**
Summary	Reasonably high level of agreement (4.0) although it tends to not be in development (and in many cases not a high priority).

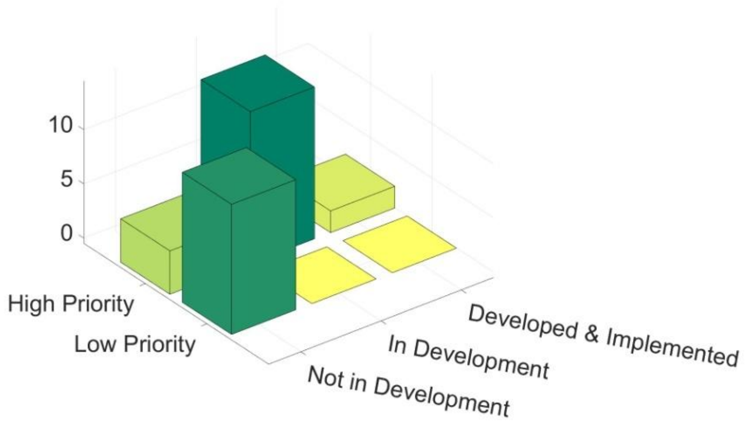
18.	**Road asset objects should include information about construction tolerance and as-built deviation.**
Numerical Analysis	Reasonably high level of agreement (4.0) although it tends to not be in development (and in many cases not a high priority). Low level of agreement in Belgium (2.5) and low level of priority & implementation
Text Responses	There are some conflicting views on this statement with some indicating that this information is essential and others indicating that as-built information does not need to be related to deviations from design as asset managers do not need/use such information - they are only concerned with the as-built information.
Figures	
Summary	Reasonably high level of agreement (4.0) although it tends to not be in development (and in many cases not a high priority).

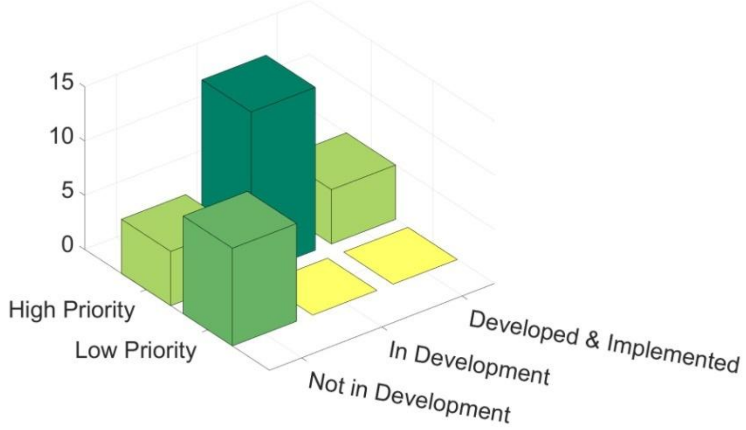
19.	**Asset information standards should be flexible so they can be used at the <u>national, organisation and project level</u>.**
Numerical Analysis	High level of agreement (4.5), generally a high priority and in many cases, it is in development or implemented. Lowest level of agreement in France (3.0 based on 1 No. respondent) with low priority and not implemented. Highest level of agreement by ICT/Information managers (4.9) & Business developers (5.0)
Text Responses	Not too many text responses on this one, with one of the responses indicating that "Exchanging flexible data isn't always easy. Fixed structures have their own advantages, because you know what you get." It is noted that "OKSTRA provides a facility called OKSTRA profiles to tailor its models to organization, project or use case specifics." and one other respondent states that "AI (*Asset Information*) standard should be there for organisational and project level"
Figures	
Summary	High level of agreement (4.5), generally a high priority and in many cases, it is in development or implemented.

20.	**Standards for exchange and sharing of asset information should be <u>built on established open web standards</u>.**
Numerical Analysis	Reasonably high level of agreement (4.3) High priority in the vast majority of cases and typically in development (in some cases implemented or not in development). In about one-third of cases it is not in development and not implemented Sweden (3.0) and France (3.0) show the lowest level of agreement although in the case of the Swedish respondent it is a high priority and in development.
Text Responses	Not too many text responses to this statement. A Norwegian respondent indicates "We have a long way to go, as we use SOSI, as a national open standard. We should move towards international open standards" One respondent states "Maybe today it is 'web' standards, but what about tomorrow. I think it suffices to define 'open standards'."
Figures	
Summary	Reasonably high level of agreement (4.3). High priority in the vast majority of cases and typically in development, with some exceptions.

21.	**<u>Common European standards</u> for information management of <u>road infrastructure assets</u> should be based <u>in English</u>, with the possibility to translate to other languages.**
Numerical Analysis	Reasonably high level of agreement (4.2) with a fairly even split between high and low priority, it is in development or implemented in about 35% of cases. Lowest levels of agreement in Germany (3.6), Sweden (3.0) and Luxembourg (2.0) with these countries typically indicating that it is low priority. Contractors showed the lowest level of agreement (3.7).
Text Responses	Test responses to this statement do not appear to indicate any strong opinions on the matter, with some saying that they should be created and translated at the beginning to avoid confusion and most others agreeing with the statement, but also mentioning that translations would be useful. It is noted that a German respondent has indicated that they currently only deal with standards written in German.
Figures	
Summary	Reasonably high level of agreement (4.2) with a fairly even split between high and low priority, it is in development or implemented in about 35% of cases. It seems that there is probably some level of indifference towards this statement.

22.	**Asset information management should facilitate a <u>gradual transition</u> of existing asset information <u>to smart information</u> (semantically rich information).**
Numerical Analysis	Reasonably high level of agreement (4.2) with two-thirds indicating it as a high priority (and typically in development). Low level of agreement (3.5) in the UK & Ireland and low priority/not in development. ICT/Information managers (4.7) are the most in agreement with this statement
Text Responses	There are a few text responses on this with two indicating that they did not understand the term "smart" or "semantically rich". One respondent indicates the transition should be step-wise rather than gradual, with another highlighting the scale of such a task with the vast amounts of information in existence. One respondent indicates that this should only be done where there is a business need/benefit.
Figures	
Summary	Reasonably high level of agreement (4.2) with two-thirds indicating it as a high priority (and typically in development), however in many cases it is a low priority.

23.	**Implementation of new information management standards should be focussed on <u>major projects first, and minor projects later</u>.**
Numerical Analysis	This statement has the lowest level of agreement of all (3.4) with almost two-thirds indicating that this was a high priority (and in many cases in development or implemented). The Netherlands indicated low level of agreement (3.0) despite it being a high priority and implemented or in development. Interestingly, Sweden showed a low level of agreement (2.0 based on 1 No. respondent) and that it was not in development and a low priority - this contradicts the interviews in which the Stockholm bypass (large project) was heavily BIM focussed. Low level of agreement in France (3.0), Ireland (3.5) and Latvia (2.0). Contractors not in agreement (2.0) and low priority/not in development. Generally lower levels of agreement across the board compared to other statements.
Text Responses	Quite a few opinions on this in the text responses which can generally be grouped as follows; (i) smaller projects are simpler and better for testing new things, (ii) could be either (need to assess risk of it going wrong on a large project) (iii) implementation should not be decided based on project size, rather suitability of the project. "In most cases, there is a lot of sub-contractors in large projects. Sub-contractors might be quite small. it's better to try to educate hole industry at the same. There is also possibility that client/owner offers some kind of support for small projects so that contractor/service producer doesn't need to by expensive software etc. "
Figures	
Summary	This statement has the lowest level of agreement of all (3.4) with almost two-thirds indicating that this was a high priority (and in many cases in development or implemented). Many opinions indicating some level of disagreement with this statement.

24.	**Implementation of new standards for road asset information management should be supported by <u>change management processes</u>, e.g. communication, training, guidance.**
Numerical Analysis	High level of agreement (4.4) with a high priority level and in many cases in development or implemented. Even in countries (e.g. Norway) where it is a low priority there is still a high level of agreement. Latvian respondent strongly disagrees with this statement (1.0).
Text Responses	There are a few text responses on this one, all in agreement, with some making suggestions: "The most important is to create asset management necessity from administrative point of view." "OKSTRA has a well-tested, simple and effective change management process." "Change management not only for technical issues is needed but specifically for people and working cultures. Change is not implemented by introduction of a new tool or system, it will need a different way of human operation" "E.g. RHDHV school of asset management" "To change it can best work when people also understand what is in for them and to change it has to be practical and visual. Show and do. Only abstract concepts doesn't move people to change."
Figures	
Summary	High level of agreement (4.4) with high priority level and in many cases in development or implemented.

Appendix F - Business and Data Needs Statements

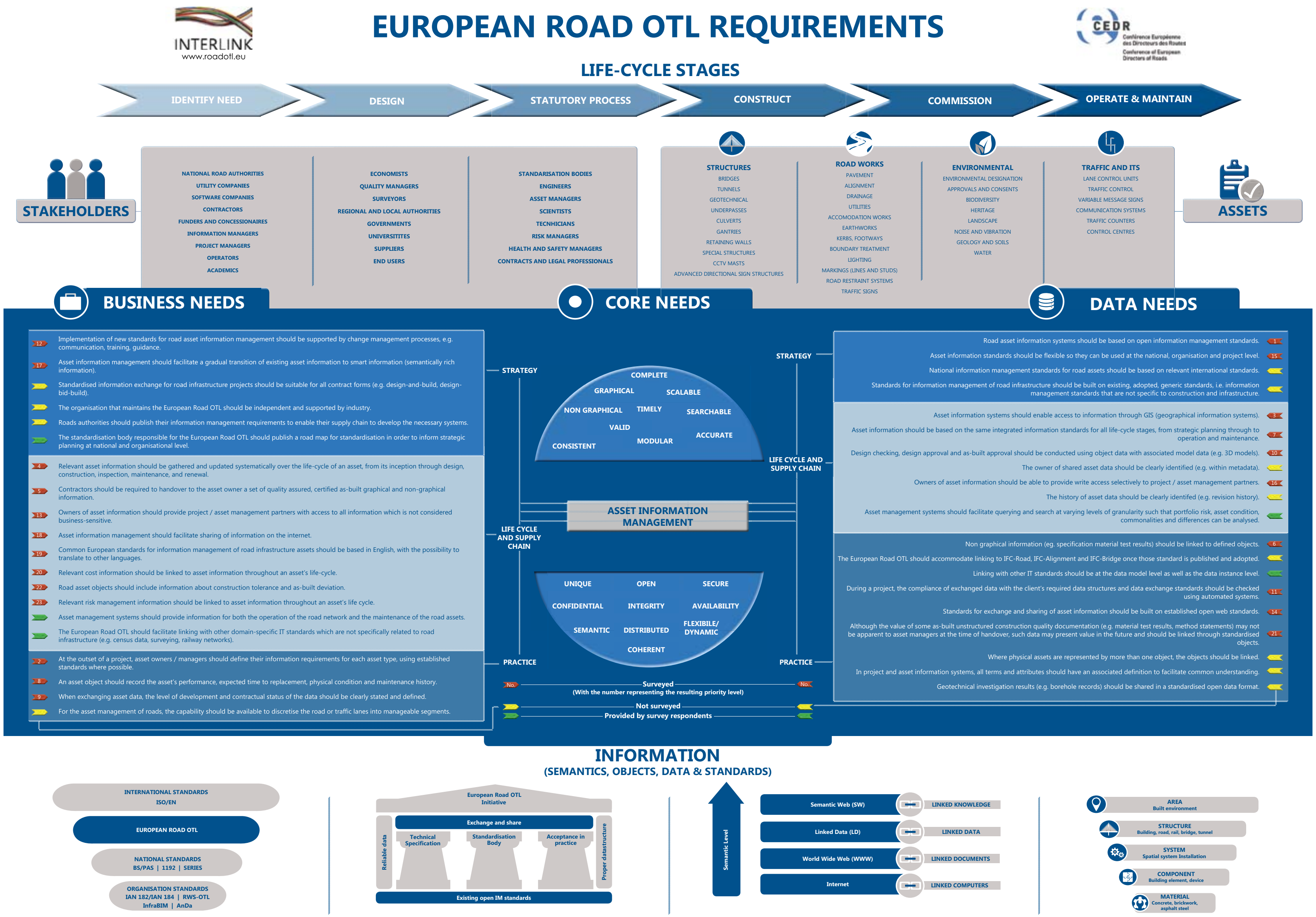


Figure F.1 - Business and data needs statements poster - refer to this link for a separate PDF