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Asset information management for European roads using linked data

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Abstract

European National Road Authorities recognise that an inadequate or inaccurate information asset leads to higher capital and operational expenditure on physical assets. By gathering data throughout the life-cycle of assets, asset owners and managers create so-called 'digital twins', to enable them to optimise their assets' performance and operation. With these virtual replicas of their assets they can liberate data from legacy/proprietary computer applications and thereby reuse it for making better decisions. The INTERLINK consortium seeks to enable this asset information challenge. This paper reports the first results of the ongoing INTERLINK project: the business and information needs of asset managers and the common principles for modelling so called object-type libraries. These principles will be tested in three cases and will lead to a basic version of a European road object-type library. This will allow for a new approach towards standardisation of information exchange and sharing in the industry, based on evolutionary, bottom-up development and reuse of best practice whenever possible.

Keywords: asset information management; digital twin, object-type library; linked data.

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Nomenclature

BIM	Building Information Modelling
bSI	buildingSMART International
CEDR	Conference of European Directors of Roads
GIS	Geographic Information Systems
INTERLINK	INformation managemenT for European Roads using LINKed data
NRA	National Road Authority
OTL	Object-type Library

1. Introduction

This paper addresses a main challenge in road infrastructure: asset information management. Asset managers are generally aware of the value of the information they are gathering during the assets' life-cycle. However, today this information is often not easily reusable. The ongoing INTERLINK project seeks to overcome this challenge.

1.1. The asset information challenge in road infrastructure

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

From the time when the strategic need for a new road is identified, through design, construction and operation, a large amount of information relevant to the road assets is developed. The set of information about these physical assets is also an asset and European NRAs recognise that an inadequate or inaccurate information asset leads to higher capital and operational expenditure on physical assets. Likewise, NRAs are aware that effective acquisition and management of information incurs significant costs. These costs, predominantly transactional, are exacerbated by insufficient interoperability between stakeholders' information management systems.

1.2. The CEDR INTERLINK project

The Conference of European Directors of Roads (CEDR) seeks to improve interoperability by embedding the use of asset information management (a.o. building information modelling (BIM), geographical information systems (GIS) and systems engineering), based on open standards, into the life-cycle processes of road infrastructure. Through its Transnational Road Research Programme, CEDR has commissioned the INTERLINK consortium to design and test an open, scalable, future-proof, basic object-type library (OTL) to facilitate improved interoperability. The term OTL will be elaborated further in chapter 3. For the first chapters it is sufficient to understand that an OTL describes the structure of the data that has to be shared in a specific domain, in this research European roads. The INTERLINK consortium comprises a research institute (TNO from the Netherlands), engineering and asset management consultants (Roughan & O'Donovan from Ireland and Royal HaskoningDHV from the Netherlands), ICT consultants and software companies (AEC3 from Germany, Trimble from Norway, interactive instruments from Germany, and Semmtech from the Netherlands), and a national BIM implementation body (planen-bauen 4.0 from Germany).

The main objectives of the INTERLINK research are:

- To explore the procurement of road asset information by NRAs for better asset management;
- To investigate suitable data structures for asset information;
- To develop common principles for a European Road OTL; and
- To design and test a basic European Road OTL connected to existing open standards.

By achieving this, INTERLINK will support asset owners and managers to create so-called digital twins of their assets. The term digital twin has been around since 2002 and has many definitions. In general, a digital twin is a virtual model of a process, product or service (Marr, B., 2017). For the construction industry, the digital twin is meant to be an up-to-date and accurate copy of the asset's properties and states, including shape, position,

gesture, status and motion. A digital twin can be used for monitoring, diagnostics and prognostics to optimize asset performance and operation (Wikipedia, digital twin).

The CEDR INTERLINK project will define a European Road OTL with three supporting pillars to optimise the success of subsequent implementation:

- A quality Technical Specification, how to describe the structure of the data of the digital twin;
- A suitable and sustainable Standardisation Body, with a plan for development beyond this project; and
- Acceptance in Practice by the industry through engagement and dissemination.

1.3. Status of the project and reading guide

The INTERLINK project started in September 2017 and will take two years. At the time of writing of this paper, in September 2017, the INTERLINK project just completed its first year successfully. The first two work packages investigated and elicited the typical needs of project managers and asset managers, both from a business and a data perspective. The results are summarized in chapter 2. Based on the business and data needs, and on experience of the consortium members in previous projects, the term OTL is elaborated further and common principles for a European Road OTL were defined (see chapter 3). In parallel, three test cases were defined and agreed upon with the national road authorities (see chapter 4). Chapter 5 describes the expectations for the second year of the project.

2. Needs statements of asset managers

Underpinning the three pillars—Technical Specification, Standardisation Body, Acceptance in Practice—is a thorough understanding of the NRAs' typical needs for the management and use of asset information from a business and a data perspective. The business and data needs were investigated through a literature review, stakeholder interviews and an industry survey. This process resulted in a set of requirements for road asset information management, represented as 36 needs statements (O'Keeffe, 2017). These statements will be used to inform and steer the development and validation of a basic European Road OTL.

2.1. The as-is condition

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

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

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

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

2.2. Needs statements

The research process described above facilitated the development of two sets of needs statements, representing the business needs of NRAs for the management of asset information, and the data needs necessary to meet those business needs. The full list of needs statements is provided in the publicly-available INTERLINK report from the first phase of the project (O'Keeffe et al., 2017). Selected statements follow for example:

- Road asset information systems should be based on open information management standards.
- At the outset of a project, asset owners / managers should define their information requirements for each asset type, using established standards where possible.
- Asset information systems should enable access to information through GIS.
- Relevant asset information should be gathered and updated systematically over the life-cycle of an asset, from its inception through design, construction, inspection, maintenance, and renewal.
- Contractors should be required to handover to the asset owner a set of quality assured, certified as-built graphical and non-graphical information.
- Non-graphical information (e.g. specifications, material test results) should be linked to defined objects.
- Asset information should be based on the same integrated information standards for all life-cycle stages, from strategic planning through to operation and maintenance.

2.3. Recommendations after the first phase of the project

The first phase of the research enabled the INTERLINK consortium to identify various recommendations. Firstly, the verified business and data needs should underpin the principles for the European Road OTL. Secondly, various existing and forthcoming international and national data standards and initiatives should be considered for integration with the European Road OTL. These recommendations were adopted for the subsequent research phase completed in September 2017 and described in chapter 3 below. Thirdly, the test cases for the final phase of the project should focus on use cases of business value across Europe, including the reuse of existing asset information, and the handover of information from construction to asset management.

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

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

3. Common principles for the European Road OTL

This chapter describes the solution the INTERLINK consortium proposes to the NRAs: the European Road object-type library (OTL). It first elaborates on the term OTL in general, followed by the rationale behind a European Road OTL for NRAs and its requirements and common principles. The chapter concludes with a high-level roadmap for the further development and implementation of the European Road OTL.

3.1. Definition of object-type library

An object-type library (OTL) is a key concept in INTERLINK. Like the term digital twin, it has many definitions. In general, an OTL is an abstract, shared view of a part of reality to be represented for some specific purpose. More practically, an OTL is a set of declared or defined object-types, attributes, relationships and constraints. An OTL can be used as the data structure of the digital twin to control the actual asset data that are being dealt with in applications, shared in asset management processes and managed by asset owners. These data have the object-types as their type and values and references for the defined properties and relationships. The constraints can be utilized to validate the data, i.e. determine whether they comply to the OTL.

A small example clarifies these abstract concepts. A contractor has a performance-based maintenance contract with an NRA to inspect certain roads, road barriers and lighting systems. When the contractor identifies issues (like pavement failures) it notifies the NRA. Each notification is modelled according a data structure shared between contractor and NRA, e.g. an OTL with "issue" as the main object-type having several attributes such as the kind of issue, severity level, and planned repair date. The issue also includes a link to the affected object, e.g. a road segment in the network. A constraint could be that each issue has exactly one responsible party defined.

An OTL is thus a library with standardized object-types, properties and relationships. An object is described with its object-type data, geometry data and metadata. Metadata are data (or information) about the data of objects, e.g. who created the data, when and with what purpose. By using an OTL, assets are described with a standard language, syntax and semantics, which are required for a reliable exchange and sharing of information.

In this research the domain is roads, therefore the OTLs will contain road related object-types such road, road segment, road axis, viaduct, sign, and gantry. A Road OTL can be used to fully define a view on the assets related to roads. Many views are possible, from a software application, from a company, from a country and also from an international context, each with their own scope of application (V-Con, 2016).

3.2. Rationale behind a European Road OTL for NRAs

As explained earlier, several NRAs are already improving their asset information management, each with their own focus and embedded in their national practice. Some are already using dedicated Road OTLs, others focus on BIM and national classification systems. It was observed that many specifications of OTLs exist as partial solutions on international, European, national and company level that solve, or try to solve, part of the issues mentioned above. They can be regarded as pieces of the data puzzle that need to be harmonized and aligned before they can fit. Pieces are e.g. open BIM standards like the Industry Foundation Classes (IFC) and the buildingSmart Data Dictionary (bSDD) from buildingSmart International (bSI), and open GIS standards like (City)GML from the open geo-spatial consortium (OGC). Both BIM and GIS tend to focus on geometry data which led to the need to develop more meaningful object-based OTLs in several countries like COINS/CB-NL in the Netherlands, OKSTRA in Germany and CoClass in Sweden. Examples of company-specific OTLs are RWS-OTL for the Dutch NRA and ANDA for the Swedish NRA. These OTLs unfortunately use different underlying systems including different modelling formats, languages and modelling styles, and typically overlap in their intended meaning.

To improve asset information management in an economically viable manner, the solution for the NRAs is to extend and align the use of Road OTLs on the company, national and European level. A prerequisite for NRAs and industry is the continued use of existing open standards and company specific or national classification systems. Each of these standards can be seen as a part of an OTL framework, describing the data structure of a part of the domain. When such a standard is shared publicly, it can be considered an 'open standard'.

Ideally, the company, national and international OTLs form a harmonized framework of OTLs, to allow for best practice sharing and optimising of modelling and implementation efforts. Those concepts that are shared between several OTL on a specific level, are candidates for a shared OTL on a higher level. For example, when several national OTLs describe the geometry in road designs, a shared geometry OTL could be placed on the international level. Sometimes such a shared OTL already exists, e.g. in the IFC standard with its geometrical description of 3D road alignments. As IFC is an open standard, widely supported by road design software vendors, NRAs would like to use it as part of their OTL framework rather than developing their own geometrical data standard. Another value of the harmonized framework of OTLs is that one NRA wants to reuse (part of) the OTLs of another, more advanced NRA. This approach allows for maximum reuse of parts of the OTLs that NRAs are in agreement about or that are already well established in the sector.

Typically, a NRA strives for a nationally standardised OTL prescribing the asset information the industry needs to deal with, maximising the reuse of existing and well-established national and international standards. To allow the CEDR members and their supply chain partners to share best-practice and optimise modelling and implementation efforts, INTERLINK proposes to establish a common European road OTL—the European Road OTL—that contains that part of the OTLs for road assets upon which the NRAs in Europe agree. The European Road OTL, with a standardization body to manage it, can be used operationally in asset management for roads by using the standardized definitions of road assets with standardized specifications. These standardized specifications of assets make a 'lean', efficient and effective collaboration possible, thereby leading to improved outcomes for road asset management. Furthermore the European Road OTL can function as a blueprint for other countries to start work with (giving them a head start) or for existing national OTLs to harmonize and align their views.

The first predominant expected benefit of this approach is a reduction in transaction costs throughout the life-cycle of asset information. Subsequent benefits will result from applying the digital twin to optimise performance of the assets, especially maintenance and operation. A third benefit is that it stimulates the European open construction market.

3.3. Requirements for the European Road OTL

INTERLINK's first basic version of the European Road OTL targets the identified NRAs' asset information management needs and issues (see chapter 2). From the discussion in the previous sections it can already be derived that there is not just one OTL for some part of reality. There are many purposes, each requiring their own view on reality having their own OTL. In INTERLINK the part of reality of interest is road networks, with three main dimensions observed during the analysis of the needs:

- The life-cycle of an asset: plan, design, build and operate (covering realization, maintenance, renovation, and repurposing);
- The supply-chain for an asset: environment, network, entity, system/sub-system, component and material; and
- The perspectives on the asset's data by the various stakeholders: societal, business, functional, spatial and physical aspects.

The first two dimensions are depicted in the Figure 1, which is based on the well-established V-diagram for asset management (Institute of Asset Management, 2016).

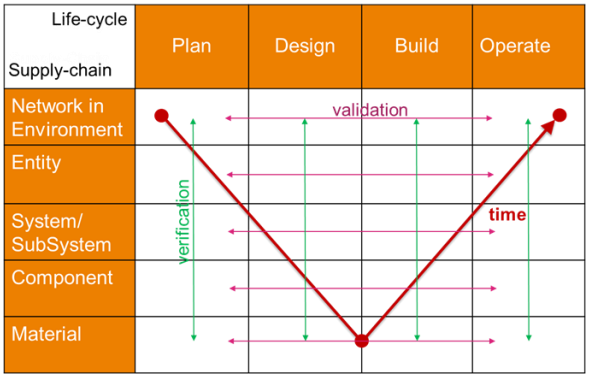

Figure 1: The life-cycle and supply-chain dimensions of asset management

The general information need is that NRA asset data along these dimensions should be (i) better specified: better structured, more complete, more accurate, less ambiguous, up-to-date, consistent, uniformly represented and (ii) better communicated and reused. This should apply along the asset's whole life-cycle and supply-chain. Better communicated here means 'shared with others by linking' instead of 'exchanged to others by conversion', keeping data close to their original source and avoiding cumbersome and error prone data transformations.

3.4. A shift with the INTERLINK approach

The INTERLINK approach is to found the European Road OTL on the technologies of linked data and the semantic web provided by W3C—the world wide web consortium. This choice was the main conclusion from the European research project V-Con (V-Con, 2016) and is in line with developments towards linked data in the industry's main standardisation body buildingSMART International (buildingSmart International, 2016). These W3C technologies will enable CEDR and its NRA members to implement a data-driven and open (vendor-neutral) system, which is applicable to the whole life-cycle of road assets, and accommodates various existing and future open data standards. In this way the European Road OTL will facilitate a hybrid approach of linking semantically-rich data to more traditional document-based information. Ultimately, INTERLINK envisages that road asset data will remain at their source, shared over the web through a system of harmonised OTLs with strengths from the international, national and company levels, and interrogated via flexible, software-as-a-service applications. The INTERLINK approach focuses on the commonalities of the national approaches and allows for national differentiation when considered necessary.

3.5. Common modelling principles for the European Road OTL

The linked data term for an OTL is an ontology.

The common principles describe this hybrid approach combining the strengths of currently applied open standards with linked data / semantic web technology. Bringing the available OTLs together in a harmonized framework requires a set of modelling and implementation principles to reuse and interconnect those OTLs. INTERLINK defined, in line with the European V-Con project and the bSI Linked Data Working Group, the following types of guidelines:

- Many languages/formats, styles and meanings are potentially relevant for dealing with road data. Hence, INTERLINK proposes a so-called hybrid approach, related to hybrid formats ('multiple languages'), hybrid styles ('multiple ways of modelling') and hybrid specifications ('multiple views').
- The W3C linked data / semantic web technology enables the realisation of this hybrid approach using:
  - Resource Description Framework (RDF) as basic language or 'data model' and vocabulary;
  - RDFS/OWL/SHACL as standard vocabularies to defines object-type libraries; and
  - SPARQL as query language for accessing the linked data.
- Recommendations for modelling styles with linked data:
  - How to model attributes, enumerated data types, code lists, quantities and units; and
  - A simple and a powerful modelling style are defined.
- Detailed technical modelling and implementation guidelines dealing with a.o. naming conventions, version management, and precise linked data formats to be used.
- Guidelines on linking data sets and OTLs making data sharing possible beyond the traditional data conversion, which results in unwanted duplicates of data with unclear ownership (Figure 2).

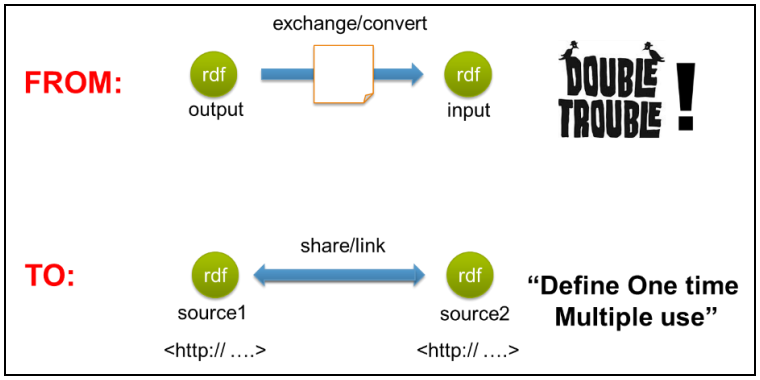

Figure 2: Towards sharing of data without duplicates

3.6. Roadmap for development and implementation of the European Road OTL

In the roadmap for development and implementation of the European Road OTL three periods are distinguished:

- Short-term: during the life-time of INTERLINK, a proof-of-concept of the approach will be developed by starting to use some of the selected OTLs in three test cases. Based on the experiences from the cases, a basic European Road OTL as a combination of (parts of) those used OTLs will be proposed (Figure 3).
- Mid-term: after the project, NRAs can start nationally themselves with the linked data approach and the suggested basic European Road OTL, adapting it to their own needs, and sharing experience with other NRAs. In the course of time, when commonalities become clear, they are promoted to the European Road OTL. The European Road OTL is also a blue print for countries starting to develop a national OTL.
- Long-term: NRAs use their influence in relevant standardization bodies (e.g., ISO, CEN, W3C, bSI) to promote the approach and specifically the European Road OTL.

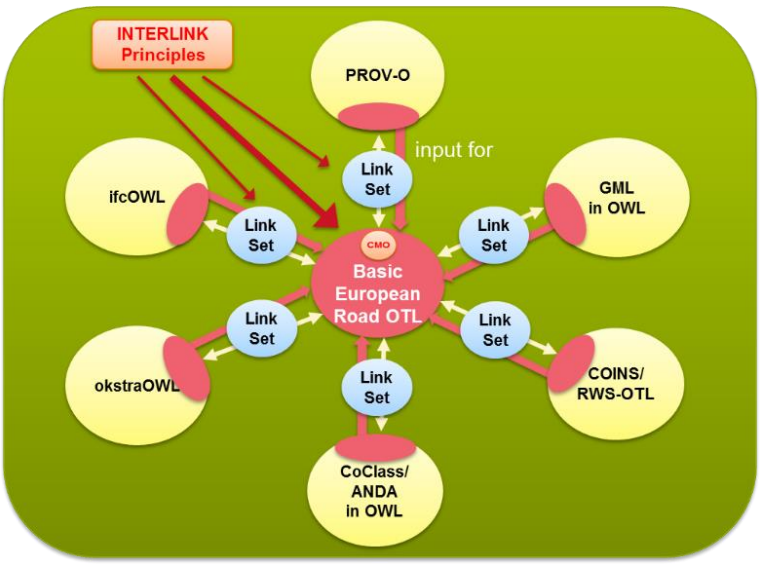

Figure 3: Defining a basic European Road OTL

4. The specification of the three test cases

In the second year of the project, the proposed approach will be thoroughly tested via three test cases. The objective of the test cases is proving the concept in realistic business processes that the proposed European Road OTL and the associated open standards can be efficiently implemented in practice. This will be achieved by testing the developed and implemented OTL framework for consistency with the needs statements derived in the first phase. At the time of writing this paper, in autumn 2017, the three cases were specified following a generic test case approach. These plans are decribed briefly in this chapter. At the conference in spring 2018, the first results of the test case execution will be presented.

4.1. The German test case

An existing bridge in Hamburg is due for demolition and replacement. The design team and NRA aim to use BIM processes during the design stage and specify the handover of BIM-based asset data at the end of construction. The test case will involve linking selected bridge objects represented in international and national data standard formats (IFC and OKSTRA, respectively) with document-based information, e.g. calculations or specification, with road alignment data, and with provenance data. Testing will entail the finding, viewing and interrogating asset object data through various front-end systems.

4.2. The Nordic test case

Pavement management on a road network requires extensive inspection, recording and analysis of pavement conditions to facilitate effective decision making regarding maintenance expenditure. Value can be derived from having improved understanding of the relationships between design standards, traffic volumes, alignment geometry and location, as-built surface geometry, pavement condition, and pavement deterioration models. The test case seeks to link data from some of these related domains using international data standards such as IFC Alignment and InfraGML and national standards such as SOSI (Norway) and CoClass (Sweden). National asset management database systems will be used along with commercially available modelling software.

4.3. The Dutch test case

As for the Nordic case, the Dutch test case will focus on pavement management. The test case will reflect the activities by a pavement asset owner of reviewing as-built records and pavement inspection records to determine maintenance requirements. The case will use international data standards such as GML and INSPIRE along with national data standards and OTLs such as COINS, CB-NL and the RWS-OTL. Objects representing pavement segments will be linked with data on repair records, pavement performance, and accident records. The validation of repair and performance records is important for future trust in the data. As such, provenance data will be linked to selected records by way of demonstration.

5. An outlook into the second year of the project

At the time of writing the paper, in autumn 2017, the common principles for the European Road OTL were defined and the three cases were specified. This chapter gives an outlook into the second year of the project.

5.1. Test cases

The three test cases will be conducted from September 2017 until August 2018. Three test teams will use existing software tools and selected datasets provided by the NRAs. The test cases aim at proving the concept of the approach with OTLs based on the defined common principles. The development of OTLs in the test cases will be supported by a linked data and semantic web environment, which also supports publishing and deployment of the OTL in the test cases. This enables a feedback-driven (bottom-up) approach. This approach is in line with the agile scrum-like development process in which small, but manageable, steps are taken in interactive specification – development – testing cycles. In each case, testing will require integration between end-user interfaces for loading and querying data, and a back-end plaform-as-a-service linked data room for storing the data, the links and references, and the OTLs. At the conference in spring 2018, the first results of the test case execution will be presented.

The result will be a proof of concept of a software vendor-neutral and open system, which will eventually be applicable to the whole life-cycle of infrastructure assets, relevant to all stakeholders, and focused on data sharing. The powerful semantic web technology will be applied to demonstrate how to express infrastructure asset object-based information and knowledge on a European level. Being able to integrate and reuse existing and forthcoming open standards in flexible ways will minimise obsolescence of earlier investments by NRAs.

5.2. Development of the basic European Road OTL

As explained in section 3.6 in the roadmap for the European Road OTL, its first basic version will be developed based on the experiences from the test cases as a combination of (parts of) the specifications of OTLs used in the test cases (Figure 3). Those OTLs that were implemented successfully in the test cases and that show relevance to other cases in other countries will be made part of the first basic European Road OTL. The resulting European Road OTL will be documented and made available for reuse by others, starting with the NRAs involved in the INTERLINK project. When NRAs are reusing, and where necessary updating, OTLs of others, the OTLs will mature step-by-step in an evolutionary, feedback-driven approach.

5.3. Dissemination and implementation

During the INTERLINK project the results will be shared as much as possible, starting with the NRAs involved in CEDR, and to any other interested organisation. This dissemination will be continuous via the website, www.roadotl.eu, on which the latest deliverables can be found. The website is a platform for interaction between INTERLINK, CEDR members and other organisations about the development and implementation of the European Road OTL. Here also the intermediate OTLs and the final basic European Road OTL can be examined and deployed, i.e. used for implementation, by any other interested organisation. In autumn 2018, at the end of the project, dissemination events are planned with demonstrations of the test cases.

Together with CEDR, the consortium will also actively target a standardisation organisation such as buildingSMART, CEN TC442, ISO TC59 or W3C, for standardisation of the proposed common modelling principles and, in a later stage, the resulting European Road OTL.

5.4. Relevance of the project to the infrastructure sector

The INTERLINK project proposes a new approach towards standardisation of information exchange and sharing and seeks to prove this concept in test cases based on real-life use cases. Applying linked data, semantic web technologies give NRAs the opportunity to guide standardisation initiatives towards an evolutionary, modular and bottom-up approach. Most standardisation efforts today rely on a top-down, monolithic approach in which an all-encompassing data structure (the so-called mother-of-all-data-structures) is defined and imposed upon the whole sector. The INTERLINK approach allows NRAs to build up their own national modular OTLs step-by-step, when possible reusing existing internationally defined and implemented OTLs. These reused OTLs can be part of existing standardisation initiatives or just be best-practice in the sector. These OTLs preferably only focus on a limited scope, and are defined and tested by others. Those parts of the OTLs that are reused more often are candidates for being part of the European Road OTL, and thereby will be identified as preferred OTLs. For NRAs, these preferred OTLs will then be of interest for internal adoption and for inclusion in life-cycle and supply-chain specifications, because OTL maintenance and implementation is shared with other NRAs and with the software industry. It also reduces the likelihood of obsolescence. Consequently, this will lead to demand-driven software development that meets the asset information management needs of NRAs.

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