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Connected Data for Effective Collaboration (CoDEC)

CODEC summary report of findings from WP1.1 and WP1.2:

Literature Review and Stakeholder Engagement on Legacy Data and the Data Dictionary

Deliverable D1a

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CoDEC Deliverable D1a (Summary report of findings from WP1.1 and WP1.2)

Literature review and Stakeholder Engagement on Legacy Data and the Data Dictionary

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Author(s) this deliverable:

C V Geem, BRRC, Belgium

S Biswas, TRL, UK

J Proust, TRL, UK

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Executive Summary

The CODEC project

Building Information Modelling (BIM) can be considered an information management process for assets that support their management from concept to the end of life. The process is designed so that asset information can be generated, captured, maintained and used efficiently and effectively to optimise asset management. However, to date BIM processes have been focussed on the information gathered during the construction phase of the asset lifecycle and do not cater for the data requirements specifically for the operational phase. There is a gap in defining the information requirements for the operational phase, and in how to define/accommodate these across BIM systems. The CODEC project aims to provide a better understanding of how BIM principles could be practically applied, within the European highways industry, to manage asset data during the operational phase. In particular, the project aims to develop a specification that will support the building of connections between asset management systems and BIM platforms - to make best use of the legacy and sensor/scanner data. CoDEC will deliver a “Master Data Dictionary” for key infrastructure Assets that can form the base for the data structure for integration between different data management systems. CODEC therefore aims to free-up and enrich the data flow to and from BIM and asset management systems.

The research is divided in 6 Work Packages. Of these, Work Package 1 (WP1) has examined the aspect of legacy data and Work Package 2 (WP2) has examined the aspect of new data from sensors and scanning systems. In combination, WP1 and WP2 aim to develop a standardised specification for a “Data Dictionary” for three key infrastructure asset types.

This Deliverable

This report captures the findings from the WP1 literature review & stakeholder engagement on legacy data. The main objectives of this report are:

- To find out about asset data types that are being collected, managed and used for asset management across different NRAs for three key infrastructure asset types: Roads, Bridges and Tunnels.
- To understand how different authorities are integrating AMS data within BIM on these key asset types.

The information was gathered primarily through publicly available information and research publications, supplemented by information received directly from different NRAs via a stakeholder consultation. The review has given CoDEC an insight into the current situation within NRAs on their priority data types for managing Assets, and into their roadmaps for integrating AMS data with BIM. This will help CoDEC to establish a “Data Dictionary” containing relevant sets of data types for roads, bridges and tunnels.

Based on the findings of this report, a Data Dictionary will be developed, which will define the logical and hierarchical connection of the asset data and its meta data or attributes. Due to the scale of this project, CoDEC will develop the data dictionary on a sample of data types for each key asset type. The Data Dictionary will provide the list of data types and the connection to meta data or attributes for creating an Object Type Library (OTL) for the BIM platform.

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1 Introduction

1.1 The CODEC project

Building Information Modelling (BIM) can be considered an information management process for assets that support their management from concept to the end of life. The process is designed so that asset information can be generated, captured, maintained and used efficiently and effectively to optimise asset management. However, to date BIM processes have been focussed on the information gathered during the construction phase of the asset lifecycle and do not cater for the data requirements specifically for the operational phase. There is a gap in defining the information requirements for the operational phase, and in how to define/accommodate these across BIM systems. The CODEC project aims to provide a better understanding of how BIM principles could be practically applied, within the European highways industry, to manage asset data during the operational phase. In particular, the project aims to develop a specification that will support the building of connections between asset management systems and BIM platforms - to make best use of the legacy and sensor/scanner data. CoDEC will deliver a "Master Data Dictionary" for key infrastructure Assets that can form the base for the data structure for integration between different data management systems. CODEC therefore aims to free-up and enrich the data flow to and from BIM and asset management systems. The project's key objectives are to:

- Understand the current status of information management across the highways industry in Europe, and the risks and opportunities for the coming years
- Derive best practice guidance in the use of sensor/scanning technology to drive asset management, by investigating real examples of application to assets
- Demonstrate and develop practical methods for the implementation of BIM, by demonstration in real world use cases
- Provide recommendations to align the software industry with CEDR's objectives for BIM

1.2 CODEC Deliverable D1a

This deliverable has been developed under Work Package 1 of CODEC. WP1 has focussed on understanding the legacy data used by to NRAs for assets management and ultimately within the context of BIM requirements. Work Package 1 therefore aims to:

- Assess the current status of information management of legacy asset data across European NRAs using a mix of desktop research and consultation we will produce a report on current practices and identified gaps
- Develop a data dictionary for legacy data by a review of existing data dictionaries, and develop a specification for a data dictionary for legacy data for up to 4 key assets
- Provide direction to Work Package 3, which will undertake pilot projects, through alignment of the pilot projects with NRA requirements and practice.

This report focusses on the first two of these tasks.

1.3 CODEC Research Rationale

Currently, most NRAs use separate Asset Management Systems (AMS) to manage different types of infrastructure asset. Usually they have a well-defined process of data collection on different assets and well-defined process within AMS to use that data to manage these assets. These processes are well integrated within the NRA but works in silos for each asset type. This type of data is termed in this research as "Legacy Data". With the recent shift in the industry towards BIM to manage infrastructure assets, it has become paramount that the data held and used in AMS are connected and used in BIM platforms in an efficient way. Additional to this, with more drive towards the use of remote sensors and other new technologies (e.g. Satellite monitoring, LiDAR etc.) to monitor assets, there is an increasing amount of data which needs to be connected to both AMS and BIM.

The objective of this research is to enable systems to hold "one version of the truth"' (i.e. same data in different systems) and enable the exchange of data between different systems to help NRAs make more informed decisions about their assets.

Due to the nature of the broad categories of infrastructure assets and the vastness of the data on each asset, the scope of this research has been limited to three key asset types; roads, bridges and tunnels, and for a prioritised sub-set of data on each key type.

The first step of this research has been to understand the current situation within different NRAs with respect to their asset data management processes and BIM. CoDEC has carried out an extensive literature review on publicly available information supplemented by the information received directly from different NRAs, which is captured in this report.

The research will rationalise the information gathered at this stage and, with further direct engagement with NRAs, CoDEC, aims to develop a "Data Dictionary" on the key asset types for a subset of asset data. The Data Dictionary will then provide a structure to develop an Object Type Library (OTL) for the asset data to be included in BIM platforms. CoDEC will use the existing framework for OTL that is in use by NRAs, but extend that to include new object types if necessary. Building on this, CoDEC aims to create an Open Application Protocol Interface (OpenAPI) to connect the sata to BIM platforms. For practical purposes, CoDEC will use BEXEL Manager as its BIM Platform to demonstrate the connection and exchange of data from AMS to BIM system.

As outcomes of this research, CoDEC will provide a "Data Dictionary" on a set of data types on three key assets and an OpenAPI.

1.4 D1a Objectives, Methodology and Report Structure

1.4.1 *Objectives*

This scope of this report is to capture the current situation with regards to legacy data in three key asset types. The objective has been to understand:

- The types of legacy data in Asset Management Systems (AMS) and BIM across different NRAs.

- The availability and accessibility of legacy data from the current organisation of asset management.
- Any existing data dictionaries that are used by NRAs

1.4.2 *Methodology*

CoDEC followed a two stage processes to gain insight into the current situation on legacy data within NRAs:

- **Literature review**: a thorough desktop research was undertaken to gather information on legacy data from publicly available domain.

- ***Stakeholder Engagement****: CoDEC carried out two step processes to engage with NRAs; first through an online survey then through directly contacting the interested NRAs. Through this engagement process, three NRAs (Belgium, Finland and The Netherlands) confirmed to be the three Implementation Partner for CoDEC. A full detail report on the Stakeholder's engagement process is provided in Appendix A.*

1.4.3 Report *Structure*

The report content is structured in three main sections:

1. Legacy Data
2. Data Dictionary & OTL
3. AMS and BIM systems

Each section consists of further two main sub section on:

1. Outcome of the Literature review, and
2. Information received from NRAs.

The report is then concluded with a "Summary" section outlining how the findings of this report will be used in developing the "Data Dictionary".

2 Definitions

2.1 Legacy Data

Most NRAs have a well-defined process of asset data collection on different assets and well-integrated processes within the Organisation to use that data to manage their assets. These data are defined, maintained, managed and used in their AMS to manage infrastructure assets. These data are termed in this research as “Legacy Data”. Legacy data is firstly, the physical information about the asset itself and its various components, in terms of its geographical position and inventory information. It also includes conditional, constructional, maintenance and operational information on each component of the asset. Legacy data is the primary set of data on asset that has been in use for the purpose of asset management.

2.2 Asset Management Systems (AMS) and BIM System

An Asset Management System (AMS) is a system that holds information (data) about a specific asset and which allows users to analyse that data to make informed maintenance decisions. Each NRA has their own way of defining the data requirement within their AMS to suit their needs for maintenance. Often, each Asset type has its own AMS and does not allow interaction of data across different AMS.

Building Information Modelling (BIM) is the system of creating a digital model of a built asset. BIM facilitates the creation and sharing of information throughout the design, construction and operation phase of an asset. Creating a digital Model of the asset in BIM enables those who interact with the asset to optimize their actions, resulting in a greater whole life value for the asset.

2.3 Data Dictionary and Master Data Dictionary

ISO 23386:2020 defines a data dictionary as “a centralized repository of information about data such as meaning, relationships to other data, origin, usage and format”.

According to this definition, a property is defined not only by a name and a textual description but also by the entire set of related attributes permitting a seamless understanding of the property: for example, the link to a reference document, the data type, the possible value types, the dimensions, etc.

A road network can be seen as a complex system, subdivided in facilities (corridors with nodes and links), which are composed of entities (earthwork, carriageway, etc.) and their elements (the components of the entities). For each stage of the life cycle of an asset, different levels of detail are of interest. An Asset (Master) Data Dictionary is a data dictionary that describes (master) data about the assets, which includes a description of the physical elements of asset and their properties, associated asset data (condition, performance, etc.) and their properties, and the key relationships between all of these. A global asset data dictionary would have information on all assets and for each stage of their life cycle. The CoDEC Data Dictionary is concerned primarily with the data important for Asset Management (which focuses mainly on the “Operational Phase” of the asset lifecycle).

A data dictionary in the context of this research is a logical hierarchical system of data written in plain language (English) that gives the "logical" flow of the data (and metadata) to build "Data Queries" between Database Systems (e.g. between AMS and BIM). This is essentially based on the well-defined structure of legacy data within AMS. However, different NRAs tend to have different ways of defining data systems for their assets. For the purpose of standardising the data connectivity between different systems, it is essential to have a common data definition and hierarchical system structure. In this work the data dictionary aims to define a common data definition and data structure for three key assets, and for a set of chosen data types. The master data dictionary in the context of this work is the combined data dictionary for the three assets. There are three purposes of the Data Dictionary:

1. To provide the data structure to build Object Type Library (OTL)
2. To be understandable by Asset Managers
3. To be expandable in the future to incorporate other data types for a given asset.

2.4 Object Type Library (OTL)

Within the BIM environment, any single entity is called an "Object". In our case, the asset (e.g. Road, Bridge Tunnel) is an "Object", and so is each component within it (e.g. Lane, abutments, pillars etc) – in effect anything that needs to hold information (e.g. width of lane, depth of abutments, height of pillar etc) about any component of an asset. Within the BIM environment, each of the objects (hence each data) needs to be defined with standardised "Object names". An Object Type Library (OTL) is a library that hold object-types names and properties or specifications in a standardised format. An object is described with its object-type data and metadata - where metadata is data "about the data". Metadata are needed because each object type has its own properties. How the object types are grouped is called an ontology. The OTL can be linked to a data dictionary using the definitions of object-types. Within an OTL assets are described with the standardised language, syntax and semantics required for reliable information exchange.

An Object Type Library is a generic information model in which object types are organised in a structured way and in which they are described and defined. The object types in the information model are structured in such a way that they have a certain relationship with each other. An OTL can be linked to a data dictionary with the definitions of the object-types.

2.5 Ontology

Ontologies are a formal way to describe taxonomies and classification networks, essentially defining the structure of knowledge for various domains: the nouns representing classes of objects and the verbs representing relations between the objects. Ontologies resemble class hierarchies in object-oriented programming but there are several critical differences. Class hierarchies are meant to represent structures used in source code that evolve fairly slowly (typically monthly revisions) whereas ontologies are meant to represent information on the Internet and are expected to be evolving almost constantly. Similarly, ontologies are typically far more flexible as they are meant to represent information on the Internet coming from all sorts of heterogeneous data sources. Class hierarchies on the other hand are meant to be fairly static and rely on far less diverse and more structured sources of data such as corporate databases (reference: *Knublauch, Holger; Oberle, Daniel; Tetlow, Phil; Wallace, Evan (March 9, 2006).* *"A Semantic Web Primer for Object-Oriented Software Developers".* *https://en.wikipedia.org/wiki/W3C" \o "W3C Retrieved November 19, 2017*).

2.6 OWL

The Web Ontology Language (OWL) is a family of knowledge representation languages for authoring ontologies. The OWL languages are characterized by formal semantics. They are built upon the World Wide Web Consortium's (W3C) XML standard for objects called the Resource Description Framework (RDF) (reference: OWL 2 Web Ontology Language Document Overview (Second Edition)". *W3C*. 11 December 2012).

2.7 RDF

The Resource Description Framework (RDF) is a family of World Wide Web Consortium (W3C) specifications originally designed as a metadata data model. It is also used in knowledge management applications.

2.8 Knowledge management

Knowledge management (KM) is the process of creating, sharing, using and managing the knowledge and information of an organization. It refers to a multidisciplinary approach to achieving organisational objectives by making the best use of knowledge. Knowledge management is driving the adoption of tools that enable organisations to work at the semantic level.

3 Legacy data

Throughout Europe many NRA's have legacy data stored in separate databases that are governed by separate departments. Data are often stored separately and at different locations (at different divisions of an NRA). For instance, in many cases the NRAs have separate divisions for the management of bridges, tunnels and roads. Each division has its own approach to (maintenance) management of the asset it addresses, stores the asset data relevant and needed for that asset in a local database to which other divisions do not necessarily have access, and use their own specialised management software.

3.1 Literature Review

Although there is extensive literature on data, measurement techniques, asset management etc., the CODEC literature was specifically aimed at understanding the concept of legacy data within NRAs and how this might be addressed. There was very little publicly available information identified.

Highways England (HE, UK NRA) have developed and published an Asset Data Management Manual (ADMM) which sets out a common asset data format requirement for data registering and sharing between different stakeholders and systems. The ADMM sets out Highways England's asset data requirements to achieve both its corporate objectives as well as its asset management objectives. It brings clarity and consistency to reflect the asset data needs of HE and is revised every six months to accommodate changes and expansion to the business needs. The ADMM contains the Organisation's asset data requirements to ensure the company collects and maintains the asset data it needs to operate safely and efficiently. It is for use by anyone creating, maintaining or using data on behalf of or within Highways England.

ADMM contains recommendations on how to set the requirements for the handover of as-built data by a contractor to the NRA (cf. "DMRB Volume 0 Section 2 GG 182 General principles and scheme governance. General information. Major schemes: enabling handover into operation and maintenance - formerly IAN 182/14"). Further HE publications, identified via the INTERLINK project, include IAN 184/16 ("Instructions on naming conventions, file types and data structures for the delivery and transfer of CAD / BIM files to the Highways Agency and its supply chain") now replaced by GG 184 "Specification for the use of Computer Aided Design". In document GG 184, we find a definition for "metadata": "*Metadata is a set of data that describes and gives information about other data. It can help manage a file, such as when it was created and revised, file type and other technical information."*. These form major schemes containing Data & CAD Standard Instructions on naming conventions, file types and data structures for the delivery and transfer of CAD / BIM files to Highways England.

As a Collaborative project in the Seventh EU Framework Programme ROSANNE aimed to develop/harmonise measurement methods for skid resistance, noise emission and rolling resistance of road pavements as a preparation for standardization. This project identified a primary list of legacy data collected by different countries on pavements (such as Friction, texture etc), and the purpose of the data as acceptance criteria for newly built road surfaces or as monitoring tools for maintenance management (Table 1).

	acceptance		monitoring	
	Friction	**Texture**	**Friction**	**Texture**
France	-	X	X	X
United Kingdom	X (Scotland)	X	X	X
Germany	X	X (concrete)	X	-
Denmark	X	-	X	-
Spain	X	X	X	X
Slovenia	X	-	X	X
Portugal	X	X	X	X
Italy	-	-	-	-
Czech Republic	X	X	X	X
Sweden	X	X	-	X
Norway	-	-	-	-
Finland	-	-	-	-
Belgium	X	X	X	-
Netherlands	X	-	X	-
Austria	X	-	X	X
Switzerland	X	X	X	-
Hungary	X	-	X	-
Slovakia	X	-	X	-
Romania	X	-	-	-
Poland	X	-	X	-

Table 1: sample of legacy data on road (ROSANNE)

3.2 Information received from NRAs

The CODEC Stakeholder Engagement (See Appendix A) directly contacted NRAs to gather information on their legacy data. This approach was found more useful in gaining insight of their asset data collection and management processes than the literature review. NRAs were willing to share their internal documentation and information on processes, which are not publicly available. The following sections provide the details found from the following nine NRAs: *Belgium (Flanders and Wallonia) The Netherlands, Norway, Sweden, Denmark, Austria, Portugal and Lithuania.*

3.2.1 *Flanders (Belgium)*

The Flemish NRA (AWV) pavement management system (PMS) has its own database containing condition data (in a format for several indicators) and imports other data from several sources. The PMS is a stand-alone system. Bridge management is the responsibility of another division of AWV that manages the asset and condition data of bridges. The objective of AWV is that their OTL will eventually integrate all relevant asset data and that all data are migrated to the globally defined format. The objective is that in future there will be no need for maintaining any links between different data formats.

3.2.2 *Wallonia (Belgium)*

Currently the data are distributed over several databases and divisions. There is little communication between these databases.

For roads a database with a link to a GIS platform contains the geographical localisation and the results of road monitoring. It does not contain information about the road structure (layer materials, layer thicknesses, and age of each layer) and often these data are simply missing. For the road database, the access to the database is simplified by the semi-dynamic link between map and database. Everyone at the Walloon NRA (SPW) has access to the road database. In particular, the local teams that are responsible for the daily operational management of some small part of the road network, make use of the direct access to this database.

Another database exists for bridges and tunnels. This database does not have a link to a GIS platform. For tunnels, the database only contains the engineering part: the electronics equipment is not in the database. The bridge management team and those who have interest in the data on bridges have simple access to the database of inspection data.

Bridges are equipped with fixed sensors. The type and amount of sensors differs sensitively: every bridge is different. Currently the sensor data are only used for real-time monitoring. However, SPW is currently building a tool that will allow a centralised access to all sensor data of the bridge sensors. Even today, all data are stored and kept so there is a large amount of existing but largely unexploited historical sensor data.

The NRA has another system for sensors in tunnels: the MIDAS system. It is used for real-time monitoring, not for asset management.

The WIM installations on motorways are fixed sensors providing traffic load statistics. These are again a separate system, managed by the mobility division of SPW. Results of fixed traffic counting sensors are published and are publicly available on the website of SPW.

3.2.3 *The Netherlands*

In the Netherlands, the NRA (RWS) has large amount of legacy data but this is stored in a very distributed way. There are no data dictionaries for these old data structures. The existing data sets contain a large variety of very useful data for asset management.

Condition data for roads (ARAN data) are transformed and stored as indicator values (1 value per 100m road segment). Raw data are not kept for a long time. The indicator values are used in the PMS.

Condition data from sensors (in bridges, sluices, electro technical equipment, tunnels) are stored in several separate databases and software tools. There is an ongoing development for complete integration of these data in a unique storage system.

There is no common RWS approach on asset management. There are a number of different, dedicated systems such as the separate system for bridges, a separate system with maintenance information, etc. Historical data are very important and therefore developing new systems and shift the existing data to them is considered a challeneg. New systems often require new data types and new data formats. The NRA leans toward a linked-data approach to make communication between the old systems through scripts and AI-solutions that can access and analyse data from different systems and in different data dialects. Since the data must be kept for a very long time (several decades), RWS finds it more appropriate to store such data locally and to make them accessible as linked data.

Open data are available at the "dataregister" (https://geoservices.rijkswaterstaat.nl/apps/geonetwork-dataportaal/srv/dut/catalog.search#/search?topicCat=structure) and also on a GIS platform (https://geoservices.rijkswaterstaat.nl/portaal/). For instance, data on traffic are available on a map for about 4000 road segments. It reports the total number of vehicles in three classes (light vehicles, medium heavy vehicles and heavy vehicles), as yearly average, per day, at peak moments, on working days, on weekdays, during the night.

Not all data are disclosed as open data: some security issues are still discussed, for instance on some of the pavement condition data. In future, additional API's will further facilitate the access to the open data. In the case of DBFM contracts which thus include a part for maintenance, there is a contractual obligation for the exchange of (condition) data and the responsibility lies with the private partner.

The maintenance planning as a result of the asset management processes is presented to the decision makers (politicians), mostly in the form of a dashboard. This is a mostly 2D-GIS representation with very little 3D-data. The dashboard is created for the most part in a manual way in a rather time-consuming effort.

3.2.4 *Norway*

In Norway several relational databases with legacy data exist: the National Road Database (NVDB), "Brutus" for bridge asset information, and "Plania" for tunnels. They are all accessible through a UI (web viewer). Both "Brutus" and "Plania" have an API for data exchange with the National Road Database (NVDB).

3.2.5 *Sweden*

There is a National road database with similar data as in the Norwegian National road database (NVDB).

Road condition data collected with dedicated measuring vehicles are shared internal to the NRA and sometimes with external parties in particular contracts. Depending on the project data can be provided by specific logins in NRA's systems or some data can be exported. The same holds for bridge inspection data. This kind of data is exclusively used for asset management purposes.

Sharing condition or inspection data with contractors (e.g., for maintenance and repair) can be of use to the contractor for him to deploy appropriate equipment. Also for financial monitoring (costs and payments) can be done more efficiently when contractors update data on the AMS. The update of asset data by contractors who have performed a maintenance operation (and thus made "changes" to the assets) helps the NRA in later lifecycle management.

LiDAR is mainly used for characterization prior to designing and building new assets (e.g. roads). LiDAR is also in use mounted on railway vehicles, especially for scanning in tunnels. When the data is collected during the design process, it is not integrated with the AMS.

Sensors mounted on structures (bridges) are just used with low frequency (e.g., twice per year). This situation is similar for bridges on the road network and for railway bridges. There is a central AMS for bridges ("Batman"). Its database is separate from the road pavement AMS. The current ANDA project is trying to integrate BMS with PMS but is not yet fully in production. Currently the data is being used by the bridges and railway specialists. It is not shared.

Vehicle feet data from Volvo cars are presently used for assessment of skid problems during the winter and for corrective (winter) maintenance. These skid resistance data are stored but not shared for asset management.

The results from dedicated asset management systems is shared inside the NRA only and is used to make choices and prioritization.

3.2.6 *Denmark*

In Denmark a lot of legacy data exists but it is dispersed over different databases. There are different AMS for different assets. There are very separated, old systems: hardly any link between them. The data are usually not geometric data, there are also lots of drawings.

GIS-related systems (vejkort.vd.dk) are used for administrating the roads but not for asset management.

There is an asset register (where, what, names) for roads, which is an ordinary database, not a GIS. A new system for road referencing is being implemented and the announced precision for location data is +/- 2m. Historical data are considered important but there is an even greater need for more precise data.

Some of the existing systems are:

- Pavements: a local GIS-system called "Belægningsoptimering", where some data are kept as geographic components.
- Bridges: the system "Danbro" (and "Danbro+" for large bridges)
- Drainage: "DAS"
- Lighing: "Gridlight" and a local system called "vejlys"
- state registration: "VIMS"

There are few links between these separate systems. They contain drawings, various other data, and GIS systems. There is ongoing work to implement a new model for pipes and electricity based on arcgis.

The Danish NRA has a very elaborate system for pavement condition survey data. However, it is an old system and accumulates data using linear referencing. This is a separate system used for forecasting condition and for maintenance planning.

The Danish NRA was a very early adopter of bridge asset registers and has more than 30 years of data. Precision about the location for bridge data is much better than that for roads. A major detailed general assessment inspection takes place every six years. In between these inspections, there are many routine safety inspections and at least one overall inspection a year. Sometimes additional destructive testing is necessary. The information is loaded into the bridge asset management database. A bridge asset management report is produced yearly.

The directorate is looking to migrate its data to a new asset management system. Currently the NRA is looking to buy a new asset management system (one system that could manage everything especially bridges, pavements, etc.). Also, with the increasing use of BIM a new asset management system will have to accept data downloads and produce 3D detailed drawings (cf. “Highly relevant: Denmark’s asset management for bridges”, in Road Structures, July 12, 2019, https://www.worldhighways.com/wh10/feature/highly-relevant-denmarks-asset-management-bridges).

So far, at the Danish NRA the effort on BIM has been focused in the design and construction phases. Asset management and design are in different silos. The ISO standard is looked at for passing on the project information model to an asset information model. Designs are all 3D CAD models stored in an archive. The Asset Management team can access the CAD models but doesn't use them: currently no extraction of information is done from the design models for asset management purposes. It is considered to use an ArcGIS tool for this.

3.2.7 *Austria (Asfinag)*

Currently Asfinag have separate pavement (in-house), bridge (IMS) and tunnel management systems. This management specific data is not shared, but there is an initiative for trying to combine and use one GIS for overview of the network.

3.2.8 *Portugal*

Although different assets have different databases, the use of a common GIS platform facilitates the establishment of relationships between elements in different databases. Every user inside the NRA can have access to the database if it is related to their work.

Condition data collected on roads are only used for pavement management purposes. The data are accessible by people within the NRA. Occasionally they may also be shared with external entities in case of specific contracts. Every user inside the NRA can have direct access to the database if it is related to their work. Data is extracted and provided for external users working in specific contracts.

The same holds for inspection data collected on bridges: only used for bridge management, directly accessible to those within the NRA who need the data for their work, extracted and provided to external users in the frame of some specific contracts.

The situation is not different for data collected by fixed sensors.

There is a new project under implementation for opening the accessibility of specific data to the public (not all data). This will be supported in the GIS, with a limited number of layers.

The results of asset management processes are shared internally.

3.2.9 *Lithuania*

The Lithuanian NRA (LRA) has two different information systems. Both are integrated between one another but not with pavement management systems. The first system is the “Eismoinfo” system and contains open data accessible to all. It contains “operational data”: information about weather conditions, traffic restriction, traffic management data, camera data, average speed control and fixed speed camera locations, EV charging points, Road winter maintenance levels, road surface type, toll roads, vignette selling points, accident-prone road sections, road incidents (obstacles, traffic jams, etc.), objects for tourists, places to visit, rest area locations, AADT, noise maps, soil freeze depth, asphalt surface thermo-mapping zones.

The second system is the “Lithuanian State Road Information System” (LAKIS). It contains data about road network inventory, attribute information, information from contractors that provide construction data. There are several user interfaces (e.g. for public, for managers). The UI for the public contains the following data: road information, accidents, accident-prone locations, rest areas, AADT, bridges, pavement type, ITS (WIM locations, planned WIM locations, variable message signs, RWIS stations, CCTV locations, ANPR camera locations, traffic flow sensors, road lighting, average and fixed speed cameras, electrical supply boxes, traffic lights, EV charging stations, lighting with solar panels), road cadastral information, noise levels (day and night), road parameters (pavement type, road class, number of lanes, acceleration/deceleration lanes, intersections, road winter maintenance levels, AADT, etc.), obstacles above the road), etc. The UI for road managers contains additional data with condition data: rutting in both wheel paths, transverse and longitudinal cracking, grid-type cracking, ravelling, bitumen bleeding, IRI for both wheel paths, transverse and longitudinal gradients, friction, lane width, etc.

However, although the condition data are uploaded in this system the pavement management is done with the PMS software dTIMS that is not linked to the LAKIS system.

Another separate system exists for bridge data management. That database is currently maintained by the Transport Competency Agency. After introduction of new asset management system, the bridge management system will remain and will be integrated with the new asset management system.

Yet another important information system called “Keliu projektai” (Road projects) deals with the economic and financial aspects of the asset management. All information to this system is manually gathered by specialists and then uploaded. There is no integration with other systems.

4 Data Dictionary and Object Type Library (OTL)

4.1 Literature review

The Literature review on Data Dictionaries has again found little published information on their use by NRAs. As noted above, attempts have been made by Highways England via its Asset Data Management Manual (ADMM). Further, the Lithuanian NRA has a Lithuanian State Road Information System (LAKIS). However, in general, the system of data management is very much customised to individual AMS within NRAs and not much work has been carried out on creating a standardised “Data Dictionary” for any asset type.

However, there has been quite a lot of work undertaken on the OTL aspect industry wise and individually by different NRAs due to the recent drive towards BIM implementation on infrastructure projects. The review found some NRAs have made advances towards standardising data format and data sharing in terms of Industry Foundation Classes (IFC), but the focus of that has mainly been on data needed for construction and less so for legacy data supporting asset management.

The study also found that most of the time “Data Dictionary” and “OTL” are referred to or understood as being one and the same by most NRAs in the context of BIM. However, we do distinguish a “data dictionary” from an “OTL”.

A data dictionary is a structured list of descriptive information about data () in plain language (easily readable by humans). Its main purpose is to set out a common language to describe data.

An OTL is the unambiguous description of built environment concepts, a library with standardised object-types names (e.g. road, viaduct) and properties or specifications. An OTL is a ‘translation’ of a data dictionary to an explicitly machine-readable format. In an OTL, the links/relationships between datasets are more rigorously structured and are explicitly linked by some mechanism (e.g.: hyperlinks), and each entry is given its own unique reference, structured according to a defined ontology. The OTL can refer to a data dictionary as its basis, however this is not a requirement: an OTL can be built without separating out the data dictionary part. In some cases, NRA’s developed and published an OTL but did not explicitly publish a data dictionary. In those cases, the OTL contains in a non-explicit way the information expected from a corresponding data dictionary. Inversely, a data dictionary may exist and be published without the development of the corresponding OTL.

Most NRA’s do not have a separately published data dictionary. Some data dictionaries were identified (England, Lithuania, Norway, Sweden, Germany) as well as other sources containing similar information (France, Australia/New Zealand). In other countries, there are no data dictionaries as such, but the NRA’s may have developed (or are developing) their OTL (The Netherlands, Flanders, Finland). Most OTL’s or data dictionaries include roads, bridges and tunnels. For bridges, we identified additional documents: definitions of terminology specifically related to bridges, a classification of bridges, information about bridge management systems, and information about inspection and testing approaches. For tunnels, we identified a classification of tunnels.

The list and reference of the legacy data dictionary developed for roads, bridges and tunnels across NRAs is shown in **Error! Reference source not found.** below.

The following sections provide further details on the Data Dictionary and OTL status within selected countries.

Asset Type	Description
Road	• Lithuania data dictionary • Highways England data dictionary (UK-ADMMv10_Part_3_Data_Dictionary_FINAL_20191024.xlsx) • German data dictionary OKSTRAData standard (Australia/New Zealand): Austroads Publication No. AP-T334-18, June 2018Norway National Road Database (NVDB) https://www.vegvesen.no/fag/teknologi/nasjonal+vegdatabank/datakatalogen • Swedish National Road Database: http://www.nvdb.se/en • OTL of Flemish NRA “AWV”
Bridges	• Glossary of bridge terms (http://www.iabmas.org) • Data standard (Australia/New Zealand): Austroads Publication No. AP-T334-18, June 2018 • Classification of types of bridges in article “Identification and Classification of European Bridge and Tunnel Types” by the authors Ingo Kaundinya and Frank Heimbecher, presented at: 35th Annual Symposium of IABSE / 52nd Annual Symposium of IASS / 6th International Conference on Space Structures, London, September 2011 • COST action 1406 – report of WG5 • German data dictionary OKSTRA • Highways England data dictionary (UK-ADMMv10_Part_3_Data_Dictionary_FINAL_20191024.xlsx) • OTL of Flemish NRA “AWV”
Tunnels	• Classification of 5 main types of tunnels in article “Identification and Classification of European Bridge and Tunnel Types” by the authors Ingo Kaundinya and Frank Heimbecher, presented at: 35th Annual Symposium of IABSE / 52nd Annual Symposium of IASS / 6th International Conference on Space Structures, London, September 2011 • German data dictionary OKSTRA • Data standard (Australia/New Zealand): Austroads Publication No. AP-T334-18, June 2018 • OTL of Flemish NRA “AWV”

Table 2: List of Data Dictionaries and OTLs developed in different countries

4.1.1 *France (the MINnD project)*

The French national project MINnD made a report in 2015 where they discussed different key elements for the introduction of BIM in the whole life-cycle of assets. They addressed who are the stakeholders, what are the processes, which stakeholder needs which data for each of the processes and who is supposed to provide these data, which tools are currently in use (e.g. GIS, dedicated databases) and for which activity in the life-cycle a support by BIM is useful. In the report we also find quite detailed data dictionaries, even if the authors say that they are not to be considered as exhaustive.

For instance, for roads they listed the macro-processes in the life-cycle of a road: opportunity, design, construction, the annual cycle of monitoring, diagnosis, programming and maintenance, and the final dismantling, completed by a few processes that are running in parallel: evolution of the transport plan, change of category or function, etc.. For each of these, they identified sub-processes, each of which are executed by a unique profession. For examples, the construction of a road has two sub-processes: organisation of the works and execution of the works. The stakeholder associated to these sub-processes is for both the road constructor. The document then lists a number of subtasks for the road constructor per sub-processes and then looks for the data. For instance, one of the data the constructor must receive for the execution of the works is the “order to start the works” that has to arrive at the road constructor and must be issued by the road manager or road operator.

The intention of the authors was to contribute to the development of IFC and in particular to the new parts that address a specific asset (IFC road, IFC bridge). The report considers BIM as in “building information modelling” where the 3D-model takes a central position. They conclude therefore that BIM is mainly of interest in the design phase, during the construction of new assets and for the delivery of an as-built model, whereas for the management and maintenance of roads during the exploitation phase the 3D-model is not so useful.

The International Association for Bridge Maintenance and Safety (IABMAS, http://www.iabmas.org/) made a “glossary of bridge terms”. This is a dictionary of terminology in English and French related to bridges.

4.1.2 *UK/England*

The CEDR Technical report 2017-05 “Utilising BIM for NRAs” states mentions that the UK BIM Strategy is based on the following hypothesis: “Government as a client can derive significant improvements in cost, value and carbon performance through the use of open sharable asset information”. Highways England is adopting the UK BIM Government Strategy for the delivery of assets through life cycle information from planning through design, construction and operation. It was supported in implementing this supported by the UK BIM Task group (2011-2017).

The Centre for Digital Built Britain (CDBB) is a UK government-funded body, established in partnership with Cambridge University in 2017 and the successor of the UK BIM Task group. The Digital Built Britain strategy expanded the remit beyond BIM to include other digital processes and technologies, including new contractual frameworks, open data standards, data analytics and big data. The government initiative concerns the whole building sector and its implementation is now at the stage of Level 3 BIM, working toward BIM for the whole Life-cycle of infrastructure and buildings.

4.1.3 *Germany*

In Germany, there is the OKSTRA (Objekt katalog für das Straßen- und Verkehrswesen) project (http://www.okstra.de/forschung/linked-data_EN.html). The object catalogue OKSTRA is a collection of objects with attributes and relations in the range of roads and traffic. The initiative is led by BASt.

Within the framework of this project, the data exchange standard OKSTRA for the description of road data, defined in XMI, was converted into a representation based on the Ontology Web Language (OWL). This means that Semantic Web methods and techniques are now also available for OKSTRA data sets. In particular, the Linked Data approach makes it possible to link data sets with other schemata or domains. This can be done by using the SPARQL query language for the integrative analysis of the data of various ontologies.

As shown in case studies, data from the Dutch road ontology CB-NL/OTL-RWS can be retrieved and analysed together with OKSTRA data. This makes a range of cross-border application scenarios possible, such as the planning of heavy load transports.

For the conversion of OKSTRA into okstraOWL, a multitude of different mapping options were available, the respective advantages and disadvantages of which were studied and reported. Certain characteristics of the OKSTRA standard, such as the Fachbedeutungslisten (technical definition tables), make mapping more complex, but in principle a conversion that preserves the semantic structures is possible.

The consistent use of description frameworks (RDF) and query languages (SPARQL) for both schema and instance data across all subject models represents a significant advantage over other approaches such as programming interfaces (APIs, web services, etc.).

Although Linked Data functionalities using the okstraOWL are now available in principle, it became apparent in the course of the project (especially when working with real data sets) that the real challenge in linking different ontologies lies in the different semantic structure and granularity of the different data models. Methods of semi-automatic matching based on textual matches are also of limited help here. Instead, the user of the query mechanisms needs to have detailed knowledge of the semantics and structure of the ontologies involved and must create implicit or manual links based on this, the design of the query and the result they wish to achieve.

The OKSTRA project concluded that despite the availability of Semantic Web and Linked Data technologies, the consistent, possibly pan-European use of street information databases therefore requires a fundamental harmonisation of data structures, especially with regard to their semantic structure and granularity.

4.1.4 *Australia and New Zealand*

A data standard was defined and published by Austroads for use in Australia and New Zealand (Austroads Publication No. AP-T334-18, June 2018) and has the look of a data dictionary. Indeed, the introduction to this data standard states that it provides road agencies and their suppliers, in Australia and New Zealand, with a specification for the data that supports common operational activities. Furthermore, it also provides road network funding agencies with a specification to inform structure of reports and submissions requested from road agencies, to enable more equitable evidence-based investment decision making. Specifically, the Standard establishes a common understanding of the meaning or semantics of the data, to ensure appropriate use and interpretation of the data by its stakeholders. The document also recognises various levels of sophistication in inventory and asset planning practice and provides relevant data item details in this regard. The Standard includes roads, bridges, tunnels and other assets.

The data standard contains descriptions for inventory data for a large number of assets (among which, roads, bridges and tunnels) and for condition data. For roads, these include condition data for road characteristics obtained by measurement devices on vehicles such as cracking, roughness, rut depth, skid resistance and deflections). In case there are different ways of inspection, the data standard foresees a field for storing the type of measurement device (e.g. Benkelman beam, Falling Weight Deflectometer or Traffic Speed Deflectometer for deflection measurements on roads). For bridges, the data standard describes “condition states” of different levels, as decided upon from visual inspections by a bridge inspector.

The data standard includes a number of data descriptions related to asset management: how to report on the current performance of the assets (“condition”), data for information about traffic data (“demand” and “utilisation”), a representation of the importance of the assets (“criticality”), “risks”, “resilience” (vulnerability to a loss of quality or serviceability of an asset), “performance” (technical levels of service as derived from condition measurements), financial performance (financial level of service), customer level of service, accessibility, and works and costs (related to maintenance operations).

4.2 Information received from NRAs

As part of the Stakeholder Engagement (See Appendix A), NRAs were directly contacted to find more details of any the Data Dictionary and OTL they may have developed within their Organisation. NRAs were willing to share their internal documentations and information of processes that are not publicly available. Following section will provide the details found from the following nine NRAs: Highways England (UK), Lithuania, Belgium (Flanders and Wallonia) The Netherlands, Norway, Sweden, Denmark, Austria, Finland and Portugal.

4.2.1 *England (UK)*

The Asset Data Management Manual (ADMM) sets out Highways England’s asset data requirements to achieve both its corporate objectives as well as its asset management objectives. It brings clarity and consistency to reflect the asset data needs of HE and is revised every six months to accommodate changes and expansion to the business needs.

The ADMM contains the Organisation’s asset data requirements to ensure the company collects and maintains the asset data it needs to operate safely and efficiently. It is for use by anyone creating, maintaining or using data on behalf of or within Highways England. It is composed of three documents, among which a data dictionary. The data dictionary defines the structure and rules for individual assets and attributes. It consists of a set of large listings.

4.2.2 *Lithuania*

The Lithuanian NRA (LRA) has two different information systems. Both are integrated between one another but not with pavement management systems. The first system is the "Eismoinfo" system and contains open data accessible to all. It contains "operational data". The second system is the "Lithuanian State Road Information System" (LAKIS). It contains data about road network inventory, attribute information, information from contractors that provide construction data. For LAKIS a data dictionary is published in a document with the title "Rules for the Provision of Road Data of Lithuanian State Importance" and used for the introduction of additional data to the existing database. Some example of the data specification of qualitative road surface indicators is shown in Appendix B.

4.2.3 *Flanders (Belgium)*

There is no data dictionary as such. The "vocabularia" contain listings of objects and data information in plain language. The relations and types of these data are defined in the "implementation models". Both the vocabularia and the implementation models are freely available to all on a website:

- The AWV Vocabularia, can be found at https://wegenenverkeer.data.vlaanderen.be/#Vocabularia .
- Their implementation models (publically available at https://wegenenverkeer.data.vlaanderen.be/#Implementatiemodellen

Together they contain the information one would expect to be in a data dictionary.

The vocabularia (and the OTL) describe many notions that allow building a model of the assets related to carriageways (e.g. layers in a pavement, road markings) and equipment (e.g. traffic lights, traffic sign). It also includes objects related to data collection (e.g. test of roughness, test of skid resistance, condition of a tree, test on a traffic sign after placement), at different levels of abstraction.

The gradual official publication of the extension of the vocabularia and OTL to bridges and tunnels is expected in the forthcoming months: these are currently in a final test phase, where the descriptions and specifications are already used for a few BIM models of tunnels.

Currently the skid resistance is only considered for the acceptance of newly built pavement layers. It is not yet extended to the application of regular monitoring of existing pavement sections for pavement maintenance purposes. The skid resistance data collected during the regular monitoring programme for the whole road network is stored in a separate database and is not (yet) disclosed through the data dictionary and OTL. Sample of this data is shown in Appendix B.

4.2.4 *Wallonia (Belgium)*

There exist instructions for the access to the databases currently in use but there are no data dictionaries or descriptions of the data and their format. For the fixed sensors (mainly on bridges and tunnels), the data format is almost unique for each sensor, so it seems impossible to make a standard format for those

4.2.5 *The Netherlands*

The CB-NL (Concepten-Bibliotheek NL) is an initiative that involves the modelling of national infrastructure assets in the Netherlands. As the INTERLINK Deliverable D2-D3 explains, 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. The BIR "Bouw Informatie Raad" (Building Information Council, The Netherlands) developed COINS (Construction Objects and the INtegration of Processes and Systems). COINS is a Dutch standard for the exchange of BIM information for the whole building industry. It provides a data exchange format by means of a container for BIM related data/information. The RWS-OTL is an fairly large 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'). There is no real data dictionary but the information is hidden in the RWS-OTL.

4.2.6 *Norway*

The Norwegian NRA makes use of an OTL for their "National Road Database" (NVDB). This Object Type Library is based on ISO TC211. This is quite developed with a User Interface (UI) consisting of a Web viewer and Web editor, and a Application Programming Interface (Open REST API) consisting of an API Viewer and an API editor. The API are integrated with other systems for data exchange using file formats GML and SOSI.
For bridges, the ontology (OTL) is in implementation phase based on Linked Data/Semantic Web technology. It makes use of the RDF technology. The OTL is based on the Norwegian handbook for bridge classification: V440. The current ontology is accessible (in Norwegian) at http://rdf.vegdata.no/V440/ (ontology server) and http://rdfspatial.vegdata.no:7200/ (SparQL endpoint). The data dictionary of the "National road database" (NVDB) is available at: https://www.vegvesen.no/fag/teknologi/nasjonal+vegdatabank/datakatalogen. The data directory defines which subject data can be entered into the NVDB, it can be viewed as a detailed content register for NVDB. The Data Directory defines road object types.

4.2.7 *Sweden*

For the "National road database"(http://www.nvdb.se/en) similar to one in Norway (but it does not have tunnel and bridge data) there exists a data dictionary.

Also for asset condition data there are no data dictionaries.

There is no data dictionary for the data that are the outcome of the dedicated asset management systems.

4.2.8 *Portugal*

There is a common dictionary for the assets inside the organization as used in the different databases, but there is no data dictionary.

For all data that are stored in the different databases, there is no data dictionary. People have access to the databases and can consult the data. Data can be selected and partially exported for sharing with external parties in the frame of particular contracts but there is no standard description in the form of a data dictionary.

4.2.9 *Finland*

In the INTERLINK deliverable D2-D3 the National BIM data formats and classification systems, such as InfraModel are mentioned. The report explains that there was a large R&D project called InfraFINBIM in 2010, giving rise to the InfraModel. The work was continued under buildingSMART Finland.

The Common InfraBIM Requirements cover the entire life cycle of an infrastructure project: initial material, different phases of design, construction, as-built documentation and, in the future, operation and maintenance as well.

The InfraBIM classifications form a common ground for assets including roads, bridges and tunnels - but much more.

Inframodel is an open method for the exchange of infrastructure information. It is based on the LandXML-standard. The initial version includes parts for terrain models, subsoil surfaces, road and rail geometries and construction layers. It also covers water sewage and supply and some facilities. Inframodel documentation explains the Finnish method for using LandXML. Inframodel does not gather all the elements in LandXML. On the other hand some Inframodel specific extensions have been added. The most important of these is the Infra classification system. Inframodel is the exchange format required by the Finnish Traffic Agency and major cities since May 1st 2014. An online version of the specification is available at http://buildingsmart.fi/infra/inframodel/index.html.

In the INTERLINK deliverable D2-D3, 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). In Finland consultants are given limited access to the Bridge Management System.

4.2.10 *Denmark*

In Denmark there are no data dictionaries for the assets. There is an initiative at the IT-division of the Danish NRA where they look at establishing an information modelling system based on ULM and short descriptions. They concentrate on the design of the data model with an emphasis on strengthening the data delivery between areas.

For CAD files are organised with a layer standard, there is a national standard for classifying these. A (Level Of Development) LOD-DK designer’s guide is defined and published (https://biminfra.dk/wp-content/uploads/2020/02/Discipline-Model-Specification.pdf). The objective of the standard and the guide is to make it possible to share files. When a 3D design of assets in CAD files is asked for, the contractor requirements impose the use of the layer standard. In that respect, BIM is mandatory for contractors, with demanded ICT specifications but mainly focused on 3D design in CAD files with layered structure.

For bridges, an effort is done with first projects where 3D models are created from images, mostly for new constructions, new assets. Also a project is ongoing for the import of a large amount of data on pipes (assumed utilities, buried piping).

The BIM effort at DRD focusses on the design and construction phases and hence on project information models. The objective is to strengthen the project information models and the data associated to the models. They plan to deliver object information by 2022, looking at ISO standards for project information models and asset information models.

There is a high need for a method to structure data (on different assets) in a common way. A lot of thought on how to structure data in the new asset management system (one common system for roads, bridges and more), taking into account the currently available data and future possibilities.

A collaboration with Danish railroads is set up in order to define common models. There is also some collaboration between the Nordic countries with the goal to have similar data definitions.

The CoClass classification system, CCS ("construction sector system", Denmark) that is based on ISO standards, is proposed for the definition of the data.

The Danish NRA has not used EurOTL although the modelling and linking guide of Interlink is considered as a possible help.

5 Asset Management Systems & BIM

Most NRAs who have started using BIM did not immediately develop the use of BIM beyond the reporting of the “as-built” situation after a project, especially not for the long-term asset maintenance management. Consequently, the existing data dictionaries and OTL’s address the design, construction and “as-built” reporting phases but not (yet) the asset management phase. Asset management tools (PMS, BMS) have their own databases and function independently even if they use data that are available in existing asset inventory databases and other external databases (e.g. for traffic data). Only a few NRA’s[1] wish to connect BIM and AM systems so that their asset data management system also integrates asset management throughout the whole life-cycle of the assets.

The typical ingredients for asset management are independent of the asset type. Whatever asset has to be managed and maintained, the manager must have an inventory of the network asset elements. The manager must also express the expectations of stakeholders about the asset. These expectations can be expressed in functional and technical indicators: a functional indicator expresses the expectations about the function or service delivered to stakeholders, whereas a technical indicator expresses the technical condition of the asset element.

5.1 Literature Review

The literature review captured the information available on previous research projects carried out in standardising BIM and AM processes, current BIM standards in use and current standardised AMS processes in use by different NRAs.

5.1.1 *Interlink and AM4INFRA*

The Interlink project had the objective to provide NRAs and their supply chains with future-proof information management standards for the delivery and operation of infrastructure assets. The proposed solution uses cutting-edge capabilities of Linked Data for a proposed European Road Object-Type Library. Their approach is 100% software vendor-neutral and open; applicable to the whole life cycle and supply-chain of infrastructure assets; and focused on data exchange and sharing. The approach consists of applying powerful Semantic Web technology to express infrastructure asset object-based information and knowledge on a European level. The system is designed to integrate and reuse any existing and forthcoming BIM standards in flexible ways, thereby minimising obsolescence of earlier investments by NRAs.

The data dictionary review by the Interlink project looked at several existing initiatives such as the AM4INFRA project, the Crossrail asset data dictionary, and buildingSmart.

[1] For the additional survey by CoDEC 8 NRAs were contacted. All respondents saw a benefit to BIM, including having an as-built model, for project information, for collaboration, sequencing and economics. To get to the next stage of BIM, 4 of the 8 NRAs who responded thought that better integration between BIM and AM software was necessary.

Asset management is based on information on the assets - hence the importance of data management. The AM4INFRA project (Delivery D3.1) pointed at the importance of a unique source for all data needed for asset management in order to share data between all transportation network stakeholders (owners, managers and operators) in an efficient way. A data dictionary supports this by defining a unique description of the data. The AM4INFRA considered the possibility of constructing cross-European information management (which data, how to use it, and how to translate it into the required information) for infrastructure. Their Asset Data Dictionary allows the effective sharing of information for common data needs. In the AM4INFRA project, two ways of analysis were used:

- Top-down analysis: existing literature on data dictionaries.
- Bottom-up analysis: current practices at three levels (data dictionaries in use, existing data strategies, and existing asset data management processes).

It was also stated that asset data are needed to support all the asset management processes:

- To provide the data required to support the approach to asset management;
- To describe the asset and its performance;
- To provide the basis for informed decision making;
- To facilitate communications with stakeholders;
- To inform the assessment and management of risk;
- To support the management of statutory requirements;
- To support continuous improvement.

The AM4INFRA project went on to design an Asset Data Dictionary. Key data groups were identified:

- Two groups ("Network Location Referencing" and "Asset Inventory") to identify both the network topological model and the asset register.
- Within the asset register, asset types should be characterized according to the network type (e.g. road, rail or waterway). Six data groups, which information could be common across transportation assets (Construction, Condition & Performance, Risk & Safety, Maintenance, Financial & Accounting, Operational) were identified.

The asset data dictionary was developed from these identified data groups, through the description of related datasets and data items and whose final contents represent an organized index of assets information.

5.1.2 *CrossRail*

The CrossRail Asset Data Dictionary describes the group of specifications of how assets are classified, i.e. grouped into similar types, what these classes do/don't represent and the attributes that should be collected for each class of asset. The Crossrail Asset Data Dictionary defines:

- Facility classes – systems grouped logically to create major facilities;

- System classes – assets grouped logically to create systems or sub-systems;
- Asset classes – representing the different class/type of physical items;
- Functions – assets recorded by what they are primarily designed to perform;
- The valid configuration of Asset to Systems and Systems to Facilities;
- Class specific requirements for attribute information.

5.1.3 *buildingSMART and IFC*

The worldwide industry body “buildingSMART” is driving the digital transformation of the built asset industry. Its scope is clearly wider than only road asset infrastructure. The purpose of the actions of buildingSmart with respect to infrastructure is to combine, enhance and develop open standards for intelligent data, which enable process and data integration for infrastructure. The scope includes information exchange and process standards to support effective management of the constructed built environment and linking and integrating across BIM and GIS. Key objectives of the initiative related to infrastructure are:

- Enable data exchange based on open standards for the planning, realization and maintenance of infrastructure works and ultimately all aspects of the built environment;
- Enable the exchange of information and open data access between asset management databases;
- Enable enduring archives of asset information based on open standards;
- Enable life cycle information management for infrastructure based on open standards;
- Enable the merging of project related information e.g. requirements and risks, with asset information.

buildingSMART’s technical core is based around Industry Foundation Classes (IFC) which are ISO certified in 2013. IFC is a standardized, digital description of the built asset industry. It is an open, international standard (ISO 16739-1:2018) and promotes vendor-neutral, or agnostic, and usable capabilities across a wide range of hardware devices, software platforms, and interfaces for many different use cases. Currently, work is concentrated on the development of IFC for specific assets such as roads, bridges, tunnels, ports and waterways. However, particular attention is given to the common scheme so that consistency with other area is guaranteed.

A MVD, or "Model View Definition", is a subset of the overall IFC schema to describe a data exchange for a specific use or workflow. The BIM Collaboration Format (BCF) allows different BIM applications to communicate model-based issues with each other by leveraging IFC models that have been previously shared among project collaborators. The IFC alongside other tools like MDF and BCF make data exchange easy and supports the idea of openBIM (i.e. BIM working with open standards).

5.1.4 *BIMconnect*

BIMconnect is a not-for-profit organisation dedicated to providing the industry with accurate, current and relevant information about Building Information Modelling. The usefulness of the different standards, formats and definitions are explained on their webpages. Following statements place the work of buildingSMART in perspective.

- Rather than seeing IFC as a means for data exchange, it is more accurate to think of IFC as a means of referencing or archiving (BIM) model content. In an IFC-based workflow each discipline remains author and owner of their model content but it allows different stakeholders with their own competences and responsibilities to efficiently work together.
- In an ideal workflow, a receiving party should request the information that they want and have it delivered to them in a form that is suitable for their use. Model View Definitions (MVDs) support openBIM workflows in delivering information as required. MVDs are filtered views of the IFC schema, built for a specific purpose. This is an evolution from the "push system", where the supplier of information ultimately decided on how this information would be passed on.

5.1.5 *EUROTL*

In the frame of the Interlink project, the EUROTL was developed shows a principal view of the EUROTL framework. The **Figure 1** shows the interoperability of different data frameworks throughout Europe.

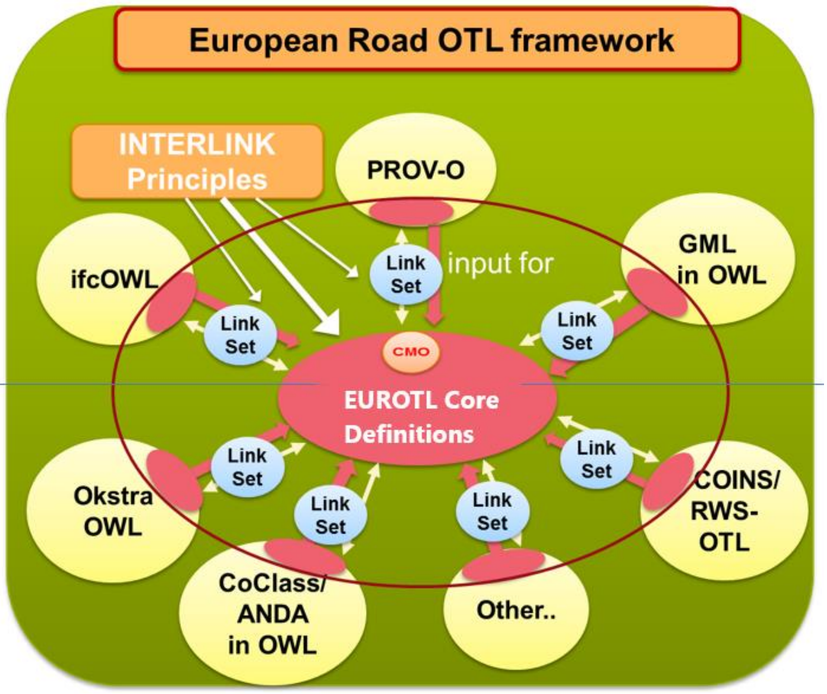

Figure 1: European Road OTL framework

The framework essentially consists of the following parts:

- **European Road OTL Core Definitions**
- This is an ontology that serves as a hub to which more specific domain ontologies may be linked. This ontology covers highly reusable definitions such as provenance, quantities and units, temporal and spatial locations, transport networks, basic support for asset lifecycle and also main asset types and properties as needed for sharing asset lifecycle data.
- **Domain ontologies**
- Which are ontologies that already exist in some form and that covers specific needs for specific use cases. These ontologies are linked with the core definitions using Linking Rule Sets.
- **Linking Rule Sets (LRS)**
- Which are ontologies or mapping descriptions with the only purpose to provide the relationships between elements in ontologies (e.g. between the domain ontologies and the European Road OTL Core Definitions) in a machine-readable way
- **Modelling & linking guide (MLG)**
- It contains recommendations for how to model the above ontologies to enable a smooth integration into the framework

The EUROTL also defined an "ontology metadata": an abstraction of metadata. This tool allows the introduction of sets of metadata such as the ones that will be developed by CoDEC.

5.1.6 *BIM and AMS Standards*

5.1.6.1 INSPIRE Directive

Since the assets of transport networks have geographical and geometrical properties, the EUROTL makes use of the INSPIRE Directive of the European Commission. The INSPIRE Directive aims to create a European Union spatial data infrastructure for the purposes of EU environmental policies and policies or activities which may have an impact on the environment. This European Spatial Data Infrastructure will enable the sharing of environmental spatial information among public sector organisations, facilitate public access to spatial information across Europe and assist in policy-making across boundaries. One of the data themes covered by the INSPIRE Directive is "Transport Networks"

The challenges regarding the lack of availability, quality, organisation, accessibility, and sharing of spatial information are common to a large number of policies and activities and are experienced across the various levels of public authority in Europe. In order to solve these problems it is necessary to take measures of coordination between the users and providers of spatial information. The Directive 2007/2/EC of the European Parliament and of the Council adopted on 14 March 2007 aims to establish an Infrastructure for Spatial Information in the European Community (INSPIRE) for environmental policies, or policies and activities that have an impact on the environment. INSPIRE will be based on the infrastructures for spatial information that are created and maintained by the Member States. To support the establishment of a European infrastructure, Implementing Rules addressing the following components of the infrastructure are being specified: metadata, interoperability of spatial data themes (as described in Annexes I, II, III of the Directive) and spatial data services, network services and technologies, data and service sharing, and monitoring and reporting procedures. INSPIRE does not require collection of new data. However, after the period specified in the Directive1 Member States have to make their data available according to the implementing rules. Interoperability in INSPIRE means the possibility to combine spatial data and services from different sources across the European Community in a consistent way without involving specific efforts of humans or machines. It is important to note that “interoperability” is understood as providing access to spatial data sets through network services, typically via Internet.

Taking into account the variety of responsibilities in collecting, managing and using the data and different approaches in the data base management practice, from simple models to complex data arrangements, this data specification is provided as basic framework and with the purpose to maximize the reuse and sharing of the data about a network. It is mainly focused on the “widely reused – widely referenced” segments of spatial objects, supporting the loose linkage between the diverse organizational data with these spatial objects and allowing the extensibility to fit into diverse applications and user needs. This approach provides a framework for users to configure and associate their own information (from surface condition surveys, to journey planning, to trans-European transport policy making etc.) using existing transport networks information in each Member State.

The Road Transport Networks application schema (Roads Schema) employs a link and node structure to represent a road system used for the transportation of vehicles in the form of a linear network. The Roads Schema inherits classes from the Common Transport Schema and also creates its own classes to describe properties of the road network such as Ownership and traffic direction that can apply to whole sections of the network element or subsections that can be described using linear referencing. The primary aspects modelled for road network elements are:

- Spatial. Geometric (point, line and area (topographic)) representation of various elements that are parts of a network. Typically, the network is handled as a network of connected linear elements (links) with points (nodes) at the ends of the lines (at junctions, road ends etc). Also real objects with a function in a network may be represented in the dataset. Network connectivity within the roads network is essential but between elements in the other networks is an optional spatial aspect.
- Temporal. All elements in a network may have a temporal validity (i.e. description of when the network element exists in the real world) and optional information on when data was entered, modified or deleted in the dataset.
- Thematic. The road schema can be thematically displayed via several of the attributes defined within the specification such as ownerAuthority or speedLimits

The other transport modes are treated similarly, introducing also notions related to bridges, tunnels, etc..

5.1.6.2 Open Data

Open Data comes in many different shapes. The first international Open Data Standards Directory was developed by universities of McGill and Johns Hopkins. It contains more than 60 Open Data standards on how governments could publish Open Data. The standards prescribe quality levels of datasets, including ones on public facilities, road construction and crime statistics. By doing so, the initiative boosts Open Data interoperability on a global scale. The European Directive on open data and re-use of public sector information provides a common legal framework for a European market of government-held data.

5.1.6.3 ISO 55000

ISO 55000:2014 suite provides an overview of asset management and asset management systems. It also provides the context for ISO 55001 and ISO 55002. ISO 55001 specifies requirements for an asset management system, while the other standards detail sector-specific, asset-specific or activity-specific technical requirements or give guidance on how ISO 55001 should be interpreted and applied within a specific sector or to particular asset types. The standard recognises that asset information systems can be extremely large and complex, and that there are many issues involved in collecting, verifying and consolidating asset data in order to transform it into asset information. It also recognises that some asset data comes from control systems, which are often isolated from other information systems; and that integration of this data through the asset management system can provide new asset information, leading to improved organizational decision making.

5.1.6.4 PAS 1192

ISO 19650:2019 establishes the methodology for organisation and digitisation of information about buildings and civil engineering works, including BIM. This supersedes portions of PAS 1192. BS 1192 and PAS 1192-2 have now been withdrawn, but the other PAS standards remain (covering information management for the capital/delivery phase of construction projects (PAS 1192-2:2013); information management for the operational phase (PAS 1192-3:2014); collaborative production of information using COBie (PAS 1192-4:2014); specifications for security-minded BIM (PAS 1192-5:2015); and specifications for collaborative sharing and use of structured Health and Safety information using BIM (PAS 1192-6:2018).

5.1.6.5 DATEXII

DATEXII is the electronic language used in Europe for the exchange of traffic information and traffic data. The development of DATEXII was initiated in the early 90s because of the need to exchange information between traffic centers of motorway operators. Soon there was the need to open this information to service providers. DATEXI was somewhat too limited for this and used outdated technical concepts. DATEXII was developed in the early years of this millennium. By means of DATEXII, traffic information and traffic management information is distributed in a way that is not dependent on language and presentation format. The increasing scale on which ITS services are being dimensioned, as well as the new digitization requirements arising from autonomous vehicles, requires increased use of standards. DATEXII and TN-ITS are working together towards the interoperability of standards in the traffic management domain. TN-ITS is a European platform for exchanging changes of road data for Autonomous Driving.

5.1.7 *Asset data management processes*

5.1.7.1 Pavement asset data management processes

Pavement management is a widely used example of asset management. Pavement management is the management of the "pavement" component of the road. The pavement manager must have an inventory of the pavement sections that are part of the road network, including information about the materials used for the construction of the pavements, and the construction date of (each layer in) the section. Performance expectations are for instance expressed in the number of heavy vehicles (or standard axle loads) that make use of the road section, the minimum expectation of skid resistance, etc.. The manager makes use of data collected on the road sections that express the current condition of the pavement (the skid resistance expressed by the "Sideways Force Coefficient" measured by a device like SCRIM or SKM, the result of a visual inspection of surface damage, etc.). These technical indicators may be combined into higher level indicators that then help the pavement manager to determine the urgency, necessity or efficiency of a particular maintenance operation on a particular road section. Pavement management software exists and is widely used for the optimisation of maintenance planning and budget allocation.

COST action 354

Conventional data collection methods for pavement management and the technical parameters, individual and combined indicators were listed and studied in the COST action 354. Most NRA's are using dedicated vehicles that are equipped with sensors. These vehicles inspect the whole (primary) road network once a year or every other year.

A set of single (individual) performance indicators was identified, for which the Action sought to define corresponding "Performance Indices" (PI) for the assessment of key properties of road pavements: longitudinal evenness, transverse evenness, macro-texture, friction, bearing capacity, noise, air pollution, cracking, and surface defects. Most NRA's use some performance indicator for most of these key properties of road pavements.

The definition of Noise and Air Pollution indicators was considered but, despite their recognised importance, there was insufficient data concerning the influence of road pavements on these environmental impacts for their use in the COST action. Due to this situation only a textual description for the use of environmental indicators was given. In the meantime, other projects studied noise and air pollution and advances have been made since.

The Action also defined "Combined Indices" (CI) from the PI's. At the start of the Action almost no combined index could be identified as being in use by an NRA.

ERA Net Road project HEROAD

The HEROAD project studied the current practice of asset management within European NRA's. Whereas maintenance management for road pavements, bridges, tunnels and some of the electronic equipment is commonly implemented (although not always fully implemented at different NRA's), it was concluded that for many other assets an asset management approach has not been developed.

CEDR project PREMiUM

The PREMiUM project studied the different ingredients needed for managing four particular asset types: road markings and studs, road signs, vehicle restraint systems (VRS), and noise barriers. The project addressed potential maintenance operations, inspection methods, indicators and thresholds. Concerning the inspection methods, the report mentions promising techniques based on automatic image processing but acknowledges that the technology had not yet reached the level required for implementation. Meanwhile, much of the condition assessment is done by humans and consists mainly of visual inspections and punctual further investigations with specific monitoring equipment.

5.1.7.2 Bridge asset data management processes

The 2019 JRC Science for Policy Report "Research and innovation in bridge maintenance, inspection and monitoring" (ISBN 978-92-76-03379-0) gives an overview of the relevant research projects of the last few decades. In the introduction, the report states that bridge maintenance requires both scheduled and unscheduled actions. For the latter, it is common to perform visual inspections. Since the 1980s, there have been attempts to "automate" the process, implementing Bridge Management Systems (BMS) and Structural Health Monitoring (SHM). SHM usually focuses on the assessment of deformation and displacement via the use of external or embedded sensors. The report also remarks that the condition monitoring of ordinary bridges is a complex task. There are thousands of short- to medium-span bridges in Europe that would be impossible to retrofit with fixed instrumentation. Also, very few new bridges are integrated with monitoring sensors due to the high cost. Ad-hoc solutions are sometimes applied (e.g. using portable SHM systems, including instruments for non-destructive inspection).
Another aspect that the report found worth highlighting is the specific bridge infrastructure stock in Europe, and as a consequence, the differences in bridge research. While in the US there is a relatively high number of steel bridges, in Europe the bridge construction industry relied extensively, after World War II, on reinforced concrete, including pre-stressed.

SeRoN

The European project "SeRoN – Security of Road Transport Networks" undertook classification of types of bridges and tunnels on the highway network in Europe (also presented in the article "Identification and Classification of European Bridge and Tunnel Types" by the authors Ingo Kaundinya and Frank Heimbecher, presented at: 35th Annual Symposium of IABSE / 52nd Annual Symposium of IASS / 6th International Conference on Space Structures, London, September 2011). Stakeholders from 14 countries provided general data > 45,000 bridges. In total 38 different bridge types were identified as relevant in the EU. The article presents a classification of these types.

IABMAS

The International Association for Bridge Maintenance and Safety (IABMAS) compiled a report on the bridge management systems of the world, presented in 2010 at the IABMAS conference. A second edition was published in 2012. The report is based on completed questionnaires on 21 bridge management systems, from 16 countries (including from Europe: DRD of Denmark, FTA of Finland, BASt of Germany, INRA of Ireland, Autonomous Province of Trento in Italy, Latvian NRA, RWS of The Netherlands, Polish Railway Lines and Local Polish Road Administrations, Spanish ministry of public works, the Swedish road administration, and the Swiss federal roads authority). In total, the systems are being used to manage approximately 980,000 objects. It provides a general overview of the bridge management systems, in particular about inventory information, inspection information, intervention information, prediction information, information use, and operation information.

- Inventory information: The majority of these systems are owned at the country level (13/21), and only one (SZOK in Poland) was owned at a municipality level. Seven of the systems permit basic construction information to be archived in the systems, although the majority of the systems allows the information to be either stored in some way or referenced. Except Bridgeman (the system used in Vietnam) all systems in operation in 2012 allowed archiving of inspection information. Most of the systems (19 systems) allowed archiving of intervention history (information for the SZOK was not given). All systems allowed The location of the objects in the system (2D or 3D coordinates) and loading information to be archived in the system. The majority of the systems allowed to archive the use of the objects.
- Inspection information: All systems that were in use in 2012, allowed the storing of inspection information at both the element and structure level. At element level, all of the systems handle information on condition. At structure level, all of the systems but one handle condition information from inspections, seventeen systems handle information on load carrying capacity, fifteen of the systems handle information from inspections with respect to safety, and fourteen of the systems handle information from inspections with respect to risk.
- Intervention information: Most systems allow user defined interventions and more than half of them have predefined interventions. The majority of the systems handle intervention costs, while only some systems handle inspection costs, accident costs, traffic delay costs or environmental costs.
- Prediction information: More than half of the systems can predict deterioration, and the effect (improvement) of a future intervention, are capable determining optimal intervention strategies and providing a work program. The most common time frame for prediction and planning is a ten-year horizon, even when some of the systems may cope with any period between 5 and 30 years ahead.
- Information use: Eighteen of the systems are used to prepare budgets. Eleven of the systems are used to set performance standards. Seven of the systems are used to match funding sources. Seven of the systems are used to manage special transports.
- Operation information: Inventory information as well as inspection and asset information are normally collected and entered by both the infrastructure owner and

private companies. Intervention information is normally entered by the owner. The planning of interventions using the system is normally only done by the infrastructure owner.

HEROAD project

The ERA Net Road project HEROAD produced a deliverable (D2.1, available on the CEDR website) on "Structures performance assessment". The document makes a distinction between condition assessment and structural safety assessment.

Condition assessment is the process where, starting from the results of the inspection, the final result is the determination of the functional capability and the physical condition of bridge components including the extent of deterioration and other defects. The condition assessment can be either qualitative, in the form of definition of classes, or quantitative, in the form of a so-called "condition rating", a value that indicates the global state of conservation of the bridges and their ranking according to its value.

Structural safety assessment is the process where, starting from the actual resistance of the structure (up-dated with the results of the inspection and testing) and the actual loading, the remaining safety (measured in terms of partial safety factors, reliability index, probability of failure or similar) is derived.

Figure 2 (from HEROAD) presents the three phases that constitute optimal assessment of highway structures, particularly bridges. HEROAD stated that, while bridge inspection procedures and methods of condition assessment (system of inspection, catalogues of damages etc.) are similar in most European countries, the method used for quantification of a condition rating varies. Generally, evaluation of the whole structure's condition based on the condition assessment of its elements can be grouped into two approaches (COST 345, 2007):

- *Cumulative condition rating*, where the most severe damage on each element is summed for each span of the superstructure, each part of the substructure, the carriage way and accessories. The result is the condition rating for the structure, which can be used for a preliminary prioritisation of the structure.
- *Highest condition rating* of the bridge components as the condition rating for the entire structure.

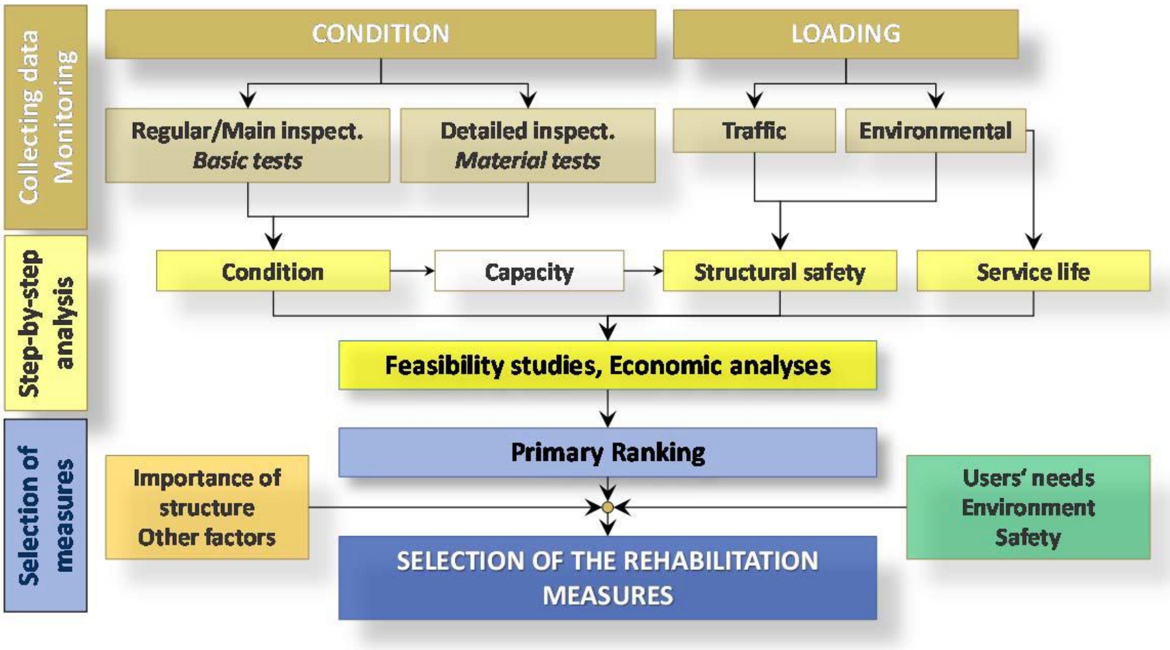

Figure 2: optimal assessment of highway structures including bridges (from Deliverable 2.1 of HEROAD)

5.1.7.3 *Tunnel asset data management processes*

The already cited article "Identification and Classification of European Bridge and Tunnel Types" related to the European project SeRoN also presents a classification of tunnels. Stakeholders from 13 countries provided general data of overall 638 tunnels. In total 12 main tunnel types were identified as relevant in the EU. The tunnel types differ from one another regarding construction method/system (e.g. NATM tunnel) and cross section (e.g. 1 tube, 2 tubes).

5.1.8 *Combined asset management*

As described above, many NRA's have separate divisions for the management of bridges, tunnels and roads and these divisions managed the different asset types separately and independently.

However, projects like PROCROSS and ASCAM (Eranet Road) show that cross-asset management and global asset management is technically feasible. There is not necessarily a need for total centralisation of data: for a particular application such as asset management a connection and a way to interrogate several data collections suffices. Projects like AM4INFRA address the technical aspects of cross-asset management or even global asset management.

For optimal asset data management, it is important to identify the workflows, their use of information, the (elsewhere) available data, and the data these workflows could propose to other workflows that occur later in the life cycle of the assets. Workflows may also change in the next decades.

5.2 Information received from NRAs

During the Stakeholder Engagement (See Appendix A), different NRAs shared their internal documentation and information on processes that are not publicly available on their AMS for different Assets. The following sections provide the details found in: Germany, England, Lithuania, Belgium (Flanders and Wallonia) The Netherlands, Norway, Sweden, Austria, Finland and Portugal.

5.2.1 *Pavement management in Bavaria (Germany)*

The federal motorways and federal (main) roads in Germany are managed at the Federal (national) level using a dedicated PMS. However, the State of Bavaria is responsible for the state roads. Road maintenance management in Bavaria is carried out by decentralised (local) offices. The total annual budget for maintenance is distributed over these offices, based on three criteria: the total length of the road network in the subnetwork of each office, the traffic (Annual Average Daily Traffic - AADT) on the subnetwork, and the current condition (total number of km of road sections that need maintenance) of the subnetwork. The latter is determined based on condition measurements.

The monitoring of pavement condition is performed with dedicated measuring vehicles. These devices collect data that are reported as longitudinal unevenness, rut depth, virtual water depth, skid resistance, cracks and patching. Virtual water depth and skid resistance are used in the definition of the combined indicator “usage value” and longitudinal unevenness, rut depth, cracks and patching are used in the definition of combined indicator “substance value”. Two thresholds for each of the two combined indicators give rise to a total of 9 classes of “emergency” (Figure 3).

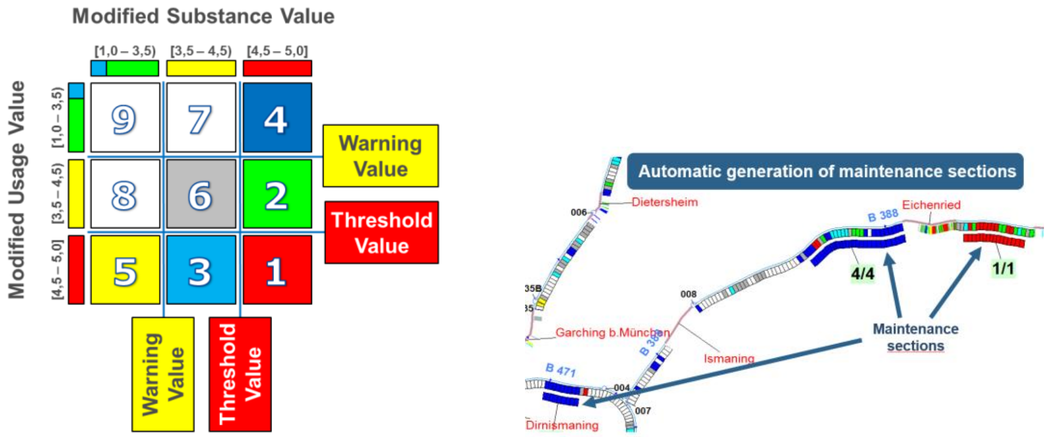

Figure 3: Germany – combined indicator

Each road segment of a length of 100m (outside cities) or 20m (inside cities) is assigned to one of the emergency classes. Then, consecutive segments with similar emergency levels are automatically grouped together into longer road sections with a need for maintenance. The data collected by the pavement condition monitoring vehicles are also presented (as shown in Figure 4 in an interface in the form of different key performance indicators and are visualised on road profiles and with the online expert-system IT-ZEB-Server.

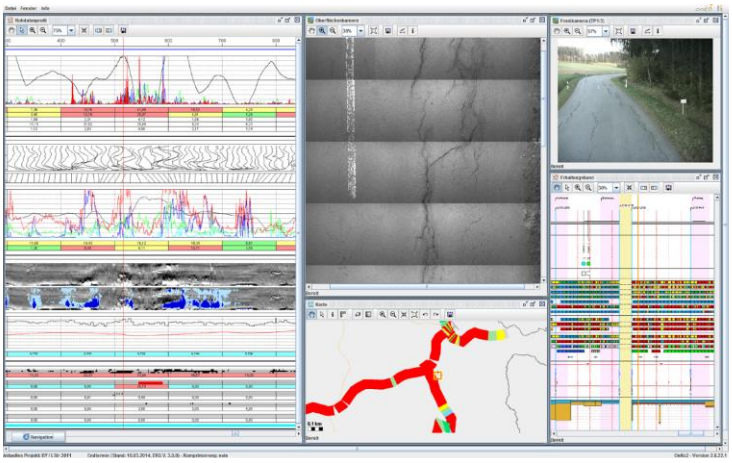

Figure 4: Pavement management in Bavaria

5.2.2 *England*

The HEROAD deliverable D1.1 on “Pavement performance assessment” listed the characteristics that are evaluated. These include transverse profile, longitudinal profile, gradient, crossfall, curvature and texture measurements collected annually on strategic roads and every 2-4 years on other roads. HEROAD also mentions annual routine skid resistance measurements (with SCRIM). Several annual surveys have been carried out on the strategic network in England using the Traffic Speed Deflectometer (TSD) for the evaluation of structural strength. Visual condition obtained from images collected at traffic-speed is done on the English strategic road network.

All survey devices must be accredited before starting any survey work. They are then subjected to regular QA regimes, to ensure consistency in the data delivered. This applies for all network types. For example, the TRACS specification for machine measured condition requires fully accredited survey vehicles and regular QA checks by an independent body. For the TSD, new quality documents were edited and a quality control procedure was set up for a regular verification during the execution of measurements by the contractors.

One of the benefits of the system appears to be the provision of a well defined technical specification for each condition survey type. The published specifications are both technical and also result specifications for raw data. Highways England uses a PMS illustrated by Figure 5

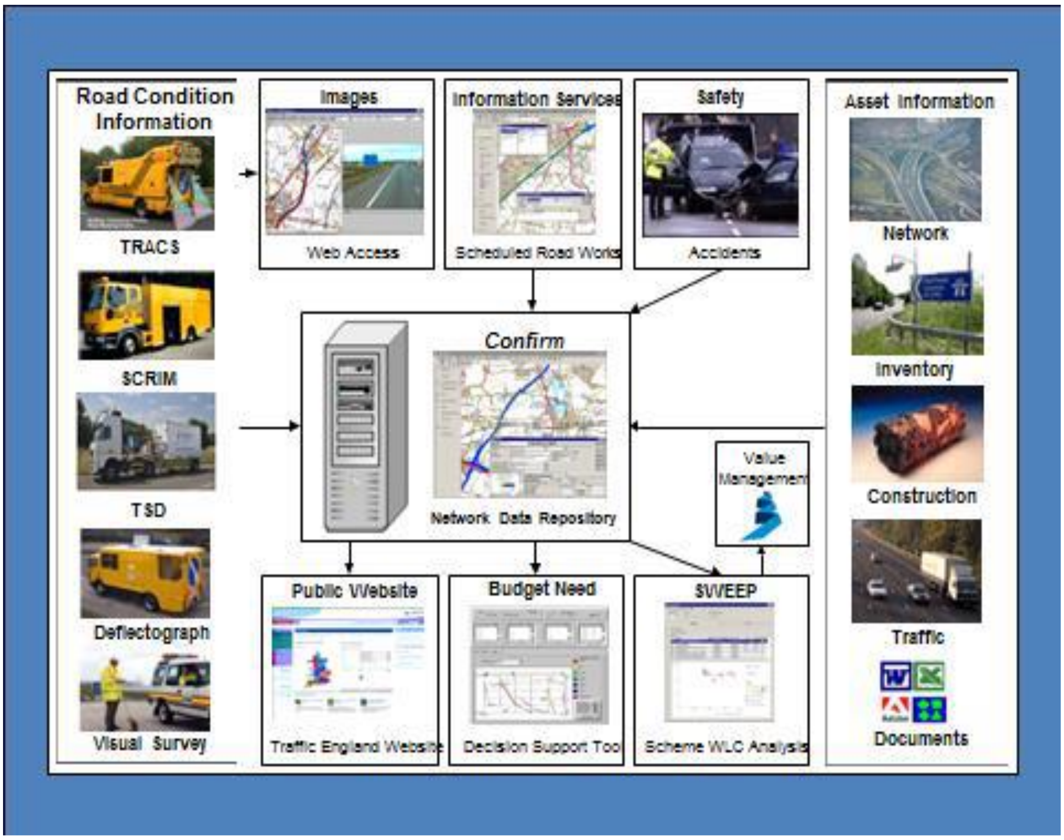

Figure 5: The PMS of HE

5.2.3 *Lithuania*

At ERPUG 2018 (in Vilnius) recent developments in Lithuania on monitoring and asset management were presented. Pavement management has been in place for several years, when several PMS software were used (HDM III, HDM IV, a national PMS software). The LRA are currently using dTIMS for pavement management. Modern monitoring devices are in use. A multi-functional device is equipped with 3 point lasers for IRI and MPD measurements (in front of the vehicle)), a Pavemetrics LCMS-2 3D laser system for transverse evenness, surface defects and point cloud, an Inertial and GNSS measurement system OxTS Survey+ , and a Ladybug5 camera for spherical view. The Pavement Condition Index (PCI) is in use for the evaluation of roads.

A new device “ViaFriction” is to replace the old SRT-3 in 2020 for skid resistance measurements. It will be used for quality checks of asphalt pavements and for monitoring skid resistance on network level. Skid resistance is considered as an important parameter for determining the road condition and the need for resurfacing of existing pavements. For the evaluation of the structural health of roads, GPR (for determination of layer thicknesses) and FWD are used. The level of road/tyre noise is certainly also a point of attention and research in Lithuania.

A separate system exists for bridge data management. They make use of real-time monitoring of bridges and viaducts during static or dynamic tests or under natural traffic.

A new asset management system is under development, based on the IBM Maximus asset management product. Currently it is in the configuration and programming phase at IBM Maximus for Lithuania. This new AMS will allow to upload CAD and IFC data for bridges and viaducts. There is a standard BIM module in IBM Maximus.

5.2.4 *Flanders (Belgium)*

Maintenance planning of motorways in Flanders is based on a PMS implemented in the dTIMS environment. The PMS is a stand-alone system. The implementation of the PMS system was object to a paper and presentation at the Belgian Road Congress (Briessinck, Margo; Van Troyen, Dirk (2013) PMS voor het Vlaams autosnelwegennetwerk. (in Dutch) In: Belgische Wegenvereniging (BWV) (Ed.): 22nd Belgian Road Congress, Luik, September 11-13, 2013).

The approach is based on condition surveys with the ARAN and the SKM (and previously a SCRIM). The rough data from these survey vehicles are temporarily stored and transformed into values for several technical parameters (averages per hm). These technical parameters are used in the PMS software and the values of these technical parameters are stored in the PMS database. Only these values are kept without date of expiration. The data collection, the computation of the technical parameters and further indicator values (computed by the PMS software) is the responsibility of the road survey division who also uses the PMS software. The model will be extended to more pavement types in 2020, implemented in dTIMS in 2021, and then also applied to the main regional roads from 2022 onward.

The PMS software further makes use of a representation of the motorway road network that includes information of the different layers of the road construction (for each layer: type of material, thickness, age). It also makes use of information on the intensity of heavy traffic. The road construction data were introduced from existing data in the Asset Data Management System of AWV and the traffic data are obtained from the data collected by another division within AWV.

The combination of survey indicator values, road structure and traffic leads to a subdivision into “to be maintained” parts of the motorway network and to each subdivision an appropriate maintenance measure is assigned. The results are transformed in a report on the current condition of the road network, a report with the proposed maintenance actions and some illustrations on a map (GIS-based presentation). Reports and maps are made available to all within AWV and beyond. The indicator values are available to all within AWV but not in an automated way (e.g. not through an internally available UI).

In the last few years, the Flemish NRA invested significant effort in setting up the conditions for the introduction of BIM. In particular, the Flemish NRA organised consultations of a wide range of stakeholders, resulting in the definition and publication of an OTL. This OTL is now used for the creation of BIM models in the frame of maintenance contracts of several projects. The measurements and laboratory tests that are typically performed during and after the realisation of road works are foreseen in the OTL. The OTL does not yet foresee the representation of the data as they are used and manipulated in the stand-alone PMS software and PMS database but this is under development.

“Tunnel organization Flanders” is a division within AWV that is responsible for the management and maintenance, renovation and new construction of all road tunnels longer than 200 meters managed by AWV throughout Flanders. Tunnels whose enclosed section is shorter than 200 meters are called "underpasses" and are the responsibility of the bridge management unit.

All people at AWV involved in the management of artworks can always call on the knowledge and expertise of the “Expertise Concrete and Steel (EBS)” department, a specialized department of the Department of Mobility and Public Works (MOW) of the Flemish government. (AWV is also part of MOW.) This department provides advice, but also carries out certain inspections, checks and examinations. In addition, EBS also organizes the Commission for the Management of Works of Art. Experts regularly meet in this committee to discuss the monitoring of the artworks and to make agreements about possible renovations and interventions.

Every infrastructure (or bridge) with a span of at least 5 meters receives a general inspection every 3 to 5 years. The frequency is determined by EBS based on the condition, age and complexity of the artwork. In specific cases, bridges may be subject to additional inspections in the meantime.

AWV distinguishes four types of inspections:

- Routine inspections: These are visual inspections, which do not have fixed rules and which are carried out fairly regularly by the staff of the managing department. They do not require any special material, except possibly a photo device. These inspections make it possible to determine that the safety of the user is at risk, or that an abnormal evolution has occurred in the behaviour of certain parts of the bridge or certain defects.
- General inspections (A inspections): The A-inspection of a bridge includes the thorough inspection of the bridge including a check on the levelling of the bridge, systematically every 3 to 5 years, by the bridge inspectors.
- Special inspections (B inspections): The B inspection is a more thorough inspection than the A inspection, for specific elements of the infrastructure, in which additional resources, specialized personnel and adapted equipment are used. A B inspection takes place at the request of the managing department or the management centre, by the Concrete and Steel Expertise department (EBS) in collaboration with the bridge inspectors.
- Occasional inspections (O-inspections): For various reasons, it may be necessary for the managing service to subject all or part of the infrastructure to an inspection outside the systematic control cycle. These inspections are called occasional inspections (e.g. after a collision).

Also in tunnels, regular checks and maintenance are carried out. A tunnel operator uses camera surveillance for constant monitoring of the safety in the tunnel.

5.2.5 *Norway*

The Norwegian NRA (NPRA) manages state and county roads, including bridges, tunnels. Among the asset management tools currently in use (source: presentation at PIARC technical committee D1 in Japan, October 2017), are:

- National Road Data Bank («NVDB»)
    - Core of AM-systems – centralized database
- Pavement management system («PMS v 3.0»)
    - Condition based maintenance planning
    - Pavement contract management
- Bridge management system («Brutus»)
    - Completely new system implemented 2013
- Tunnel/Facilities Management system («Plania»)
    - Equipment in tunnels + management of buildings/facilities
- Operational Contract Management system – Elrapp
    - Used for electronic communication in operational contracts

Figure 6 presents the global framework for maintenance management and the interactions between the different asset management tools.

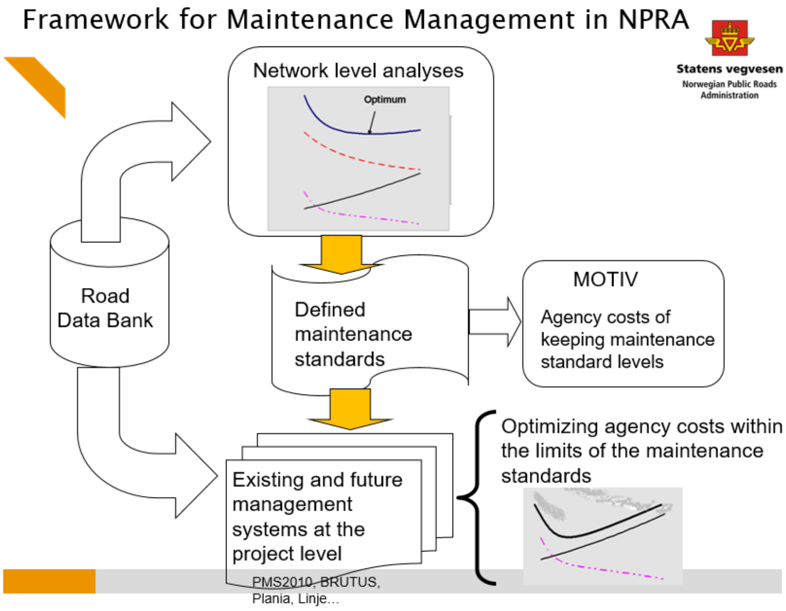

Figure 6: Framework for maintenance management and interactions between tools

In Norway the bridge asset information for operation and maintenance is stored in the relational database "Brutus" which contains information about inspections, security management, measures, sustainability and injuries. It is accessible through a UI (web viewer and editor) and has an API for data exchange with the National Road Database (NVDB). "Plania" is another relational database used to monitor the management, operation and maintenance (FDV) of tunnels with equipment, as well as other objects on and along the road that must be periodically inspected. Again this database is accessible through a UI (web viewer) and has an API for data exchange with the National Road Database (NVDB). Other separate tools exist. The MOTIV tool (Model for the allocation of maintenance funds) is used to calculate the maintenance needs on national roads. MOTIV calculates annual expenses for a number of operational and maintenance tasks based on registered road network data and normative cost models. It has an API for data exchange with the NVDB and makes use of other data sources for meteorological data. The ELRAPP tool is used to keep checklists that all contractors are required to carry out on behalf of the Norwegian Public Roads Administration for all types of contracts. ELRAPP includes the contractor's reporting of information, the Norwegian Public Roads Administration's own controls, follow-up points in contracts (deadlines and deviations) and reporting. Landslide/avalanche data can be transferred from ELRAPP to NVDB. The file format for data exchange with NVDB is the DAU format. The API of ELRAPP is a SOAP web service. ELRAPP also has a UI (web viewer/editor). The NNRA is clearly moving to a more integrated data management, where the NVDB is already based on an OTL and where the OTL for bridge management is in its implementation phase. The developments make use of IFC and of the results of the Interlink project. Ongoing projects include the development of conceptual models (based on model driven architecture according to ISO TC211) realized in GML for model-based road construction projects, and the development of tunnel management and the system solution, common processes, guidelines and routines needed for it. The view of NNRA is that sematic web / linked data can hopefully play a role in cross domain data exchange (using IFC and several OTLs). The use of the ViaTech 360° laser scanner on roads is a new development in data acquisition for the Norwegian NRA, including point cloud collection, automatic crack detection, and more efficient detection of damages (cracks, texture, homogeneity).

5.2.6 *Austria (Asfinag)*

The main road network in Austria is managed by the state owned company Asfinag. Internal agreements are made within Asfinag to use BIM in every new project. The use of BIM started off with rest areas but it will take longer to get to infrastructure coverage. Asfinag feels that it is very important to implement standards in the short term in order to give direction for procurement and implementation. The approach of Asfinag for pavement management is based on the following elements:

- Strategic objectives
- Data management
- Condition measurement System RoadSTAR
- Assessment of pavement condition
- Analysis method
- Analysis results

The objective of the pavement management system is to have systematic, objective planning of maintenance treatments. The basis for this system is the knowledge about the pavement:

- inventory data and traffic;
- the current condition.

The PMS should also ensure the consideration of strategic objectives or KPIs into the maintenance process. A PMS is a part of Asset Management, so there must also be consideration for other structures and other strategic targets.

The output of the PMS is a list of the right treatments at the right time on the right place, and this is the input for the budget (the so-called Infrastructure Investment Programme IIP).

The Asfinag data management can be listed as follows:

- Inventory data
    - Network data
    - Referencing information (GIS)
- Traffic data
- Pavement construction data
    - Materials and type of layers
    - Thicknesses
    - Year of placements
- Condition data
    - Condition measurements
    - Visual inspections
    - Investigations on project level
- Information of current budget
    - 6 years committed treatments

The current condition of the pavements is collected by inspections based on Austrian guidelines (RVS 13.01.15 and RVS 13.01.16). The following Pavement surface characteristics are collected with “RoadSTAR” (a specially equipped vehicle) on each single lane and evaluated in form of 50m sections:

- Rutting (rut depth under 2m straight edge)
- Longitudinal evenness (International Roughness Index IRI)
- Cracking (% of cracked area)
- Surface defects (% of surface defects)
- Skid resistance (longitudinal friction coefficient).

For assessment, Asfinag makes use of a transformation of technical parameters into dimensionless indices, which in then are used to calculate combined indices. This process is based on the report of the European action COST 354 “Performance indicators for road pavements” (2008). Skid resistance, rutting and longitudinal evenness are combined to a “comfort and safety index”, surface defects, creacking, the age of the wearing course and the theoretical bearing capacity are combined into a “structural index”. With the analysis of these data, heavy maintenance treatments and minor maintenance treatments are identified and the PMS allows a comparison of several maintenance strategies for each single section as a basis for LCCA and strategy optimisation. The output of this process is:

- For each road section: a projection of maintenance treatment and basic information for the preparation of further investigations on project level;
- For the whole network or for a sub-network: condition distribution, cost distribution, comparison of maintenance scenarios, treatment distribution, maintenance backlog, and the development of asset value.

Asfinag uses the PMS software dTIMS. For structures, Asfinag uses a GIS environment. Through this GIS platform they can access BIM models.

The safety equipment of the tunnels managed by Asfinag is based on the EU Directive for the "minimum road tunnel requirements" and the road tunnel safety act (Straßentunnelsicherheitsgesetz, STSG).

5.2.7 *The Netherlands*

At ERPUG 2019 Frank Bouman of RWS gave a presentation on the use of measurement data for PMS in The Netherlands. RWS makes use of LCMS measurements for determining ravelling (interpretation of data with RWS model PA), cracking (determined with the Pavemetrics model and RWS technique) and evenness (using a RWS model). Also skid resistance is measured (side force coefficient). These data are collected by contractors and their equipment (mainly ARAN and SCRIM or SKM). The collected data are reported on 100m long road segments and intervention levels are assigned to each road segment of 100m length using thresholds for each of the measured surface characteristics (ravelling, cracking, longitudinal unevenness, skid resistance). These thresholds are:

- Ravelling : > 25% (medium (11-20%) or severe (>20%) stone loss);
- Cracking : > 30% (cracking 10-20mm width);
- Rutting : >= 18mm;
- Longitudinal unevenness : >= IRI 3,5;
- Skid resistance: < 0.51 (measured at 80km/h).

This also indicates the units used in the PMS approach of RWS. Other input data for the PMS is number of vehicles and vehicle loads, climate and soil. The results of the PMS “IVON 2” is presented on 3 maps (short term 1-2 years interventions, mid term 3-5 years interventions, and long term 5-10 years interventions).

At its web site (https://www.arup.com/projects/rijkswaterstaat-bridge-renovations) Arup presents a 10 year project for RWS on steel bridges. It states: “To combat bridge fatigue and ensure ongoing operational safety, the Dutch roads authority Rijkswaterstaat has undertaken a long-term bridge maintenance and refurbishment programme that will extend their service life by about 30 more years. Arup, together with RHDHV and Greisch have been working together over the past ten years to deliver strengthening design and engineering solutions for this nationwide bridge repair programme. The joint venture has delivered this sustainable remediation programme, working from the design stage and contract preparation all the way to managing its implementation. (..) Arup has developed a Bridge Information Model (BIM), enabling the exchange, storage and management of knowledge between all the stakeholders at all stages of the project. The 3D models also help the working team to visualise advanced calculations, and enable advanced static and fatigue modelling under different scenarios. (..)”.

5.2.8 *Portugal*

Outputs of asset management systems are presented in the form of maps (with ortho-photo or satellite image as background) in the frame of public consultation, design collaboration, reporting on network condition, at the stages of asset management and of operations. Currently a BIM environment is mainly used between the contractor and the client in specific projects.Use of BIM is considered beneficial in all stages of the lifecycle: sequencing, economics, and lifecycle. However, data is not collected until the next phase requires it. It would be good also to include financial information in the system.

The Portuguese NRA sees a need for better integration of AMS and BIM systems. However, different countries have different standards, processes and practices. Also the use of BIM in linear assets is still a challenge.

5.2.9 *Sweden*

Currently asset data are stored in several separate databases. In a limited way access to the data is share, typically by discipline (e.g., bridges share with other bridges). Database on tunnels and furniture are not as advanced. Since the data are stored in databases, the data are difficult to share with people outside the NRA. Some data are provided to specific contractors "manually"; sometimes they are granted logins in NRA's systems, with limited access (typically, data is not exported).

From an AM perspective the development of a digital twin for all the assets will allow to have a digital id and to always know the current condition of the asset. A problem is how to manage such amount of data.The Swedish NRA is working to implement ISO 55000 (the Asset Management standard).A problem on how to store, integrate and share data (with exchange possibilities between different software) resides in vendor lock-in and concerns on interoperability.

BIM environment is mainly between the contractor and the client (it does not cover the full lifecycle). GIS is more related with the society (e.g. bus stops). Moving to an integrated BIM environment. The NRA is working towards a possible import of data through the IFC standard into the asset management systems but it is not yet operational.

A current objective is to have BIM for all new constructions (at NRA level), limited to the design phase of projects for bridges and tunnels. This does not include an as-built model.

A further development of BIM are in sequencing, on economics, and during the whole lifecycle. However, data is not collected until the next phase requires it and this implies that today data need to be manually extracted. There should be guides defining the type of data that should be included for specific assets and that are not focused on the architectural part. There is a need to show that it is possible to have standardized protocols to exchange relevant data between BIM and AM software.

5.2.10 *Wallonia (Belgium)*

The introduction of BIM is an initiative of the NRA (It is not a government initiative). The objective for the introduction of BIM is:

- To improve collaborative work at all stages.
- To better prepare the works. BIM make it necessary to better do preliminary studies. It leaves much less risk for surprises during the execution phase of the works and hence reduces urgent decisions made under time pressure during the works.
- De facto a as-built model exists at the end of the project - that is an advantage for management later on (in years from now). The as-built data are of crucial importance for asset management.

So far, a few pilot projects have been launched, where a BIM model has been requested. These pilot projects concern large, newly constructed infrastructure. The companies that have taken on these pilot projects have experience in BIM and were let free in designing the architecture of the BIM model.

Communication between BIM-software and Asset Management software is therefore needed. Different software (from different IT companies) must be able to do "the same things" and must offer a continuity of software over time. Standardisation is a must.

The Walloon NRA (SPW) collects condition data on roads with their own SCRIM (skid resistance) and with their own multi-functional vehicle VAMOS (longitudinal and transverse evenness, texture, surface defects). These data support the local (operational) divisions in deciding on the priorities for maintenance. The resulting list of maintenance proposals is reduced to a shorter list based on a large number of criteria and by the use of a multi-criteria selection procedure. The Walloon NRA is studying how the huge amount of condition data (collected by SCRIM, VAMOS, fixed sensors, etc.) can be stored and managed in an efficient way and how these data can be used in a better fashion for asset management.

The priorities for bridge maintenance are determined by the results of regular visual expert inspections and of additional measurements when they are needed.

The resulting asset management maintenance actions with their priority is presented in a yearly report and communicated to the cabinet of the ministry. There is no direct access to data for people outside the NRA.

In the last few years, the Walloon ministry made an effort for streamlining some of the internal work processes for asset management. This resulted in the so-called “GPS” approach. The first step in the GPS-approach is priority setting of maintenance works. The second step in the GPS-approach describes the consecutive steps in the realisation of a project (concept, planning, execution, evaluation of the result).

The current condition of the road network is presented to as “open data” to the public in the form of maps with a colour code. These maps are presented on the website of SPW. For the preparation of maintenance works (on project level, while preparing a tender document), the visualisation on a map makes access to the data in the database easy. However, this data access is only available for internal use within SPW. Such presentation does not exist for bridges or tunnels.

A “missing link” on the motorway between Amsterdam and Milano was designed and built in the last years of the 20th century. It makes a connection between the E40 and the E25 motorways. This link was opened in the year 2000 and comprises 5 tunnels. Although the design phase took place before the Mont-Blanc tunnel fire of 1999 and the publication of Directive 2004/54/EC on minimum safety requirements for tunnels in the Trans-European Road Network, safety was already an important concern during the conception. A traffic centre was included for the tunnel management.

There are 9 important tunnels on the main road network in Flanders. The strict safety regulations for tunnels imply some maintenance and modifications. This made the Flemish NRA decide to make use of BIM for tunnels. Turning the large amount of legacy data (many in the form of plans on paper) into a 3D model with information assigned to its objects was a huge effort. The models include ventilation, water management, evacuation, fire safety, telematics, lightning and more.

The objectives are large: using BIM for asset management, getting an overview of the existing relations between technics, making simulations, doing virtual exploration, training and exercises, getting support for predictive maintenance and for risk based maintenance. Indeed, BIM allows 3D visualisation, a follow-up of the “As-Is” state of the tunnel, clash detection and simulations for tunnel safety.

Many other tunnels exist on the Walloon road network and most of them are about 40 years old. The management is separated for the civil engineering part and the elect mechanical part. The civil engineering part is managed according to regulations similar to those in place for bridges. The accessibility is difficult, ideally when the tunnel is closed for traffic, often at night. The electro-mechanical part can use a cross-view for some of the tunnels, uses specific regulations for tunnel equipment and for the majority of the tunnels the management is organised case-by-case.

A master plan for the renovation of the tunnels under the responsibility of the Walloon NRA is under way. The NRA wishes a coherent vision on all tunnels. The requirements for the master plan are user safety, the visual aspect of the installations and the services to the users, management for ITS (Intelligent Transport System) and intelligent routes with a centralization of information and control, compliance with European standards and applicable legislation, good maintenance practices, and the sustainability of the infrastructure. Therefore, the general strategy is to establish a categorization of the tunnels. For this, the tunnels are completely analysed using the same functional analysis framework for the whole infrastructure. The analysis cover operational functions (security features, traffic management features), associated means to ensure safety (technical means, human resources, organisational procedures and the emergency response plan, other resources such as fire resisting equipment), the differences between procedures for different tunnels (compliance, approach with inspections, intervention planning and budget allocation), a structural inspection (visual examination, hammer sounding, cover and carbonation at 100m intervals in sidewalls and roof), a preliminary analysis of the electro-mechanical equipment of the tunnel equipment based on historical inventory compared to expected service levels), and on-site inspections of the electro-mechanical equipment (visual inspection, functional tests, performance tests of lightning and ventilation, test of the command chain). The analysis is now translated into a master plan of exploitation and into a plan for rehabilitation with budget estimate for each individual tunnel. The next step is priority setting and the start of rehabilitation projects.

5.2.11 *Finland*

The NRA of Finland is well aware of the advantages of BIM and asset data management and is developing an OTL. However, today many data are still distributed in different databases and different departments. The Finnish NRA aims at linking together the different existing databases. They find inspiration in the results of the Interlink project. For the moment no data dictionary or OTL is publicly available.

6 Summary

The review has given CoDEC an insight into the current situation within NRAs on their priority data types for managing Assets, and into their roadmaps for integrating AMS data with BIM. This will help CoDEC to establish a "Data Dictionary" containing relevant sets of data types for roads, bridges and tunnels. The Data Dictionary will define the logical and hierarchical connection between the asset data and its meta data or attributes. However, due to the scale of this task, CoDEC will develop the data dictionary for a sample of data types from each key asset. This Data Dictionary will provide the list of data types and the connection to the meta data or attributes, to create an Object Type Library (OTL) for the BIM platform.

6.1 Legacy Data

Inventory data on assets are often accessible through GIS user interfaces for everyone within an NRA and, to some extent, the public. However, pavement management data, bridge management data and tunnel management data are usually not made available to a large audience. Sometimes the data are accessible for consultation through user interfaces and GIS applications but only for members of the NRA or people who have some responsibility or role in the maintenance or management of specific asset types (e.g. pavements or bridges). In NRAs sometimes provide the results derived from the management data (including the interpretation of inspections and measurements) on the same platform, and in the form of an annual report, a map, and/or indicator values for particular locations, routes or areas.

Operational asset management data (safety and traffic management) is further management data used by NRAs (e.g. real-time traffic monitoring with cameras, counting traffic and weighing traffic loads with WIM, continuous bridge monitoring with sensors, ventilation system monitoring in tunnels). The sensors and equipment are all assets that are part of the greater road, bridge or tunnel assets and the asset network as a whole. Some of these collected data are stored for a short period only, while some are logged for a very long time. Some of the data are made available to the public (e.g. traffic counting data) while other data are only used for operational management by a particular division of the NRA.

6.2 Data Dictionary and Object Type Library (OTL)

We have found that the majority of NRA's do not have a data dictionary. However, some data dictionaries were identified (England, Lithuania, Norway, Sweden, Germany) as well as sources containing similar information (France, Australia/New Zealand). In other countries, there are no data dictionaries as such, but the NRAs may have developed (or are developing) their OTL (The Netherlands, Flanders, Finland). Most OTLs/data dictionaries do include roads, bridges and tunnels. For bridges, we identified additional information of interest to the development of an OTL/data dictionary: definitions of terminology specifically related to bridges; classification of bridges; information about bridge management systems, and information about inspection and testing approaches. For tunnels, we identified a classification system for tunnels.

6.3 Asset Management Systems (AMS) and BIM systems

Many NRAs have started using BIM during the design and building phase of large projects. They do so because of the advantages of BIM (more efficiency, better planning, better communication, etc.) but they may also ask for a digital representation of the result in the form of an as-built BIM model. The as-built model contains data on the initial condition or state of the newly built (or extensively modernized) asset.

However, BIM is not currently used for long-term asset maintenance management. Such long-term asset maintenance management is done for roads, bridges, tunnels and other assets in a traditional manner, using dedicated asset management systems, which are often "local" to different departments of the NRA.

For Pavements NRAs often have a Pavement Management System (PMS) containing data about the road network, structural information on the layers of the road, traffic density, and current condition of the road segments. Condition is expressed via parameters, which may be converted to indicators, with the values for a particular segment computed from raw measurements or inspection data. The raw data from the measurements and inspections is usually not kept for a long period, whereas the PMS software database usually does keep track of the parameter/indicator values over long periods of time (decades). Even if the inspections or measurements follow the same procedures in different countries, the parameters/indicators are not always the same (although there is a degree of commonality in some parameters, such as rutting and texture). Even if several NRAs use the same commercial PMS software, they can use different indicators and they can customize the software by setting their own parameters. The results of analyses undertaken with these PMS are interpreted within each department in customised manner. The conclusions are then communicated in different ways to other divisions, politicians and the public.

For bridges, many NRAs have an "in house". Bridge Management System (BMS). The inspection techniques are quite standard (e.g. according to the recommendations of PIARC) and even more advanced measurement techniques are similar. Still, there are differences, for example on the applicable loads for structural evaluation. As for roads, the specific data are stored locally at the division responsible for bridges and these data are sometimes made accessible (and edit by inspectors) to a restricted number of people who have some role in bridge management. Maintenance requirements for bridges are shared in non-standard formats.

For tunnels, the management comprises the tunnel structure itself and the electronic equipment. In some NRAs the management of the tunnel structure is undertaken by the same division that undertakes bridge management (using the BMS for bridges *and* tunnels), but the electronic equipment is managed by another division. The electronic and safety equipment of the tunnels is often more related to operational management. For tunnels, hindrance to traffic by maintenance works is particularly important since the tunnel may be closed to traffic (or at least one of the two tubes). Therefore, the works are done with strict work plans, during the night and/or in weekends and holiday periods.

7 Next Steps

The work described in this report, carried out under WP1 of CODEC, has reviewed the types of legacy data in Asset Management Systems (AMS) and BIM across different NRAs, availability and accessibility of legacy data from the current organisation and any existing data dictionaries that are used by the NRAs.

In the next stage CoDEC will rationalise the information gathered at this stage and, with further direct engagement with NRAs, develop a “Data Dictionary” on the key asset types for a set of asset data. The “Data Dictionary” will then provide a structure to develop an Object Type Library (OTL) for the asset data to be included in the BIM platform. CoDEC will, where practical, base its outputs on existing OTL that are in use by NRAs, but extend these to include new object types if necessary. Following that, CoDEC will create an Open Application Protocol Interface (OpenAPI) to connect the Data to the BIM platform. CoDEC will use BEXEL Manager as the BIM Platform to demonstrate the connection and exchange of data from AMS to BIM system.

This study has been carried out in parallel to work undertaken in WP2 of CODEC, which has reviewed new and emerging sensor and scanning technologies and their potential application areas. Note that the outcomes of WP1 and this WP2 report will be aligned when developing the Data Dictionary, to identify overlap between new sensor/scanning data and legacy data. Alignment of the findings will enable the work to augment the Data Dictionary with the scanner/sensor data.

8 Appendices

Appendix A: Stakeholder Engagement Report

One of the objectives of the project is to facilitate engagement among European National Road Administrations (NRAs), the software industry, and CEDR in order to align future strategies and direction around BIM and asset management. This will be achieved mainly by engaging with NRAs, software companies, and industry bodies, to understand their needs, strategies, and vision for the future.

A survey was prepared towards the end of 2019 to gauge interest of European NRAs and implementation partners. Follow-up consultations were held in 2020 to delve deeper into current and planned projects in NRAs.

The results of the survey and interviews have fed into all tasks in the project, and will also be used as inputs to future consultations with the software industry.

Survey responses

The following information is a summary of responses received to date (24 in total), from about 50 contacts of Consortium partners that have been included in the enquiry.

The responding persons come from 12 different European countries: Austria, Belgium (including Walloon region), Denmark, Finland, Germany, Lithuania, Netherlands, Norway, Portugal, Slovenia, Spain and Sweden.

Areas covered in this summary relate to maturity of organisations in asset management, in BIM, and information management of which aspects organisations would like to improve.

Who the respondents are and where are they from:

Figure A1 represents a list of responding countries.

COUNTRY	RESPONSES*
BE	6
SE	4
AT	3
PT	2
LT	2
NO	1
DE	1
ES	1
DK	1
SI	1
NL	1
FI	1
Total	*24*

*incl multiple responses from the same NRA

Figure A1: List of responding countries

Respondents have been broadly classed into five working areas:

- Asset management: asset manager, project manager, maintenance/monitoring/asset information unit
- Information management: information manager, ICT, geographic data modelling
- BIM: BIM manager or specialist, BIM strategies
- Advisor
- Lead: Head of NRA or asset related unit

Most responses were by experts in asset management (Figure A2), followed by information management and BIM experts.

WORK AREA	RESPONSES
Asset management	9
Information management	5
BIM	5
Advisor	2
Lead	3
Total	*24*

Figure A2: Working areas of responding experts

Maturity of organisations in asset management

The maturity scale used to rate the maturity of organisations in Asset Management has the following seven levels:

- *Innocent*: The organisation is starting to learn about the importance of asset management
- *Aware*: The organisation is aware of the importance of asset management and has started to apply this knowledge
- *Developing*: The organisation is developing its asset management activities and is embedding them
- *Competent*: The organisation’s asset management activities are developed, embedded, and are becoming effective
- *Optimising*: The organisation’s asset management activities are fully effective and are being integrated throughout the business
- *Excellent*: The organisation’s asset management activities are fully integrated and are being continuously improved

The vast majority (~80 %) of respondents claim that their organisations are developing own asset management activities and are embedding them, or these are already developed and embedded them and they are becoming effective. 17 % of organisations are aware of the importance and have started to apply the knowledge about asset management. Only one organisation claims to have fully effective asset management systems and is now in the optimising phase. See Figure A3.

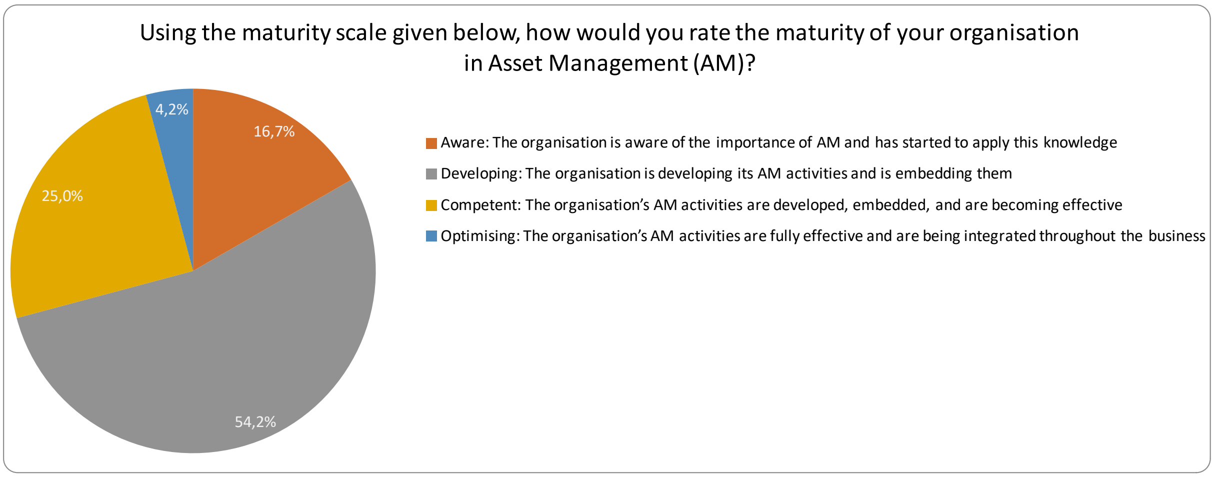

Figure A3: Maturity of organisations in asset management

Some organisations use software solutions already existing on the market to manage roads and bridges (e.g. Deighton dTIMS, IBM Maximo), while most of them have developed or outsourced development of solutions that correspond to their needs and expectations through the years.

Maturity of organisations in BIM

The maturity scale used to rate the maturity of organisations in BIM also has seven levels:

- *Innocent*: The organisation is starting to learn about the importance of BIM
- *Aware*: The organisation is aware of the importance of BIM and has started to apply this knowledge
- *Developing*: The organisation is developing its BIM activities and is embedding them
- *Competent*: The organisation's BIM activities are developed, embedded, and are becoming effective
- *Optimising*: The organisation's BIM activities are fully effective and are being integrated throughout the business
- *Excellent*: The organisation's BIM activities are fully integrated and are being continuously improved

Most responding organisations claim to be aware of the importance of BIM and have started to apply this knowledge (11 responses or almost 46 %), while 9 organisations (or 37.5 %) are developing BIM activities and embedding them. 4 organisations (or 17 %) claim competence with BIM activities developed, embedded and these are becoming effective (see Figure A4).

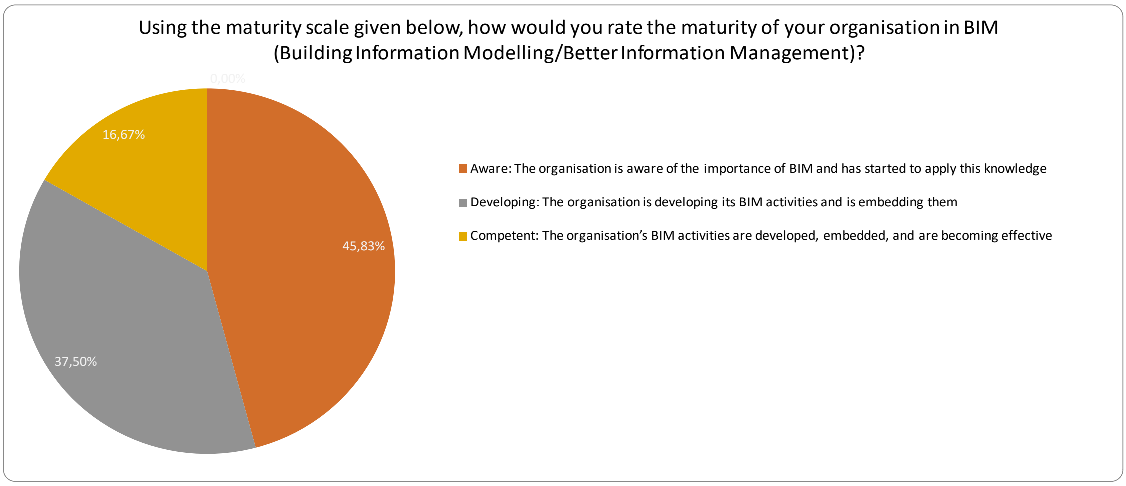

Figure A4: Maturity of organisations in BIM

7 organisations use 'BIM software' (although this covers a mixture of many different types of system) Some can be ready BIM software in the running projects; others are experimenting or using software at a project level (e.g. BIM 360).

Some NRAs request use of specific BIM or data standards from suppliers. These data standards are various and very country specific. In Belgium data are requested according to an AWV Protocol and Execution plan; in Finland the requirement is open format (Inframodel, IFC, and near-standard 3d dwg, 2d dwg AutoCAD formats); in Sweden they require standards for asset coding specific to software they use, Swedish recommendation for CAD layering (SB11) and standards for technical descriptions (AMA); in the Netherlands data standards mandated are COINS and RWS OTL. Across most organisations, DATEX II extensions and GML according to ISO TC211 standards are requested.

What information to improve?

To collect data on key highway assets, most organisations use a mix of visual inspections, surface vehicle machine surveys, and design/construction and maintenance records. Remote sensor data feeds and aerial vehicle machine surveys including drones, planes, satellites, etc. are gaining ever more attention.

Typically organisations would like to improve information and information management for roads and bridges, for street lightning, and road furniture. Tunnels, drainage, engineering structures, electro-mechanical assets, water runoff are also high on their lists of priorities (see Figure A5).

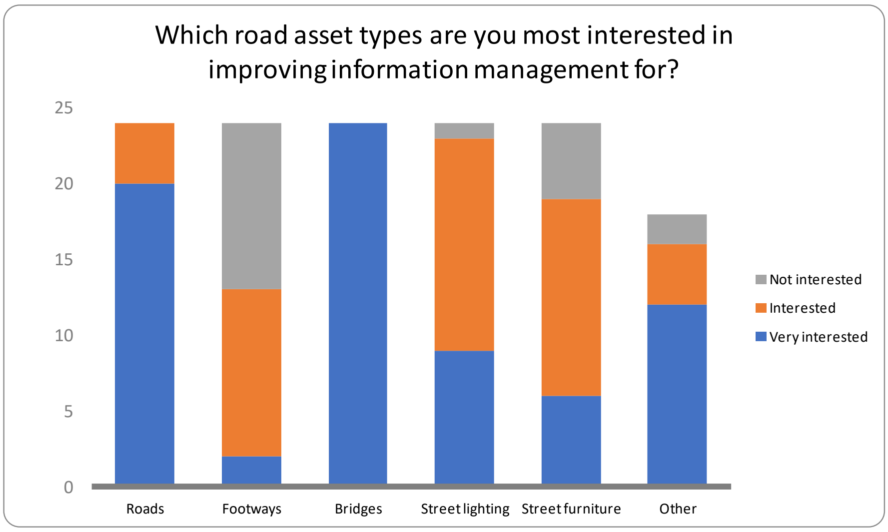

Figure A5: What information to improve

30% of organisations are looking to improve information and information management. An additional 10% of respondents are looking to improve maintenance, design and construction records.

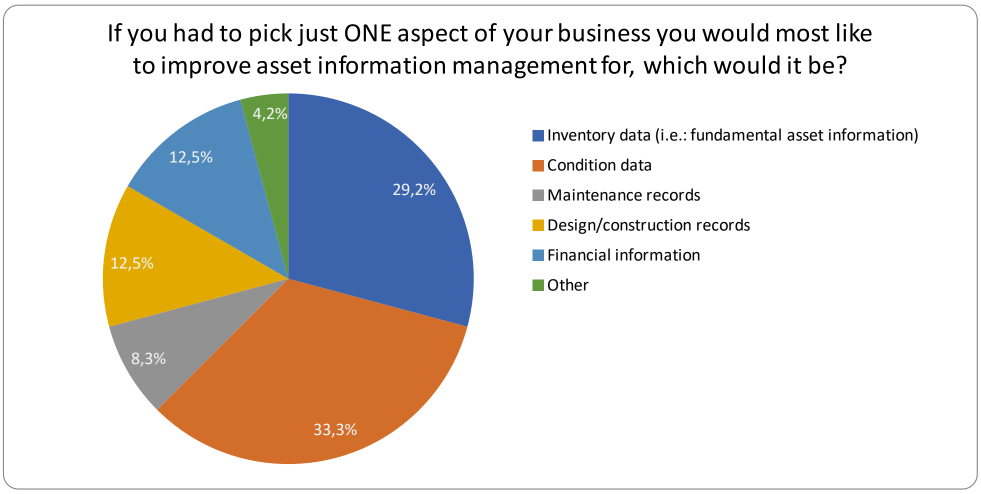

Figure A6: One aspect of business to improve

What about previous CoDEC related work?

The Interlink project was the direct predecessor of the CoDEC project, and CoDEC builds upon it. Respondents were asked on their awareness of the Interlink project. 25% participated actively in Interlink, 33% were aware but did not actively participate, while 42% were not aware. See Figure A7.

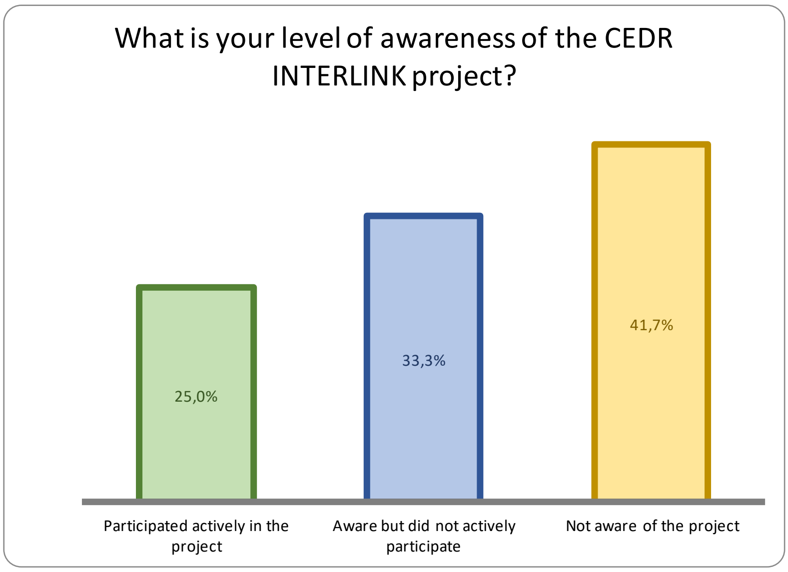

Figure A7: Level of awareness of the Interlink project

The general opinion seemed to be that Interlink was an interesting research project and a good basis for further work, however the impression was that the further work was needed to make the results implementable.

Post-Survey Direct Interviews with NRAs

Ten NRAs from 9 countries (Wallonia and Flanders both responded from Belgium) were interviewed in follow-up to the survey. These interviews got into much more detail regarding NRA use of sensors and technologies for data collection, inventory data storage and management, visualisation of asset management data and their current, and potential future, use of BIM. The information below excluded Austria, where some data is still awaited.

Sensors

UAVs / Drones Six NRAs use drones or UAVs, mainly just with camera for bridge inspections, whilst Norway use for bridge and landslide detection. Most of this remains at the experimental / trial stage.

LiDAR All NRAs use LiDAR to some extent, though this is mostly not integrated with AM systems. Some countries use it for ground condition pre-construction, some use for bridge or tunnel inspection and one (Lithuania) use it in part to plan oversize routes.

Internet of Things Not used by any.

Embedded Sensors All but one reported that they used sensors. Common applications were Weigh in Motion, strain gauges on bridges, tunnel sensors and environmental sensors (e.g. temperature etc).

Vehicle / fleet data Most had some sort of trial application though not always for AM purposes, as some were self-driving trials. Three NRAs were working with vehicle manufacturers for condition data and one taking data from snow ploughs.

<u>Software solutions</u> Three NRAs were working on digital twins and AI, one had a 360o camera and one was working with photo recognition.

<u>Future Solutions</u> Two NRAs thought AI had promise. Others mentioned sensors, laser scanning and digital twins.

Inventory Data

<u>Storage</u> All had databases and all but one had a GIS platform. Only one (Flemish NRA) had an integrated BIM database.

<u>Data Sharing</u> Where this was answered, data was shared across the divisions and around half had a data dictionary. For traditional data, most shared it within the NRA and some shared the data externally; none had a data dictionary for this. For bridges and tunnels, of the 5 that answered, all shared within the NRA and two also externally; none had data dictionaries. For fixed sensors, of the five responses, one NRA kept this data only for management, three shared within the NRA and two shared it externally. Again, none had a data dictionary.

Other than NRA use, some data is shared with contractors for maintenance, digitalisation of the paperwork and general access, assuming there are no security implications.

AM produces a result for maintenance planning; all 5 shared this across the NRA with 3 sharing externally. The results were used to plan and prioritize work, but in some cases to report to the Ministry. There were no data dictionaries for this or standardisation / specification of a data dictionary format.

AMS Output Display / Visualisation

All used visualisation to some extent. Of the six responses, all used it for Asset Management, 5 used it for reporting network condition and 5 for operations (not the same 5), 2 used it for public consultation and design collaboration, with one of the two also using it for construction sequencing.

Three collected orthophotos and 3 (not same 3) collected satellite images. One also collected 2D GIS and smart street views. One NRA collected 360o camera views. None could import IRF, although one will be able to it in the future. Three reported they were looking to integrate with BIM.

BIM use

Of the 7 responses, taking Wallonia and Flanders to both represent Belgium, there was an even split of countries where there was / was not a national requirement for BIM.

Most used BIM to some extent, e.g. Wallonia and Flanders didn't have a government requirement for BIM, but it was pushed by the NRA. Mostly, the use was for as built / construction projects and for new projects coming on line. Currently, little AM / maintenance use is in BIM, although this is a future ambition for some. All those who responded saw a benefit to BIM, including having an as-built model, for project information, for collaboration, sequencing and economics. To get to the next stage of BIM, 4 of the 8 NRAs who responded thought that better integration between BIM and AM software was necessary with 2 also requiring BIM software. Three NRAs wanted knowledge as not all people in the organisation were competent, with 1 of the 3 also mentioning the need for change management. Whilst this was only mentioned once, this could be an important success criterion. For support to get to the next level, 5 of the 8 stated they required integrated BIM/AM software, with one suggesting AI. One NRA mentioned requiring more and better data. There were some points raised about the issue of common standards and this was an area of concern to some around the software. One also suggested that the IT sector might not appreciate what was required for asset management.

Figure A8 summarises results of the interviews with the NRAs.

Figure A8: Summary results of the interviews with the NRAs.

	Belgium-Flanders	Belgium-Wallonia	Netherlands	Finland	Denmark	Norway
Use of sensors, technology, software	Some drones, lidar, some WIM stations. Digital twin under construction.	Experimental use of drones for bridges. 3D scanner and embedded sensor for bridges and tunnels. Vehicle / CAV pilot and digital twin pilot.	Wide use of embedded sensors and LiDAR for road, bridges and vegetation. Pilots of fleet vehicles but not for AM.	Dynamic data with snow-ploughs. Piloting photo-recognition.	Trials of drones for bridge inspections. LiDAR rolling out in 2021 with scans and panoramic photos. Contact with vehicle manufacturers for data.	Photo drone for bridge inspections and landslides. Significant LiDAR use. Research use of self-driving vehicles.
Data	AM software, GIS database, BIM integration. Generally data shared with others at NRA	AM software, GIS database with everyone in SPW has access	AM software, GIS database and digital map. Data shared within NRA and sometimes externally	AM. Integration with BIM in 1 - 2 years. Generally, information open for professionals	AM software, GIS database. Separate systems	AM software. National system and local storage
Asset Management Visualisation	Yes, for network condition and AM	Yes, for roads only, for network condition and AM	Yes, at many stages	Yes, for roads and bridges for all stages	Pavement / bridges to be integrated in new AM system	A number of AM systems, some with web interface
Current use of BIM	No requirement but government initiative. Want as-built info for use in management later	No requirement but government initiative.	Government requirement. Tends to be design but not yet full life cycle	Is a requirement. Not fully rolled out for all yet.	Mandatory for all new projects. Not for maintenance. Mandatory for contractors.	Some use in NPRA
Future BIM aspirations	Better integration of BIM and AM, digitalisation of assets so no need to visit site.	To collaborate at all stages. Planning the work. Need knowledge and change management	Need BIM software and better integration of BIM/AM software	For people to see benefit. Integrated BIM/AM software.	Want to strengthen project information. From 2022, BIM required for projects	Several ongoing activities. Project AM, model-based road construction, tunnel management.
Software industry	AWV tend to work with ‘big players’	Fear IT industry might not understand AM	NRA not used to IT and information management	Need international standards	Think they can bring visualisation / gaming capabilities	

Appendix B: Additional information on Legacy Data

ROSANNE (Road Surface Characteristics)

Table 4 of Deliverable 1.1 of the European ROSANNE project (Table B1) shows which devices are used for routine monitoring in different countries and what kind of index is measured by these devices.

Device	Type of index	Countries
SCRIM	Transversal	France, Switzerland, United Kingdom, Belgium, Spain, Portugal, Slovenia
SKM	Transversal	Germany, Switzerland
Odoliograph	Transversal	Belgium
Saab Friction Tester (SFT) and BV11	Longitudinal	Slovakia, Sweden, Hungary
Skiddometer BV8	Longitudinal	Switzerland
GripTester	Longitudinal	France, Portugal, Switzerland
RoadSTAR	Longitudinal	Austria
SRT-3	Longitudinal	Poland
TRT (Tatra Runway friction Tester)	Longitudinal	Czech Republic
DWW	Longitudinal	Netherlands
ROAR	Longitudinal	Denmark

Table B1: ROSANNE (Table 4 of Deliverable 1.1): which devices are in use

several exist indicators For longitudinal unevenness: International Roughness Index (IRI), Notation par Bandes d'Onde (NBO), weighted longitudinal profile (wLP), Evenness Coefficient (EC), the area under the Viagraph, power spectral density (PSD). Table B2 gives a short list for some European countries and illustrates the diversity of indicators in use.

	Indicator(s) for longitudinal evenness
England	IRI
Lithuania	IRI
The Netherlands	IRI, Viagraph area (AUN)
Belgium	EC
Germany	wLP
Austria	wLP
France	NBO

Table B2: indicators for longitudinal unevenness in some European countries

Tables 8, 9 and 10 of Deliverable 1.1 of the European ROSANNE project list the different indicators and thresholds for skid resistance in use in different countries for different types of roads. A sample of which is presented in Table B3.

Country	Device	Type of friction coefficient	Indicator	Threshold values on motorways
France	SCRIM	Transversal	SFC	[0.35 to 0.55] depending on the geometry and the network manager
Switzerland (Vmax > 100 km/h)	Skiddometer BV8 or BV11	Longitudinal	µlocked_wheel	µlocked_wheel = 0.32
Poland	SRT-3	Longitudinal	µ	µ(120 km/h) = 0.37 µ(90 km/h) = 0.42 to 0.44 µ(60 km/h) = 0.46 to 0.48 µ(30 km/h) = 0.52
Slovakia	Skiddometer BV11	Longitudinal	µlocked_wheel	µlocked_wheel(80 km/h) = 0.53
Czech Republic	TRT	Longitudinal	µbraked_wheel	µ(120 km/h) = 0.32 to 0.36 µ(80 km/h) = 0.39 to 0.45 µ(40 km/h) = 0.50 to 0.58
Germany	SKM	Transversal	SFC	SFC(60 km/h) = 0.37 SFC(80 km/h) = 0.32
United Kingdom	SCRIM	Transversal	SC (SC = SFC x 0.78)	SC(50 km/h) = 0.35 (0.30 for low traffic or low risk)
Belgium	SCRIM	Transversal	SFC	SFC(SCRIM) = 0.40
Spain	SCRIM	Transversal	SFC	LFC = 0.50
Portugal	SCRIM	Transversal	SFC	SFC(120 km/h) = 0.20 SFC(50 km/h) = 0.50
Romania	-	-	-	-
Slovenia	SCRIM	Transversal	SFC	SFC(50 km/h) = 0.48 SFC(80 km/h) = 0.39 (not defined in national standard but used in practice)
Denmark	ROAR	Longitudinal	LFC	LFC (60 km/h) > 0.40
Austria	ROADSTAR	Longitudinal	LFC	LFC = 0.45 (warning level) LFC = 0.38 (threshold)
Sweden	SFT or BV11	Longitudinal	LFC	LFC = 0.50 (summer conditions) LFC ranging between 0.25 and 0.35 depending on the road characteristics (winter conditions)
Netherlands	DWW	Longitudinal	LFC	LFC(70 km/h) = 0.42 (porous surfaces) LFC(70 km/h) = 0.39 (dense surfaces)

Table B3: ROSANNE (Table 8): friction indicators and thresholds on motorways

Appendix C: Additional information on Data Dictionary & OTL

England (UK)

The Asset Data Management Manual (ADMM) sets out Highways England's asset data requirements to achieve both its corporate objectives as well as its asset management objectives. When we look at this data dictionary, among the data field descriptions, we for example come across the following collections of data field descriptions:

- Among the condition data for pavements, we find SCRIM investigation data. The SCRIM is a measurement device mounted on a truck specially designed for surveys of skid resistance. Relevant to skid resistance, the data dictionary defines inventory data fields related to the positioning of the road section, the date of construction (and the possibility to note the date on which the section is maintained). There are also some operational data fields such as the exact place that was investigated by a survey, as well as information on the measurement results and the date of the survey. This is completed by a few system data fields for unique identifiers.
- The asset "bridge and large culvert" has a great number of inventory data fields but only the restraint system seems to have operational data fields among which one for a safety performance score.
- Other assets such as road restraint systems (for vehicles and for pedestrians), lightning, drainage (a very extensive list), and technical assets (e.g. traffic signal assets, video assets) are described as well.

Example "skid resistance":

Asset Class	Asset Name	Asset Data Category	Attribute Name	Attribute Description	Attribute Status	Format	Constraint	Domain	Shapefile Field Name
Pavements	SCRIM Investigation Data	Operational	Date of Last Survey	The date the item was most recently inspected (or digitised if from as-built records)	Mandatory	String	DD-MON-YYYY		DATE_OF_SU
Pavements	SCRIM Investigation Data	Operational	Last Survey Date Note		Optional	Date			
Pavements	SCRIM Investigation Data	Operational	SCRIM Investigation Level		Mandatory	String		PV_SCRID_INVESTIGATION_LEVEL	
Pavements	SCRIM Investigation Data	Operational	SCRIM Investigation Level Note		Optional	String			
Pavements	SCRIM Investigation Data	Operational	Site Definition		Mandatory	String		PV_SCRID_SITE_DEFINITION	
Pavements	SCRIM Investigation Data	Operational	Site Definition Note		Optional	String			

Lithuania

The Lithuanian NRA (LRA) has two different information systems. Both are integrated between one another but not with pavement management systems. The first system is the "Eismoinfo" system and contains open data accessible to all. It contains "operational data". The second system is the "Lithuanian State Road Information System" (LAKIS). It contains data about road network inventory, attribute information, information from contractors that provide construction data. For LAKIS a data dictionary is published in a document with the title "Rules for the Provision of Road Data of Lithuanian State Importance" and used for the introduction of additional data to the existing database. Some example of the data specification of qualitative road surface indicators is shown in Figure C1.

70 lentelė. *Kokybinių kelio dangos rodiklių duomenų specifikacija (linijinis objektas* **KokybiniaiDangosRodikliai**)

Eil. Nr.	Atributo pildymas	Pavadinimas	Lauko tipas	Lauko ilgis ir (ar) tikslumas	Klasifikatorius	Pastabos
1.	Privalomas	road	String	10		Kelio numeris
2.	Privalomas	Km	Double	Metro tikslumu		Matavimo vietos pradžios taškas
3.	Privalomas	Kryptis	Integer		D_Kryptis	Iš galimų reikšmių pasirenkama kryptis
4.	Privalomas	VD_Info	Integer			Reikšmės: 0, 1, 2
5.	Privalomas	lane	Integer	4		Juostos eilės numeris, reikšmės 1, 2, 3
6.	Privalomas	dist	Double	Metro tikslumu		Matavimo vieta, kilometrais

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Eil. Nr.	Atributo pildymas	Pavadinimas	Lauko tipas	Lauko ilgis ir (ar) tikslumas	Klasifikatorius	Pastabos
7.	Privalomas	iri_1	Double	Milimetro tikslumu		Matavimo vietos nelygumo vidurkis po kairiu ratu, metrais
8.	Privalomas	iri_0	Double	Milimetro tikslumu		Matavimo vietos nelygumo vidurkis po dešiniu ratu, metrais
9	Privalomas	lrut_1	Double	Milimetro tikslumu		Matavimo vietos vėžės gylio vidurkis po kairiu ratu, metrais
10.	Privalomas	rrut_1	Double	Milimetro tikslumu		Matavimo vietos vėžės gylio vidurkis po dešiniu ratu, metrais
11.	Privalomas	trut_1	Double	Milimetro tikslumu		Prošvaisa, metrais
12.	Privalomas	max_trut	Double	Milimetro tikslumu		Matavimo vietos maksimalios vėžės gylio vidurkis, metrais
13.	Privalomas	curve_0	Double	Milimetro tikslumu		Posūkio kampas
14.	Privalomas	grad_0	Double	Milimetro tikslumu		Išilginis nuolydis, %
15.	Privalomas	slope2_0	Double	Milimetro tikslumu		Skersinis nuolydis, %
16.	Privalomas	mpd_0	Double	Milimetro tikslumu		Šiurkštumas (kairė), cm
17.	Privalomas	mpd_1	Double	Milimetro tikslumu		Šiurkštumas (dešinė), cm
18.	Privalomas	gpsn	Double	Metro tikslumu		Matavimo vietos koordinatė X
19.	Privalomas	gpse	Double	Metro tikslumu		Matavimo vietos koordinatė Y
20.	Privalomas	gpsa	Double	Centimetro tikslumu		Matavimo vietos koordinatė Z
21.	Privalomas	Foto	String	250		Matavimo vietos nuotraukos pavadinimas
22.	Privalomas	def_pl	Double	8		Matavimo vietos defektų plotas, %
23.	Privalomas	Matavo	String	250		
24.	Privalomas	Mat_data	Date			Matavimo data
25.	Neprivalomas	DuomenuSaltinis	Integer		D_DuomenuSaltinis	Iš galimų reikšmių sąrašo pasirenkamas duomenų šaltinis

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Eil. Nr.	Atributo pildymas	Pavadinimas	Lauko tipas	Lauko ilgis ir (ar) tikslumas	Klasifikatorius	Pastabos
26.	Privalomas	Sutartis	String	10		Sutarties numeris

Figure C1: Sample of the Lithuanian data dictionary

Some of the entries in the table define the IRI value for longitudinal evenness (roughness) in left or right wheel track, the depth of rutting in the left or right wheel track, etc.

Flanders (Belgium)

In the last few years, the Flemish NRA invested significant effort in setting up the conditions for the introduction of BIM. In particular, the Flemish NRA organised consultations of a wide range of stakeholders, resulting in the definition and publication of an OTL. This OTL is now used for the creation of BIM models in the frame of maintenance contracts of several projects. The measurements and laboratory tests that are typically performed during and after the realisation of road works are foreseen in the OTL. The OTL does not yet foresee the representation of the data as they are used and manipulated in the stand-alone PMS software and PMS database but this is under development.

The Flemish NRA (AWV) recently started developing an OTL that it imposes for a part of the contracts for asset maintenance or asset renewal (10% of all contracts in 2020 and increasing). The initiative is taken by the NRA and is motivated by an improvement of the management of asset data. By the introduction of a BIM-oriented data management of the assets, the NRA intends to obtain and keep as-built asset data that can be used and reused for maintenance of the assets. At AWV, as is the case for many NRA's throughout Europe and beyond, the existing asset data are distributed over different departments and saved in several databases or in paper files stored in the archives. In some cases elementary data on existing assets were lost. AWV decided to define what are the relevant data that are really needed about the assets and defined these in their new OTL. One of the important strengths of the OTL of AWV is that it is easily extendible.

In order to identify the information that is needed for asset management, the developers of the OTL sat together with the managers of each of the assets. This represents a huge effort that has mobilised a very large number of personnel of the NRA. The OTL is considered as the only valid definition of asset data that will be used and managed in future.

Of course, the existing data have to be integrated into the new BIM-driven database. The OTL integrates the possibility to link to external databases and applications but for the internal data management AWV chose another solution. Rather than setting up links between different databases with different formats, it was decided to migrate the existing data into the new BIM-driven database. The advantage of this approach is that there is no future need for maintenance of links between old databases and the new one.

When drawing up the OTL, the structure and availability of existing data was not taken into account. The OTL defines the data that the NRA wants or needs to capture from a "to be" perspective: the data needed for the lifecycle of an asset, modelled in the OTL. The definition of the OTL is not inspired by obsolete databases and does not adopt existing data models. Indeed, the old databases do not comply, contain defective information, do not contain the necessary lifecycle information, and offer too limited visibility in Asset Management.

Consequently, mapping the existing data is sometimes complex and asks for combining decentralized or centrally managed data from different sources, some of which are analog rather than digital. Permanent linking is not possible for the decentralized and analog data sources because these sources are not accessible, so they must be converted to the new model. For central databases, a dynamic mapping could be used to phase out the old systems, but these mappings are usually complex and often also require manual interventions and corrections. The NRA estimates that such automatic linking mappings are only realistic for 80% or less of the data. Therefore it was decided to directly convert also these data into the new data model.

Since the development of the all-covering OTL, the setup of interfaces to the new BIM-driven database and the migration of existing data takes a huge effort, priorities were set. Tunnels received a very high priority since the use of BIM is extremely beneficial for the implementation of the strict safety regulations for tunnels. Both in the maintenance of tunnel assets and in day-to-day operational management of traffic in tunnels, a BIM-driven asset database is very useful since it increases efficiency of work processes. For some tunnels, huge numbers of old drawings on paper were transformed in 3D-models. These models were then compared to point clouds collected with Lidar. The result is a collection of 3D-BIM models of tunnels where some assets are modelled in detail when the management of the asset can benefit of the detail and other assets are modelled in lesser detail. The decisions on which detail is useful, was made during the consultation meetings between the developers of the OTL and the tunnel managing team of AWV. The level of detail of the asset data is reflected in the OTL and the BIM-models respect the OTL. Hence, the BIM-models are of lesser importance that the database behind it.

Bridge management could benefit in a similar way as tunnels from the BIM-driven database but for bridges the development of the OTL is still in an earlier phase.

Although pavement management and traffic management on carriageways can also benefit from BIM-driven data, the existence of a network-wide 3D-model of roads is less critical. For new pavement maintenance operations, some BIM-driven data are requested for but mainly for storage of as-built information on the pavements. For pavements, the OTL is defined for everything related to the standard tender documents of AWV so that as-built information in BIM-format (respecting the OTL) can be requested in a standard way through a standard tender.

Other assets like electronic assets (e.g. VMS, street lightning), road signs, etc. are also integrated in the OTL. More abstract objects in the OTL architecture allow further development of the OTL and the BIM-driven database.

Still missing in the OTL is a real OTL-description of data flows. The data flows itself are identified but the format of the data that flow from one OTL-object (asset) to another OTL-object (asset) is not yet defined. However, the OTL architecture allows the introduction of OTL-definitions of formats of flowing data. Once this is added, this will open the gate to better storage and analysis of flowing data. An example of a data flow is the information that comes from an air quality sensor in a tunnel and goes to the PLC that controls the activation of the ventilation system in the tunnel.The vocabularia (and the OTL) describe many notions that allow building a model of the assets related to carriageways (e.g. layers in a pavement, road markings) and equipment (e.g. traffic lights, traffic sign). It also includes objects related to data collection (e.g. test of roughness, test of skid resistance, condition of a tree, test on a traffic sign after placement), at different levels of abstraction.

The gradual official publication of the extension of the vocabularia and OTL to bridges and tunnels is expected in the forthcoming months: these are currently in a final test phase, where the descriptions and specifications are already used for a few BIM models of tunnels.

Example of skid resistance in:

The skid resistance (“stroefheid”) is a property (“eigenschap”) for the inspection test (“proef”) on skid resistance or on markings (“markering”).

Eigenschap *stroefheid*

Type	Eigenschap
URI	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefStroefheid.stroefheid
Domein	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefStroefheid
Bereik	https://wegenenverkeer-test.data.vlaanderen.be/ns/implementatieelement#DtcDocument
Definitie	Proefresultaten van de stroefheid.

Eigenschap *stroefheid*

Type	Eigenschap
URI	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefMarkering.stroefheid
Domein	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefMarkering
Bereik	https://wegenenverkeer-test.data.vlaanderen.be/ns/implementatieelement#DtcDocument
Definitie	Proefresultaten van de stroefheid.

The class ("klasse") is an abstraction for the common properties of the inspection test for skid resistance.

Klasse *Proef stroefheid*

Type	Klasse
URI	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefStroefheid
Definitie	Abstracte voor de gemeenschappelijke eigenschappen van de stroefheidsproef.

This class is used in two other classes: the one making the abstraction for common properties of newly built bituminous or concrete pavement top layers and the one making the abstraction for common properties of newly built other pavement layers.

Klasse *Proef a posteriori bitumineuze cementbeton laag*

Type	Klasse
URI	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefAPosterioriBitumineuzeCementbetonLaag
Specialisatie van	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefLangsvlakheid https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefStroefheid https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefVlakheid
Definitie	Abstracte voor de gemeenschappelijke eigenschappen van de proef op een bitumineuze en een cementbeton verhardingen na de werken.

Klasse *Proef a posteriori andere laag*

Type	Klasse
URI	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefAPosterioriAndereLaag
Specialisatie van	https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#Proef https://wegenenverkeer-test.data.vlaanderen.be/ns/proefenmeting#ProefStroefheid
Definitie	Abstracte voor de gemeenschappelijke eigenschappen van de proef op een andere laag na de werken.

Currently the skid resistance is only considered for the acceptance of newly built pavement layers. It is not yet extended to the application of regular monitoring of existing pavement sections for pavement maintenance purposes. The skid resistance data collected during the regular monitoring programme for the whole road network is stored in a separate database and is not (yet) disclosed through the data dictionary and OTL.

The Netherlands

The NRA opts for the use of BIM in the design and construction phase – to which the OTL is destined - but considers that the as-built models are too rich for being used in their totality for asset management purposes. However, part of these models are considered as useful for asset management. Hence, Rijkswaterstaat (RWS) sees a need for a master data dictionary containing the select group of asset data that can be used for asset management purposes. In future, these data could then be accessed – in the form of linked data – for asset management purposes. The asset management itself is seen as an operation based on separate, dedicated tools and software, and based on additional data that are not necessarily linked to the BIM models.

The CEDR Technical report 2017-05 "Utilising BIM for NRAs" states that since 2012 a large BIM program is going on at RWS. It focuses on asset information in control and information flow in control. The strategy is to directly test results in the largest road infrastructure projects. The information delivery and professional interactions (process, roles) are described in the contract. Besides that, there is a national BIM Program with involvement of all stakeholders like governments, architects, building companies, consultancy firms and installation sector (Building Information Council). BIM is seen as a motor for the Building sector in the Netherlands. There are 3 types of activities: Information technology (open BIM standards), management and organization and cultural restrains. It takes place in connection with Building Smart International (project IFC alignment and BSdd).

The OTL-Rijkswaterstaat can be found at:: https://otl.rws.nl/publicatieomgeving.

9 Acronyms and sources

No	Acronym	Title	Notes (e.g. relevant aspects)
1	AM4INFRA	Common framework for a European Life Cycle based Asset Management approach for transport infrastructure networks	https://am4infra.eu/
2	INTERLINK	Information management for European roads using linked data	Construction phase data dictionary
3	buildingSMART	Worldwide industry body driving the digital transformation of the built asset industry	https://www.buildingsmart.org/
4	ASCAM	Asset Service Condition Assessment Methodology	Project results of the ASCAM ERANet ROAD project at: https://www.cedr.eu/strategic-plan-tasks/research/era-net-road/call-2010-effective-asset-management-meeting-future-challenges/ascam-project-results/
5	HeROAD	Holistic Evaluation of Road Assessment	HEROAD project results: https://www.cedr.eu/strategic-plan-tasks/research/era-net-road/call-2010-effective-asset-management-meeting-future-challenges/heroad-project-results/
6	PREMiUM	Practical Road Equipment Measurement, Understanding and Management	PREMiUM project results: https://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2014/call-2014-asset-management-maintenance/premium-project-results/
7	PROCROSS	Development of Procedures for Cross Asset Management Optimisation	Project results of the PROCROSS ERANet ROAD project at: https://www.cedr.eu/strategic-plan-tasks/research/era-net-road/call-2010-effective-asset-management-meeting-future-challenges/procross-project-results/
8	CEDR TR 2017-05	Utilising BIM for NRAs	Technical Report of CEDR
9	InfraFINBIM		a large R&D project in Finland in 2010, giving rise to the InfraModel, work continued under buildingSMART Finland: http://buildingsmart.fi/infra/inframodel/index.html

No	Acronym	Title	Notes (e.g. relevant aspects)
10	MINnD	Modélisation des INformations INteropérables pour les INfrastructures	French national project: http://www.minnd.fr/
11	Austroads	the peak organisation of Australasian road transport and traffic agencies.	Austroads Publication No. AP-T334-18, June 2018 defines a data standard
12	IABMAS	International Association for Bridge Maintenance and Safety	Published a glossary of bridge terms and a report on bridge management systems in use (http://www.iabmas.org/)
13	ROSANNE	Rolling resistance, Skid resistance, and noise emission measurement standards for road surfaces	European Collaborative project in the Seventh EU Framework Programme on road surface characteristics: http://rosanne-project.eu/
14	ERPUG	European Profiler Users' Group	Organizes a yearly event with exchanges/presentations on recent developments and use of measurement devices primarily evaluating road profile (https://www.erpug.org/)
15	HDM (III, IV)	Highway Development and Management	PMS software (https://www.piarc.org/en/PIARC-knowledge-base-Roads-and-Road-Transportation/Road-Safety-Sustainability/Road-Assets-Management/HDM-4-Software)
16	PIARC	World Road Association	World organisation, sets up technical committees (https://www.piarc.org/en/) on several topics (e.g. tunnel safety, pavement monitoring and management, and much more)
17	JTR	Journées Techniques de Routes	Conference in French organised on a yearly basis in Nantes (France) in February (mainly oriented to a French audience): https://jtr.ifsttar.fr/
18	INSPIRE		Directive of the European Commission on spatial data (https://inspire.ec.europa.eu/)
19	JRC	Joint Research Centre (of the EU)	2019 JRC Science for Policy Report "Research and innovation in bridge maintenance, inspection and monitoring" (ISBN 978-92-76-03379-0): https://ec.europa.eu/jrc/en/publication/research-and-innovation-bridge-maintenance-inspection-and-monitoring
20	COST action 354	Performance Indicators for Road Pavements	http://cost354.zag.si/ : final report of the action and database
21	SeRoN	Security of Road Transport Networks	European project: classification of bridges and tunnels: article "Identification and Classification of European Bridge and Tunnel Types", Ingo Kaundinya and Frank Heimbecher, 35th Annual Symposium of IABSE / 52nd Annual Symposium

No	Acronym	Title	Notes (e.g. relevant aspects)
			of IASS / 6th International Conference on Space Structures, London, September 2011
22	Sustainable Bridges	Sustainable Bridges - Assessment for Future Traffic Demands and Longer Lives	European project: Deliverable 9.2 of the project (https://cordis.europa.eu/project/id/1653)
23	COST action TU1406	Quality specifications for roadway bridges, standardization at a European level	https://www.tu1406.eu/
24	ARUP	Private firm	On bridge renovations and BIM in The Netherlands: https://www.arup.com/projects/rijkswaterstaat-bridge-renovations
25	ADMM	Asset Data Management Manual	Highways England asset data requirements
26	CDBB	Centre for Digital Built Britain	https://www.cdbb.cam.ac.uk/
27	LAKIS	Lithuanian State Road Information System	
28	NVDB	National road database in Sweden or Norway	Sweden: http://www.nvdb.se/en Norway (data dictionary): https://www.vegvesen.no/fag/teknologi/nasjonal+vegdatabank/datakatalogen.
29	OKSTRA	Objekt katalog für das Straßen- und Verkehrswesen	German project, http://www.okstra.de/forschung/linked-data_EN.html , developed an object catalogue
30	CB-NL	Concepten-Bibliotheek Nederland	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 (in The Netherlands)
31	OTL-RWS	Object Type Library - Rijkswaterstaat	OTL defined by the NRA of The Netherlands
32	ARAN	automatic road analyzer	Multifunctional monitoring vehicle
33	LCMS	Laser Crack Measurement System	Equipment often installed on multifunctional monitoring vehicles
34	Aigle		Multifunctional monitoring vehicle (France, CEREMA)
35	RoadSTAR		Multifunctional monitoring vehicle (Austria)
36	VAMOS		Multifunctional monitoring vehicle (Wallonia, Belgium)

No	Acronym	Title	Notes (e.g. relevant aspects)
37	LiDAR	Light Detection and Ranging	
38	SCRIM	Sideway-Force Coefficient Routine Investigation Machine	Monitoring vehicle for skid resistance
39	SKM	Seitenkraftmessverfahren (Sideway Force Traction Measurement System)	Monitoring vehicle for skid resistance
40	GPR	Ground Penetrating Radar	For investigation of underlying structures (layers of road structures, bridge decks, tunnel walls, cable and pipe detection, etc.)
41	FWD	Falling Weight Deflectometer	For evaluation of bearing capacity of roads
42	TSD	Traffic Speed Deflectometer	For evaluation of bearing capacity of roads
43	VMS	Variable Message Signs	
44	AADT	Annual Average Daily Traffic	
45	ITS	Intelligent Transport Systems	
46	WIM	Weigh in Motion	
47	RWIS	Road Weather Information System	
48	CCTV	Closed-circuit television (video surveillance)	
49	ANPR	Automatic Number Plate Recognition (camera system)	
50	SHM	Structural Health Monitoring	Monitoring of bridges
51	AMS	Asset Management System	
52	PMS	Pavement Management System	
53	BMS	Bridge Management System	
54	IADD4UK	Infrastructure Asset Data Dictionary Group for the UK	http://www.comit.org.uk/iadd4uk
55	ISO	International Organization for Standardization	https://www.iso.org/