CoDEC

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Connected Data for Effective Collaboration (CoDEC)

Stakeholder's Engagement Report

Deliverable D4A

October 2021

TRL THE FUTURE OF TRANSPORT
FEHRL
Belgian Road Research Centre Together for sustainable roads
Royal HaskoningDHV Enhancing Society Together
ZAG
BEXEL CONSULTING
LNEC LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Project acronym: **CoDEC**

Project title: **Connected Data for Effective Collaboration**

CoDEC Deliverable D4A

Stakeholder's Engagement Report

Due date of deliverable: 31. 08. 2021

Actual submission date: 05.10. 2021

Start date of project: 01.10.2019 End date of project: 30.09.2021

Author(s) this deliverable:

D Kokot, ZAG, Slovenia

C V Geem, BRRC, Belgium

M Lamb, TRL, UK

D Alsem, RHDHV, Netherlands

Shubham Bhusari, RHDHV, Netherlands

Version: draft 4.1

Executive Summary

The CODEC project

The Connected Data for Effective Collaboration (CoDEC) project aims to provide a better understanding of how the principles of BIM can 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 to support the establishment of links between asset management systems and BIM platforms - to make best use of legacy and sensor/scanner data. CoDEC will provide a "Master Data Dictionary" for key infrastructure assets that can form the basis of the data structure for integration between different data management systems. CoDEC therefore aims to free-up and enrich the flow of data to and from BIM and asset management systems.

The research is divided into 6 work packages, comprising 4 technical work packages (WP1 – WP4). Work package 1 investigated the aspect of legacy data, whilst work package 2 considered the potential for use of new data from sensors and scanning systems and developed a standardised specification for a "Data Dictionary" for three key infrastructure asset types. Work package 3 then developed "Data Ontology" based on "Data Dictionary" and demonstrated the application of the data dictionary and ontology through three pilot projects.

This deliverable

This report summarises the activities of CoDEC project WP4 to facilitate engagement between the software industry, European National Road Administrations (NRAs) and CEDR to align future strategies and direction around BIM. It is believed that this can be achieved by:

- Engaging with NRAs and software companies, to understand their needs, strategies, and vision for the future;

- Based on the engagement, to consider the risks and opportunities for these stakeholders and create guidelines with the aim of ensuring alignment between them.

The information was collected mainly through online surveys, one targeted at NRAs and the second engaging with the software industry. The results were supplemented by information obtained directly from various NRAs and software companies via stakeholder consultation, i.e. with post-survey interviews.

Stakeholder engagement was coordinated with WP1 and WP2, as part of the results served directly as input for these two work packages.

Table of Contents

1 Introduction

CoDEC (Connected Data for Effective Collaboration) aims to develop a specification that will support the establishment of connections between asset management systems and BIM platforms. Therefore, the main objectives of the project are to understand the current status of information management in National Road Administrations (NRAs) in Europe, to investigate real-world examples of the use of sensors to drive the management of administrations' transport infrastructure, and to provide recommendations for the alignment of the software industry developing AMS and BIM solutions with NRAs' objectives for BIM.

Stakeholder engagement objective

Work Package 4 (WP4) of the CoDEC project intends to facilitate engagement between the software industry, European National Road Administrations (NRAs) and CEDR to align future strategies and directions around BIM and focuses on:

- Engagement with European NRAs (Task 4.1);
- Engagement with the software industry (Task 4.2);
- Producing guidelines with the aim of ensuring alignment between them (Task 4.3).

Engagement with the European NRAs

This first phase of work consisted of engagement activities with relevant stakeholders across the industry, starting with consultation survey with interested NRAs. This engagement survey was coordinated with similar engagement activities in Tasks 1.1, 2.1 and 2.2 to be cost-effective and efficient, and to ensure that knowledge was shared effectively within the consortium.

The Consortium held the survey open for an extended period of time during which a number of CEDR members submitted their responses. By the time the initial survey closed, a total of 32 responses had been received from NRA individuals from 14 different European countries.

The areas covered in this survey relate to the maturity of organisations in asset management, BIM and information management and which aspects the organisations would like to improve. Respondents were also asked about their knowledge of previous CoDEC related work.

This opened the door for a more in-depth phase of engagement with NRAs: interviews with representatives who have in line with the European GDPR indicated their willingness to do so. In this way the project group received information from the following countries: Austria,

Belgium, Denmark, Finland, Lithuania, the Netherlands, Norway, Portugal, Slovenia and Sweden.

These interviews went into much more detail about NRA's use of sensors and technologies for data collection, inventory data storage and management, visualisation of asset management data, and current and potential future use of BIM.

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" [1] reports on these activities and presents:

- Summary of the information gathered through the survey, and
- Summary of the direct interviews with NRAs after the survey.

Both summaries form the Stakeholder Engagement Report (Appendix A) of CoDEC Deliverable D1a. Some parts are repeated in this Deliverable for completeness of reporting on stakeholder engagement.

Engagement with the software industry

Following the interviews with NRAs, the group began preparing a survey of IT industry organisations, particularly the BIM community, but also AMS software providers. The original plan was to contact appropriate software companies and groups at a series of events (annual meetings, conferences), but these were cancelled or at least postponed indefinitely due to the Covid19 pandemic. Therefore, the group started with the same approach as with the NRAs and prepared an initial survey that was sent to contacts in the software industry.

The technical part of the survey was divided into three main sections: for respondents specialising in BIM, for those specialising in AMS/PMS, and some questions for both groups on data collection and categorization.

CoDEC collected additional information in a similar manner to the NRAs previously, through direct post-survey interviews.

Overview of the Report

The remainder of this report is divided into information on the organisations and countries of those who participated in the engagement activities (Chapter 2 *Engagement with NRAs and software industry*). Chapter 3 (*Results of the engagement*) contains a summary of the key information collected on the respondents' maturity in asset management (systems), information management in national road administrations, data use and formats and various aspects about building information management (BIM). Chapter 4 (*Interlink project*) gives information about the project that provided basic European Road Object Type Library

(EUROTL), and common points and results with CoDEC, while Chapter 5 (*CoDEC recommendations*) outlines the three main components for building connection between AMS and BIM as gained during the successfully accomplished three CoDEC pilot projects. The report ends with Chapter 6 (*Good practice approach*), which proposes a guideline or roadmap to align the visions and agendas of the two main stakeholders involved in CoDEC, namely the NRAs and the software industry.

2 Engagement with NRAs and software industry

Survey: Who the respondents are

The responding NRA individuals come from 14 different European countries: Austria, Belgium, Denmark, Finland, France, Germany, Lithuania, the Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, and the United Kingdom (Figure 1, green shading).

Survey respondents from the IT industry came from 6 different countries: Austria, France, Belgium, Germany, the Netherlands and Serbia, with Belgium and France providing more than one response (Figure 1, blue contour).

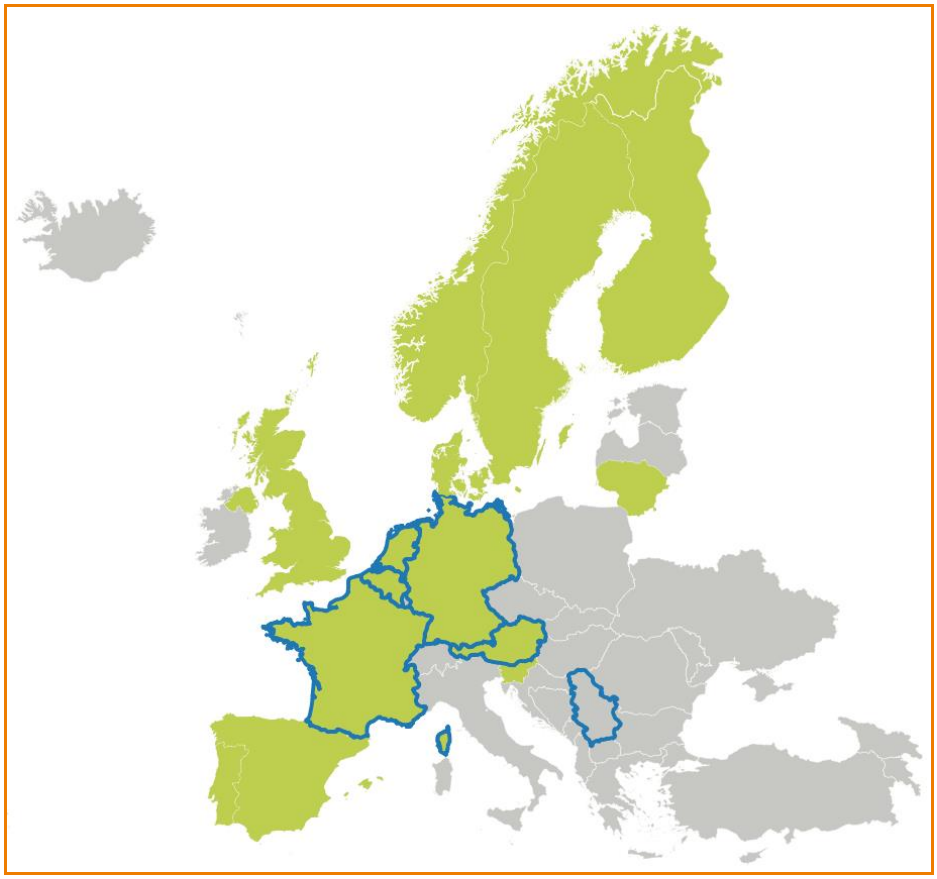


Figure 1 Countries covered during surveys amongst NRAs (green) and IT industry (blue contour)

NRA respondents were broadly classified into five work areas:

- Asset Management: asset manager, project manager, maintenance / monitoring / asset information unit;
- Information Management: information manager, ICT, geospatial modelling;
- BIM: BIM manager or specialist, BIM strategies;
- Advisor;
- Lead: Head of NRA or asset related unit.

Most responses came from experts in asset management, followed by experts in information management and BIM.

Generally, most of the IT respondents specialise in Asset or Pavement Management Systems (AMS/PMS), while few specialise only in Building Information Management (BIM, Figure 2).

WORK AREA	NRA RESPONSES
Advisor	4
Asset Management	15
BIM	4
Information Management	5
Lead	4
Total	*32*

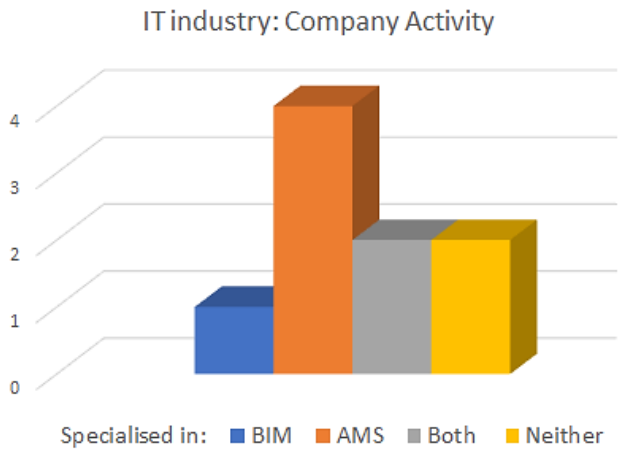


Figure 2 Main working areas of respondents from NRAs (left) and IT industry (right)

Post-survey interviews

CoDEC conducted several interviews with representatives of both the NRA and the software industry to gain a broader insight into their daily work and to learn more details about their information management practises.

The project group first gathered useful information by contacting NRA experts from: Austria, Belgium, Denmark, Finland, Lithuania, the Netherlands, Norway, Portugal, Slovenia and Sweden. This led to gathering important information on the use of sensors and technologies for data collection (UAVs / drones, LiDAR, Internet of Things, Embedded Sensors, vehicle / fleet data, software solutions, Future Solutions), on the storage and management of inventory data, on the visualisation of asset management data and on the use of BIM.

In a later round CoDEC contacted software experts from Austria, Germany, Hungary, the Netherlands and Serbia. The discussions provided an overview about the alignment of NRA expectations with BIM, and about risks and opportunities for engagement between the two sectors.

3 Results of the engagement

This chapter provides an overview of the information gathered through online surveys and in follow-up interviews. Most of this information relates to the maturity of engaged organisations with AMS / PMS and with BIM; the information management of NRAs; the use of new sensor/scanning technologies in NRAs and how inventory data is stored and managed; and various issues around BIM: expectations, benefits of implementing BIM, risks of integrating AMS with BIM software and the like.

The information is a combination of responses from NRAs and, where appropriate, the software industry.

Maturity or experience with AMS / BIM

The maturity of NRAs in asset management and in BIM was self-assessed using two scales with very similar maturity levels.

The maturity scale used to assess the maturity of organisations in Asset Management has the following six 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 maturity scale used to assess the maturity of organisations in BIM also has six 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

The vast majority (~72%) of respondents indicate that their organisations are developing and embedding their own asset management activities, or they are already developed and becoming effective. 16% of organisations are aware of the importance and have begun to apply asset management knowledge. Only one organisation claims to have a fully effective asset management system in place and is now in the optimisation phase (Figure 3).

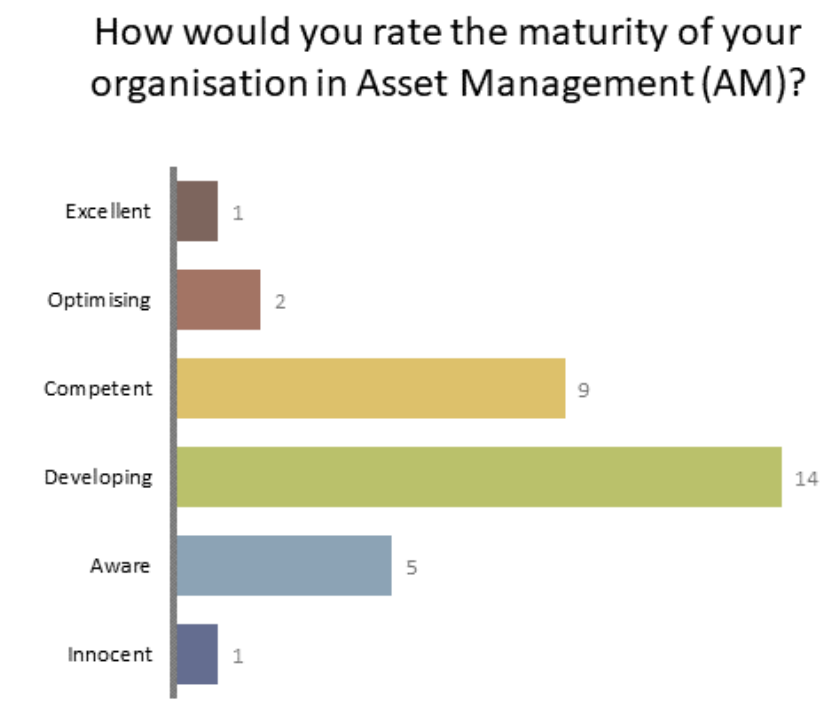


Figure 3 Maturity of organisations in asset management

Some organisations are already using existing road and bridge management software solutions on the market (e.g. Deighton dTIMS, IBM Maximo), while most have developed or outsourced solutions over the years to meet their needs and expectations.

Most responding organisations are aware of the importance of BIM and have started to apply this knowledge (13 responses or more than 40%), or are developing BIM activities and embedding them in their work. 5 organisations (or nearly 16%) have developed BIM activities, embedded them and they are becoming effective (see Figure 4).

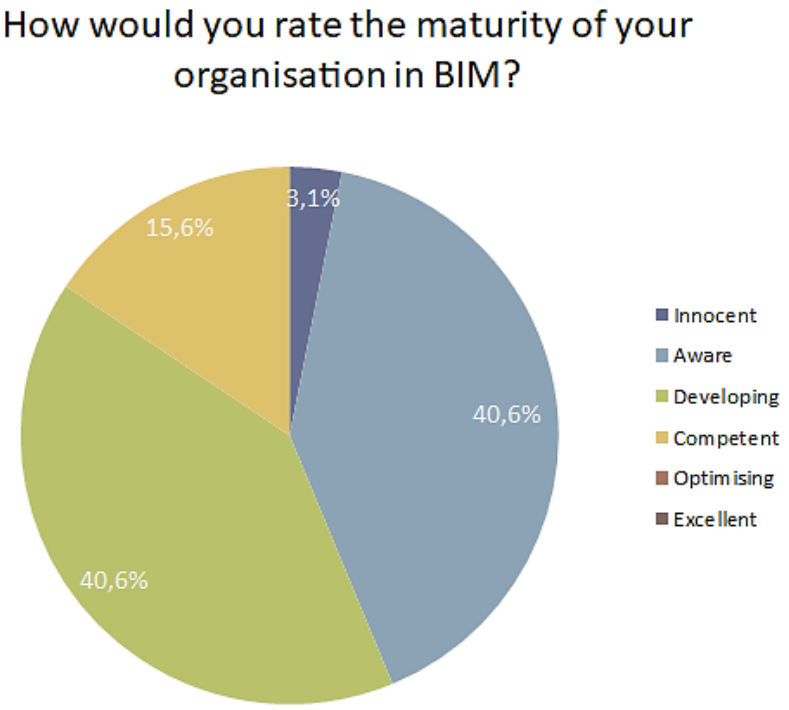


Figure 4 Maturity of organisations in BIM

Eight organisations use 'BIM software', although this includes a mixture of many different types of systems: some may be ready-made BIM software in current projects; others experiment or use software at project-level software (e.g. BIM 360).

Almost 40% of NRAs require providers to use specific BIM or data standards. These data standards vary and are very country specific. In Belgium, data is requested according to an AWV protocol and execution plan; in Finland, the requirement is an open format (Inframodel, IFC and near-standard 3D dwg, 2D dwg-AutoCAD formats); in France, ISO 19650; in Sweden, asset coding standards specific to the software they use, the Swedish recommendation for CAD layering (SB11) and standards for technical descriptions (AMA) are required; in the Netherlands, data standards COINS and RWS OTL are required. In most organisations, DATEX II extensions and GML are required according to ISO TC211 standards.

Additional post-survey interviews provided insight into the use of BIM in the NRAs.

Of the 7 responses, with Wallonia and Flanders both representing 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. in Wallonia and Flanders there was no national 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 there is little AM/maintenance use in BIM, although this is a future goal for some.

IT Industry respondents were also asked about the level of experience with AMS / PMS. The responses given ranged from:

- *Aware*: The organisation is aware of asset/pavement management systems (AMS/PMS)
- *User*: Using specific software
- *Developing*: The organisation is developing (own) AMS/PMS

Of those who responded, most are developers of AMS/PMS software (Figure 5), there are only 3 who are interested in developing BIM software or its features for NRAs.

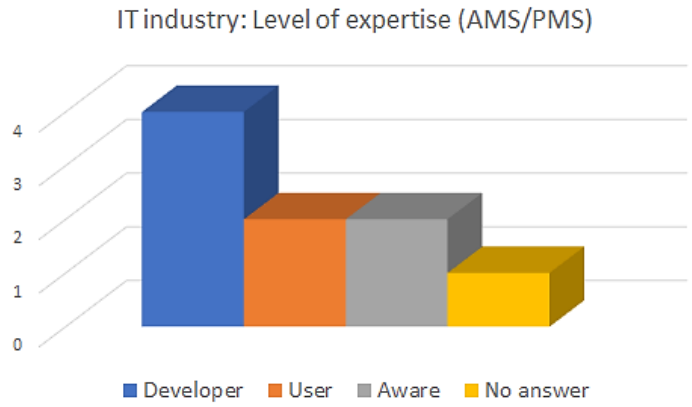


Figure 5 Level of expertise in AMS/PMS of IT industry respondents

Information management in NRAs

Most organisations use a mix of visual inspections, *surface vehicle machine surveys*, and *design/construction* and *maintenance records* to collect data on key highway assets. *Remote sensor data feeds* and *aerial vehicle machine surveys* including drones, planes, satellites, etc. are gaining ever more attention (Figure 6).

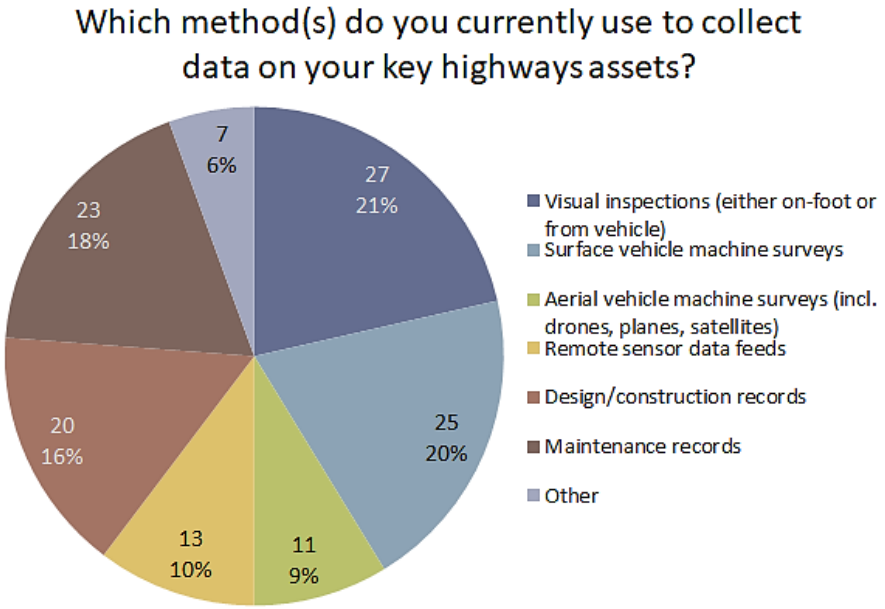


Figure 6 Methods of collecting data

Typically organisations would like to improve information and information management for *roads* and *bridges*, for *street lighting*, and *street furniture*. Tunnels, drainage, engineering structures, electro-mechanical assets, water runoff are also high on their lists of priorities (classified into "Other", see Figure 7).

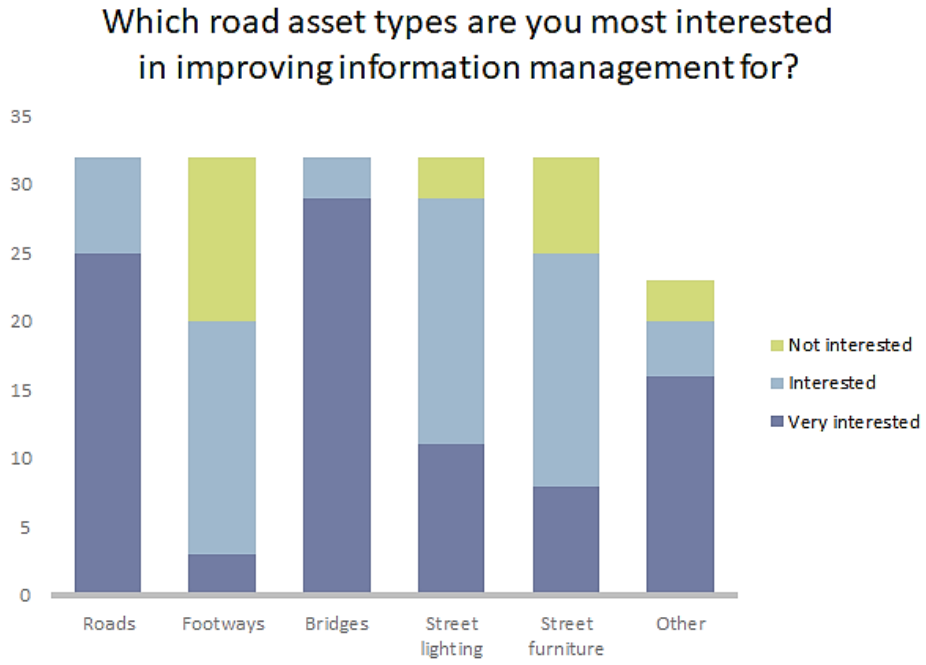


Figure 7 What information to improve

Well over 50% of responding organisations want to improve information and information management (inventory data - basic asset information such as name, type, classification or asset condition data). Another quarter of respondents want to improve maintenance, design and construction records (Figure 8).

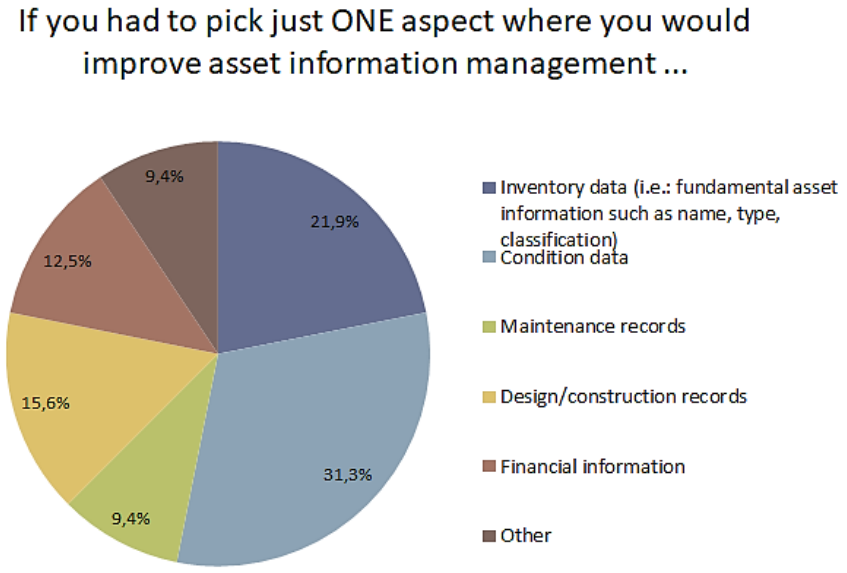


Figure 8 Which aspect of business to improve?

New technologies and inventory data in NRAs

Ten NRAs from 9 countries (Wallonia and Flanders responded from Belgium) were interviewed following the survey. These interviews went into much more detail regarding NRA's 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.

- **Sensors**

UAVs / drones: Six NRAs use drones or UAVs, mainly camera-only for bridge inspections, while Norway uses them for bridge and landslide detection. Most of this is still in the experimental / testing stage.

LiDAR: All NRAs use LiDAR to some extent, although this is mostly not integrated into AM systems. Some countries use it for ground conditions before construction; some use it for inspecting bridges or tunnels, and one (Lithuania) uses it in part for planning oversized routes.

The Internet of Things: Not used by any.

Embedded Sensors: All but one reported using sensors. Common applications were Weigh-in-Motion, strain gauges on bridges, tunnel sensors and environmental sensors (e.g. temperature).

Vehicle / fleet data: Most had some sort of testing application, though not always for AM purposes, as some were self-driving tests. Three NRAs worked with vehicle manufacturers for condition data and one took data from snowploughs.

Software solutions: Three NRAs worked on digital twins and AI, one had a 360° camera and one worked with photo recognition.

Future Solutions: Two NRAs thought AI was promising. Others mentioned sensors, laser scanning and digital twins.

- **Inventory Data**

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

Data Sharing: Where this was answered, data was shared across departments and about half had a data dictionary. For traditional data, most shared it within the NRA and some shared data externally; none had a data dictionary for it. For bridges and tunnels, of the 5 who responded, all shared within the NRA and two also shared externally; none had a data dictionary. For fixed sensors, of the five responding, one NRA kept this data for management only, three shared it within the NRA, and two shared it externally. Again, none had a data dictionary.

Apart from NRA use, some data is shared with contractors for maintenance, paperwork digitisation and general access, provided there are no security implications.

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

Table 1 below provides a summary of the new technologies and data portion of the interviews per responding country, but in [1] the results of the stakeholder engagement are presented in more detail.

Table 1 Summary results of the interviews with the NRAs (Figure A8 of Appendix A in [1])

	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	

AMS and BIM output display/visualisation

The same NRAs were asked how they visualize their AMS outputs.

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

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

Error! Reference source not found. below provides a summary of the new technologies and data portion of the interviews per responding country, but in CoDEC Deliverable D1A [1] the results of the stakeholder engagement are presented in more detail.

The BIM software of the interviewees also supports the merging and extended visualization of 3D BIM model elements, which can come from different authoring tools. Extending attributes/metadata (e.g. through Linked Data) of BIM model elements requires the development of software extension modules (add-ins) using API. Any further specific visualization of integrated data and BIM model elements is achieved by additional software development depending on the specific requirements.

Data structuring and categorization

A specific part of the survey for the software industry related to the industry's experience with structuring and categorizing data and performing queries and analyzes on such data.

Respondents were asked about their experience with:

- *Linked data / semantic web technology*, which is a method of publishing structured data so that it can be interlinked to make data machine readable and become more useful through semantic queries.
- *Scanning / sensor data* as data on asset condition collected from specialist vehicles, in situ measurements, remote sensing, etc.
- *Data dictionaries* as centralized repositories of information about data such as meaning, relationships to other data, origin, usage, and format.
- *Object type libraries* referring to a library with standardised object-types names (e.g. road, viaduct) and properties or specifications.

In general, there appears to be a high level of expertise in the responding companies for all the topics queried (see Figure 9), as well as high skill levels in the software they have developed or use (Figure 10). Here it is somewhat surprising that a small number work with software capable of using data dictionaries, although many more indicated that they use data dictionaries as part of their general work. This may be because software developers are used to exporting/importing data in certain standard formats.

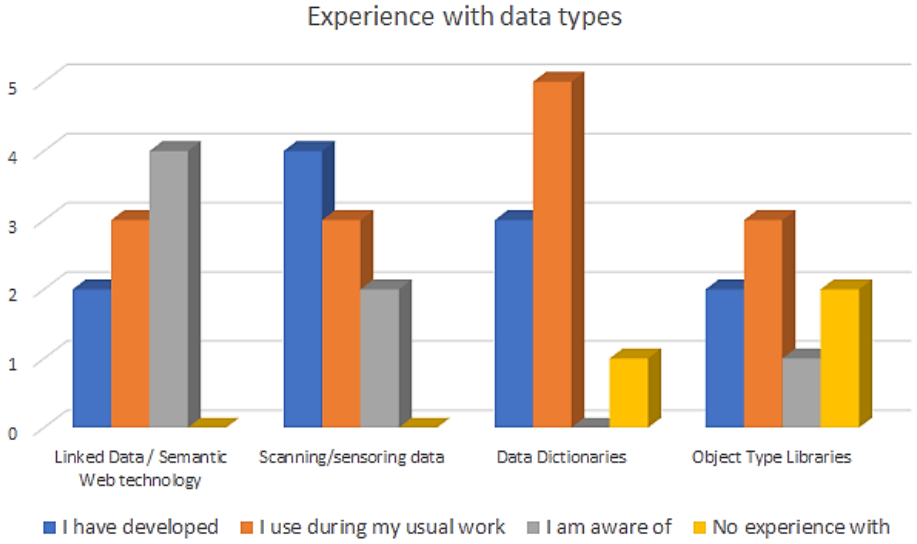


Figure 9 Experience in structuring and categorizing data topics

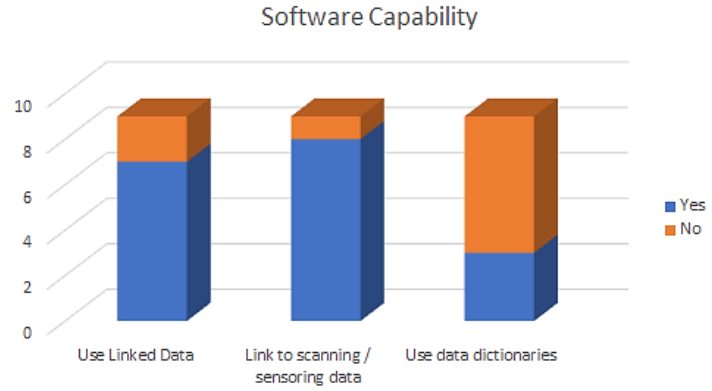


Figure 10 Software capabilities

Respondents believe that the concept Linked Data is currently used mainly in the education sector and to support the IoT (Internet of Things), but these three topics will become increasingly important, improve communication between different data sources, also due to standardization between different software programs, and form the basis for a more comprehensive analysis of assets.

BIM

This chapter groups and summarizes several responses: some from post-survey interviews that provided insight into the use of BIM in NRAs, others from working with the software industry, both through the survey and later interviews. This chapter also highlights stronger messages received during stakeholder engagement.

- **Do NRAs need to get to a higher level with BIM?**

What higher level? Why do NRAs need that level?

Half (4 out of 8) of responding NRAs believe that better integration between BIM and AM software is needed to reach a higher level of BIM, with 25% also needing BIM software. For support to reach the next level, 5 of the 8 stated that they needed integrated BIM /AM software, with one suggesting AI.

The software industry response to the above question is more or less unanimous: a key question is: to what higher level? Why do NRAs need that level or level of detail? Basically, NRAs should aim for the right or appropriate level of BIM. Different measures may apply depending on the objective, and industry can provide guidance in determining LOD that meets an NRA's need.

Answering the above question(s) will inevitably lead to some sort of software solution and industry can support this as well as the need for proper training and education of the personnel involved to fully understand the benefits of BIM and how it can be used for their projects.

A very interesting perspective is that the pursuit of ever higher levels of BIM will lead to a "two-tier" construction industry. A few construction companies will be able to meet the highest levels of BIM and the smaller companies will be excluded from competition, resulting in a competitive distortion.

- **Expectations for the integration of BIM into daily NRA work**

Change management might be needed to make organizations and people more competent

One of the main expectations for NRAs is the knowledge gain, as not all staff in the company were competent, and the need for change management. Although this was only mentioned once, it could be an important success criterion. On the other hand, and depending on the maturity level, this could involve a need for significant resources to integrate BIM into the daily work of an organisation.

Change management, as explained in Wikipedia [2], “is a collective term for all approaches to prepare, support, and help individuals, teams, and organizations in making organisational change. Drivers of change may include the ongoing evolution of technology, internal reviews of processes, crisis response, customer demand changes, competitive pressure, acquisitions and mergers, and organizational restructuring.”

With a clear vision or organizational strategy should also come the right mindset to use "the best tool for the job" as it is meant to be, and to invest in training employees to use such a software tool. The focus should be primarily on the data itself driving the decisions regarding the software.

The decision to use more modern technologies such as BIM and Linked Data should come from the top management. To grow, the use of BIM and open standards must be mandated by NRAs, but also the potential of their use must be understood and recognized by all stakeholders. The activity of NRAs will continue to push the software industry to keep pace and adopt these standards faster to stay relevant.

- **Benefits for NRAs through the implementation of BIM**

There is a need to systematically increase awareness about BIM on NRA and companies sides

All NRAs that responded saw benefits in BIM, including an as-built model, for project information, for collaboration, for sequencing, and for cost effectiveness.

Responses from the software industry ranged from digitization and promotion of digitization (digitization of all technical documents and facilitation of exchange at all project stages, prevention of building failures and crash detection, increased resilience through the national digital twin, coordination of construction activities between managers of different horizontal infrastructures); to increased productivity, cost and schedule discipline, and transparency to the owner and the public; to compatibility of BIM with other analysis packages: Tracking traffic and environmental analysis, simulations, advanced visualizations.

One opinion is also that tremendous benefits would accrue if BIM is implemented in accordance with ISO 19650 [3] and the focus is on the goals and concerns of NRAs and owners.

- **Difficulties on the way to improving NRA' information management**

BIM is clearly a management discipline

The post-survey interviews listed several difficulties that may arise when an NRA attempts to improve its own information management by implementing BIM:

- Lack of interest on the part of management
- Delegating information management to technical staff (IT), often without knowledge and awareness of the strategic goals of the organization. The goal is to optimize the technical level of the solution
- Poor involvement of the entire workforce in BIM management leads to a strong demotivating effect, as many employees do not feel involved in the BIM processes

- Concentration on data and information, and neglect of knowledge-appropriate preparation and provision of information
- Striving for "the highest" level, which causes unnecessarily high costs, when a "BIM - compliant" solution would be possible
- Lack of interest in sharing knowledge with the construction companies involved in the projects
- NRAs very often choose to purchase larger and more expensive systems with a very large feature set. Due to their complexity, the use of the systems decreases abruptly after the warranty period has expired, except for a few isolated functions, if appropriately qualified personnel can be found in the NRAs.

- **Benefits of the integration of AMS with the BIM software**

… more consistency, more effective solutions, consideration of strategic goals…

Relevant benefits cited by software companies include providing customers (Road Authorities) with a more powerful solution and more ergonomic tools. This is complemented by more consistency, the ability to track effective work through a tracking tool, having a history of the work performed and many analyses based on historical data. The combination of different interconnected systems and data sources (survey / BIM / GIS / statistics) is also seen as an advantage.

Benefits from the management perspective are the consideration of the strategic objectives of the State, the derivation of the objectives of the NRA and from them the asset management objectives, the possibility to influence the sustainability of the solutions, to increase the resilience of the infrastructure and to better respond to identified criticalities, the coordination of the management of different horizontal (road, water, telecom, rail, electricity, ...) infrastructures.

From the software industry's point of view, which data from BIM are important for AMS systems? Basically, it is all data related to inventory and condition data (of complex structures). This includes the geometric, mechanical, environmental and financial / economic / accounting information about road infrastructures and data describing all related facilities above, beside and below the road.

It is considered that it is of paramount importance to transfer the data from the Project Information Model (PIM) to the Asset Information Model (AIM), preferably within the delivery phase, but at the latest immediately after completion of the project.

- **Risks and challenges in the integration of AMS with the BIM software**

Focus too much on data modelling and not on the objectives of the AMS / PMS

One risk mentioned during the interviews with NRAs was that they need more and better data. A number of points were raised on the issue of common standards and this was an area of concern for some in relation to the software. It was also suggested that the IT sector may not appreciate what is required for asset management.

On the one hand, people are not sure that the current technical structure of BIM (as represented in the IFC-ISO standards) will soon be applicable at project level, and on the other hand, the concept of the network seems to be completely absent from these standards.

An opinion from the software industry is that by far the biggest risk would be the inclusion of the modules for planning and design and for operational construction coordination (CAD - BIM) in the integrated solution (BIM +AMS), as this risks losing the opportunity for a good and necessary solution. As for the relationship of AMS / GIS and BIM, it is not about competing for functionality, but about making the information between the two naturally interchangeable. This leads to the general consideration that the higher complexity of the final solution might hinder and delay the implementation of national projects, since as many tasks as possible need to be covered.

Since the maintenance costs of keeping a BIM solution up to date must be included in a cost-benefit analysis, the question is who would be willing to pay additional costs to update the data (whether once or repeatedly over several years)? And would such a solution provide sufficient value to the customer?

Similar to NRA representatives, the software industry already sees integration challenges in the differences between the types of data formats currently used in asset management to represent different asset data and in the BIM environment. Capturing information at different scales (BIM is very detailed, AMS can be less detailed) is also a challenge as it relates to time-varying data, integrating BIM with GIS data, conflicting updates, and communication between different software products. One of the biggest challenges is also seen in extending BIM to the network level.

- **What is needed from NRAs to better engage the software industry?**

There is a need to systematically increase awareness about BIM on both sides, NRA and companies. NRAs are to mandate the use of BIM and open standards

The software industry suggests that NRAs mandate the use of BIM and open standards, and provide guidelines, workflows, and recommendations to facilitate, educate, and explain the benefits of transitioning from traditional methods in the first place. Statewide classification standards, naming conventions, BIM object libraries, and data dictionaries also represent major advantages in implementing the open BIM workflow.

As one of the engaged software developers explains, "The BIM industry needs to recognize that NRAs need a strong connection to their respective AMS and are interested in new BIM dimensions. The digital BIM twin that meets the requirements of the NRAs must extend to the entire infrastructure system and also include the other relevant infrastructure systems, such as various pipelines, or the interfaces to such systems (the entire infrastructure portfolio)."

The opinion in the software industry is also that services related to AMS / PMS are in a niche market (currently the demand for services is low, so it is better to say that this market is yet to be developed) and can only be carried out if research and development are subsidized. On the one hand, the needs are met by government agencies at the national or regional level, on the other hand, the available budgets for road management and road rehabilitation plans at the municipal level are limited. Moreover, the awareness of the added value of road management based on informed decisions at the municipal level is still too low.

This results in the need to systematically disseminate information in order to increase awareness on the part of administrations and businesses.

- **What are the risks and benefits for the two sectors to connect / get involved?**

It is essential to provide clear expectations from both sectors and to align them

The main risk is a difference in expectations on both sides, so the focus needs to be on creating clear and understandable expectations on both sides and aligning them. The next issue for alignment is the level of detail (LOD) or granularity that both sectors would focus on.

Respondents see the following risks, which are very similar to the challenges of integrating AMS with BIM software: slow adoption of standards, unclear government investment strategy and that government initiative may compete with private initiative, and dominance of monopolists. There is a perception that smaller vendors tend to be more agile and can adapt more quickly to the ever-changing landscape of open BIM.

To continue with standards: Slow progress in the development of standards for data exchange could lead to proprietary systems for certain specialist tasks becoming dominant and stabilizing over time. In addition, the introduction of European data exchange standards may lead to the discontinuation of support for previous national standards. Furthermore, if the European standard covers fewer objects or attributes, this could have a negative impact on the functionality of existing systems.

In terms of tools, there is a risk that the focus will be on developing one type of software tool rather than

- Provide software that makes the benefits of streamlined road management visible,
- clearly shows where (financial) resources are saved,
- the risk is also with the data model that it is not aligned with the AMS objectives.

In improving information management, NRAs could (or will) also face some difficulties: lack of skills in different areas, e.g. storage of large amounts of data, effort in data collection, lack of experts with adequate knowledge.

Conversely, the benefits would be more accurate data from construction to maintenance (e.g. reduction of outages through better integration of information, accurate estimation of quantities), integration of remote sensing data, providing a basis to achieve a digital twin where data can be linked to software packages from other areas, e.g. urbanization, permitting, environmental impact.

- **Vision for the use of BIM in relation to horizontal infrastructure**

The fundamental principle of Asset Management is the necessity to consider the entire relevant Asset Portfolio

The opinion is that the BIM system integrated with the AMS must also follow the above approach and take into account all critical infrastructures at national level. Assessing the criticality of infrastructures and optimising resilience will be supported by considering individual infrastructure systems together. Also taking into account that many of these infrastructures are spatially integrated, construction activities should not be planned independently, on the contrary, coordination of construction plans by the managers of the different infrastructure systems responsible for the whole infrastructure portfolio is necessary and the impact of construction activities on users should be minimised.

Another idea is that BIM should provide NRAs with a powerful tool to improve the circulation of digital information between all parties involved in the design, construction and maintenance of roads, as well as a tool for applying the Life Cycle Analyses and tracking all elements of road infrastructures.

If you consider BIM as a "visual database", all metadata associated with a specific element (e.g. wall plate, pipe, channel, etc.) such as area, volume, length and documentation such as warranties, certificates and maintenance schedules can be useful for asset management. Having a single source of truth has the advantage for the user of not having to manage multiple data sources and analyse how they are connected.

The BIM approach also enables the integration of additional data layers for infrastructure projects (sensor information, infrastructure geometry, traffic data, loads and fatigue detection, graphical information, etc.) within a single platform. This promising technology will facilitate and optimise the decision-making process regarding maintenance issues and improve infrastructure monitoring.

- **What are opportunities with aligning roadmaps with NRAs?**

Visions, strategies and product roadmaps are a sensitive matter for some software companies and answering relevant questions would mean disclosing business strategy. As a result, CoDEC was able to gather few responses on how to align visions and roadmaps with NRAs:

- The EU is leaning towards digitisation, therefore for the software industry the intention to digitise infrastructure in NRAs is a good commercial opportunity to enter new markets and customers. Equally, setting the right BIM levels increases the chances of accelerating digitization in the construction industry,
- Spreading the principles of Asset Management among BIM professionals, but also increasing the importance and role of a civil engineer in the BIM processes,
- Establishing its own position as a trusted partner to NRAs in improving the efficiency of decision making,
- Providing AIM data to the external systems and importing measurement data from PIM to AIM in a timely manner, which is essential for an NRA,
- A major opportunity is to understand complex assets; the 3D model provides only one view,
- Common goal and opportunity for both sectors is to integrate maintenance activities, cost and time into an overall infrastructure lifecycle,
- Expanding software capabilities to include asset monitoring capabilities, historical analysis, advanced visualisations, defining standards and use cases.

4 Interlink project

Who knows Interlink?

INTERLINK [4] is a research project initiated to improve the use of Building Information Modelling for information management in the delivery and operation of civil infrastructure. The project delivered a validated basic European Road Object Type Library (EUROTL) built using powerful semantic web technology. In 2018, INTERLINK published the CEDR-INTERLINK approach and the first basic EUROTL that NRAs can use to improve their asset information management, interoperability within European NRAs and with their stakeholders.

Among other things, CoDEC has built pilot projects using the knowledge and results from INTERLINK.

More than half of the interviewed NRAs are aware of this project and its results, even more, a quarter of them have been actively involved in the project work (Figure 11).

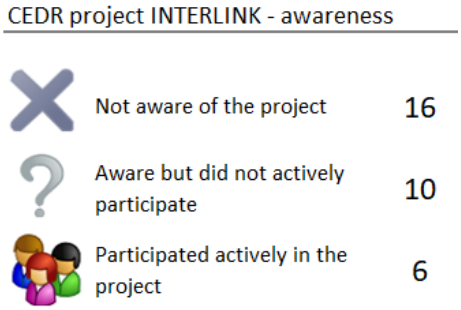


Figure 11 How many are aware of INTERLINK project

From the feedback received, it appeared that INTERLINK is an interesting research project, but more on the theoretical side. There are some difficulties in getting practical results from the project as the results are not directly implementable, but do form a good basis for further work. It is appreciated that the OTL linked data approach is used and in some NRAs the project principles are already being implemented, own OTLs are improved and aligned with national requirements.

Vision on information management

A comparison of the results of the CoDEC engagement activities and the results of the INTERLINK project [5], its vision on Asset Information Management and the step-by-step implementation plan shows many similarities in different areas.

Below is a list of responses gathered from the CoDEC stakeholder engagement and Interlink deliverables related to a specific area.

Incorporation of digital and BIM into Road Asset Management processes

With regard to the question of what benefits might arise from linking AMS and BIM, the benefits mentioned included consistency, the ability to manage the entire lifecycle and the possibility of building a national digital twin.

In terms of potential risks, responses range from no major risks - at the moment the national standards for BIM are not suitable for network level management - to risks in integrating BIM and AMS for planning, design and BIM with CAD for construction. One response focuses on the cost of creating and maintaining a digital twin, while two respondents see the risk of depending on a few large BIM companies and creating a potential monopoly for them.

Regarding the vision of BIM for horizontal infrastructures, respondents see benefits in having a network-level overview, including for resilience purposes, for sharing information between relevant parties and for lifecycle assessment, including utilities.

Many European countries are actively integrating digital and BIM processes in the delivery, operation and maintenance of their road infrastructure assets.

Developments are typically more advanced for road pavements and structures as these assets tend to be higher-risk items.

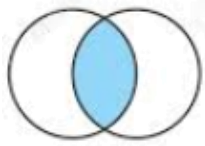
The handover of asset information from the capital delivery phase of projects through to the operations and asset management phase is a significant area for potential improvement as this process is often inefficient and does not currently work well.

NRAs and their supply chain partners are becoming increasingly aware of the value of asset information and are focusing on the full lifecycle of assets.

BIM means different things to different people depending on their role and their motivations.

BIM means different things to different people, depending on their roles and motivations.

Data standards and standards for data exchange are not sufficient without associated common business processes. The use of standards must become an integral part of all parties' daily business processes, not just another contractual requirement.



SIMILARITIES

i. The value for BIM processes for asset management is still recognized today.
ii. Current developments towards a Digital Twin are now mentioned.
iii. More specific barriers are now becoming apparent, such as:
    a. the lack of open standards
    b. the issue of ownership and storage of Asset-Data and the "lock-in" risk: Asset Owners becoming dependent on large BIM companies to manage their Asset Data.
iv. One way to mitigate the risk of this "lock-in" is to base the asset information management system on open standards rather than software from specific vendors.
v. The INTERLINK proposed using the open standard Linked Data as the basis for this. The CoDEC project with three pilot projects confirms the suitability for the use of INTERLINK Linked Data / Semantic Web technology in different countries for different applications and demonstrates the ability to link BIM data with GIS and with sensor/scanning data from assets, using open standard tools and Master Data Dictionaries.

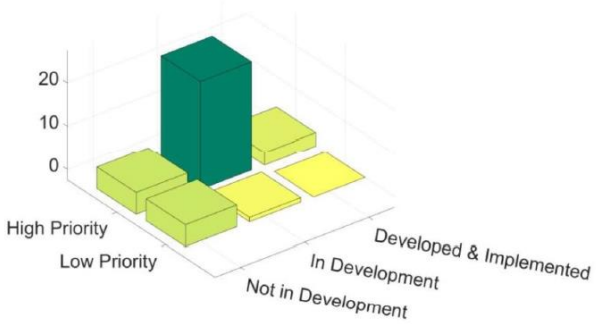
Phases of the asset lifecycle and the software covered

There is a sense that digitization of documents would facilitate sharing at all stages of bridge projects, but the benefits to pavements are not so clear at this point.

Enormous benefits are also seen for NRAs, but only if BIM is implemented according to ISO 19650 [3]. This ISO standard is aimed at: those involved in the procurement, design, construction and/or commissioning of built assets; and those involved in carrying out asset management activities, including operation and maintenance. The benefits considered range from increased productivity, promotion of digitalisation, increased resilience, cost and time discipline, to increased transparency and improved ability to form international collaborations.

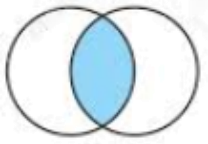
Relevant asset information should be systematically collected and updated throughout an asset's lifecycle, from design through construction, inspection, maintenance and renewal. This statement received the highest

level of agreement based on all responses, indicating that respondents strongly agree that asset information should be collected and updated throughout the lifecycle of an asset (see Figure 12).



"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."

Figure 12 Conceptualisation matrix (from [5], Figure 4.2)



SIMILARITIES

i. Both surveys show the need to apply BIM at all stages of the asset life cycle.
ii. Both also mention the need for open standards.
iii. The recent ISO 19650 for BIM deliveries is the basis for this. Ongoing developments, such as the new semantic modelling guideline, fit into this view.

Specific tools and data

Organisations use a wide range of software: Revit, Archicad, Allplan, Bexel Manager, Autodesk portfolio, arcGIS, Synchro4D, Solibri, Civil3D. On the one hand, such a situation can be seen as quite positive, but on the other hand, this could also be perceived as a disadvantage if problems with interoperability arise.

Respondents clearly see advantages in the connexion /integration of AMS and BIM software in the areas of data storage, visualisation or the presence of accurate as built / as maintained information. However, there are many challenges with such a connection, from fairly commonly identified issues around the flow and connection of data, to integration and conflicting images around time and location.

INTERLINK focused on the use of open standards in applications and tools. The European Road OTL should allow linking to IFC-Road, IFC-Alignment and IFC-Bridge as soon as these standards are published and adopted.

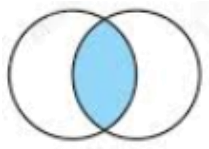
Linking with other IT standards should be done both at the data model level and at the data instance level.

Standards for exchanging and sharing asset information should be built on established open web standards.

INTERLINK [6] also mentions:

The benefits of the INTERLINK approach for the IT industry: the industry can benefit from an extended business case by developing better tools and participating in harmonisation and standardisation.

NRAs are recommended to join forces in software development through common software specifications and joint software procurement with the IT industry.



SIMILARITIES

i. In this case, the difference between suppliers (CoDEC survey) and NRAs (INTERLINK survey) is clear: suppliers mention as quite positive that there is a wide range of software used, so there is no lock-in to one or two major suppliers, however this could also be perceived as a disadvantage if it leads to interoperability issues or non-standard formats, which is a barrier for NRAs.
ii. Vendors mention the wide choice of software as a mitigation for lock-in. This lock-in is the asset owner's dependence on a particular vendor. While the wide range of software mitigates this lock-in, it does not prevent it. As long as all of an NRA's asset data is stored through one supplier, this lock-in remains. If an NRA uses a Linked Data / Semantic Web platform based on open standards (OTL Object Type Libraries, Data Dictionaries, IFC), the NRA can store asset data separately from the suppliers' shared data environments and still use that data. This can improve the mitigation of a lock-in. Such a platform allows linking and combined use of different applications (BIM, GIS, Digital Twin, sensor, scanning) for asset data.
iii. A next step is a joint approach between the IT industry and NRAs to further implement open standards and asset data storage and use. The CoDEC project demonstrates existing technologies but does not show a common approach between the IT industry and NRAs.

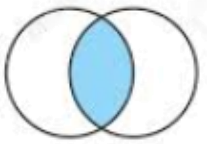
Risks

When asked what risks are seen in integrating AMS with the BIM software, there were a variety of responses, including "We do not think there are any risks." One risk is that BIM is becoming more widespread and thus more complex across different industries, and that applications are being adopted by large general-purpose software companies that know little about the application domain. Other risks cited include lack of interoperability agreements, lack of understanding of the requirements associated with AMS, and the risk of excessive maintenance costs.

Regarding the risk of developing BIM software in relation to the horizontal infrastructure, responses again range from no risk to the risk of dominance by a particular software package, slow adoption of standards, and unclear government investment strategy.

About implementing new information management standards with an initial focus on large projects and on smaller projects later is not a priority for NRAs or software suppliers. Implementing new information requirements on large projects gives incumbent contractors and their suppliers the opportunity to invest in new processes. But it also means that feedback from the process takes a long time. NRAs should consider which approach is preferable for their needs.

According to the INTERLINK report [6], NRAs expect benefits from using BIM in asset information management in terms of increasing the efficiency of road asset management.



SIMILARITIES

i. No specific risks are expected and mitigating this risk, starting with small projects first and applying to large projects in a next step is not a priority for NRAs. (CoDEC found a number of risks in the stakeholder engagement phase, but was also initiated a few years after INTERLINK, which could explain these risks as newfound experience)
ii. However, INTERLINK advises a gradual hybrid implementation of the use of Linked Data / Semantic Web technology for Asset Owners, to mitigate the risk of failure of this implementation. Hybrid means using existing data and standards first and gradually harmonising with the new standards. This approach is advisable to be able to involve asset managers in this new digital way of working. It is not a software risk as the tools used are existing tools for existing techniques, similar to the tools and applications in the CoDEC project.

Linking data user experiences now and in the future

The survey asked about user experiences with different types of data, Linked Data / Semantic Web technology, data dictionaries and object type libraries. In general, there seems to be a high level of proficiency, some companies have developed or integrated software as part of their work, others use it as part of their usual work. Scanning sensor data was strong among companies that have developed or integrated software and data dictionaries for general use. Few respondents have no experience, and these are with either data dictionaries or object type libraries.

There is also high capability of the software able to use linked data and to link to scanning / sensor data, but surprisingly only few able to use data dictionaries.

There is also a high capability of software to use linked data and link to scanning/sensor data, but surprisingly few who can use data dictionaries.

About what capabilities would be needed in the future: There is little interest in using linked data (LD) and linking to scanning data (SD). Somewhat surprisingly, few wanted the software to be able to use data dictionaries, given the low existing capability. In contrast, the general opinion is that both LD and SD will have a major impact on the highway sector, but also that standardisation would make it easier to merge data from different software or databases.

A bit less connected to the topic is the following experience from Interlink. The visualisation of the survey results related to the statement *Design checking, design approval and as-built approval should be conducted using object data with associated model data (e.g. 3D models)* can be seen in Figure 13. Here, the Nordic countries, the Netherlands and France indicated a high level of prioritisation and development.

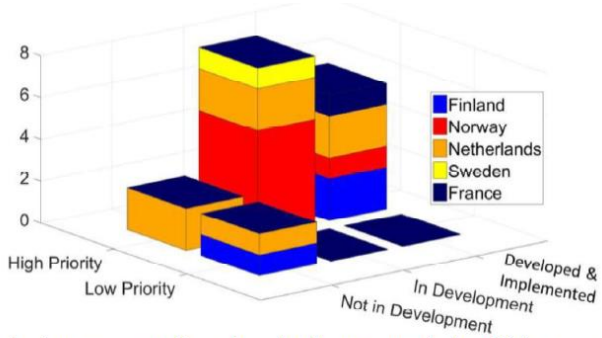
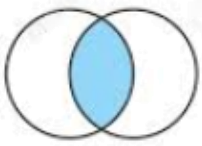


Figure 13 Conceptualisation matrix, by country (from [5], Figure 4.4)



SIMILARITIES

i. There is agreement on the possibilities and the need to link data and applications.
ii. The CoDEC project also demonstrates this capability.
iii. The need for standards and standardisation on this is also mentioned in both projects. The CoDEC-project implemented the latest developments on standardised Semantic Modelling Guideline for the sensor/scanning ontologies.

Commonalities with CoDEC

The results of the CoDEC engagement activities, as described above, in comparison to or as a follow up of the INTERLINK project, demonstrate the importance of a shared vision on asset information management and a phased implementation plan by NRAs and software suppliers.

The need for collaboration and the value of using BIM and open standards for asset management is recognised by both. The use of common standards can start with the new ISO19650 series of standards [3] for BIM deliveries.

The main issue here is the need of the road sector for sharing and linking asset data during the asset lifecycle. The CoDEC project demonstrates the possibilities for sharing asset data such as BIM, GIS and sensor and scanning data using the INTERLINK open standard approach based on existing Linked Data / Semantic Web technology.

The next step is to further implement these existing tools on Digital Twins for assets, using ongoing standardisation developments such as ISO19650 and like the development of standardised Semantic Modelling ontologies for asset objects.

Demonstration of this INTERLINK way of working via the CoDEC project may encourage implementation by NRAs in collaboration with IT suppliers and the other stakeholders mentioned in [6].

5 CoDEC recommendations

Project management usually requires considering potential risks, reviewing and mitigating them, and identifying new risks that may arise on a project. In terms of gathering external data, CoDEC identified risks in obtaining the information needed to develop the tools and guidance, and in obtaining the information needed from external stakeholders, particularly IT industry. The latter was a major issue for CoDEC, which suddenly found itself in a challenging global Covid 19 situation.

CoDEC is able to complement a limited list of risks and opportunities for the alignment of NRAs and IT industry gathered during the engagement with recommendations for both parties gained from experience during work on pilot projects (PPs).

The conclusions of the work presented in Deliverable D3A of CoDEC Work Package 3 [7] rightly state that with the development of ICT systems and the increasingly significant production of data, it is very relevant to contribute to the challenge of data integration and integrated access to critical data for decision making. The significant increase in the number of data sources, which are potentially heterogeneous, hinders the mechanisms for integrating the information and knowledge present in the data. Data integration and integrated access to critical data through semantic web techniques (such as ontologies) is a common ICT approach in a variety of domains and certainly not limited to the road or transport sector. Linking data, rather than converting existing records into copies in a different format, also minimises the energy consumption for storing data. Therefore, the use of semantic web techniques, such as in this particular case the use of the CoDEC ontology, is increasingly relevant to address the complexity of current and future data. The layered approach (architecture) proposed by CoDEC allows easy implementation of the required applications in any commercial software, as demonstrated by the use of Bexel software in PP 1 and PP 2 and by the use of BIM and GIS software in PP 3.

The three key ingredients for success are: standards, abstraction and visualisation tools.

1 Standards: The CoDEC ontology has been developed based on the ontology of the Interlink project (Road OTL), which ensures alignment with the Road OTL and thus allows the development of CoDEC ontology instances from Road OTL implementations.

2 Abstraction: The CoDEC API was developed to provide an abstraction layer for accessing (reading and writing) CoDEC ontology data. This solution created technological independence, complexity abstraction, easy service scalability and extension, easy ontology scalability and extension, and easy testing and validation.

3 Need for visualization tools: Software vendors must provide visualization solutions in a BIM environment (examples from Pilot Projects 1 and 2) or in a GIS environment (example from Pilot Project 3).

The experience of Pilot Project 1 shows that automating the linking of data to BIM model elements requires standardisation, both on the part of BIM model development and on the part of maintenance operators. Standardisation of BIM model development and naming conventions is as important as standardisation of measurement data and corresponding BIM model properties.

Normalisation and standardisation of conventions and nomenclature can greatly simplify the overall development and alignment between the BIM model and the data available in the Linked Data environment. To simplify and automate data access, it is recommended that vendors of BIM solutions provide advanced filtering mechanisms for generating ifcOWL from BIM models.

From Pilot Project 3, we have concluded that road pavement objects should be modelled in small segments, that road alignment should be included as an object in BIM models, and that there should be a way to ensure that useful information is parameterized and easily accessible. We anticipate that IFC Road will address these issues as it develops.

To facilitate future processes, it is recommended that designers of BIM models develop elements with the appropriate level of detail for visualisation mechanisms, i.e., that visualisation needs be considered in the development of BIM models.

The future direction to use the results of the CoDEC project is to automate all steps in the processes to enable a real-time approach for the whole solution. From a technical perspective, the solution is considered adequate, but it requires an effort in data instantiation and synchronisation with various data sources that limits a fully automated method.

Further implementation of asset management applications using the CoDEC approach requires an extension of the CoDEC API and, for some specific applications, perhaps also of the CoDEC Data Dictionary and the CoDEC ontology (more on this in [1]). Further development of the CoDEC API should be done in a standardised and centralised way so that the API can be used and reused by all who wish to do so.

6 Good practice approach

Instead of conclusions, this chapter forms a guide to align the visions and agendas of the two main actors involved in the CoDEC project research, namely the NRA and the software industry. The guide proposes a good practice approach and recommendations based on the project group's engagement with both sectors, taking into account the partners' experience with the Interlink project and the practical work of developing pilot projects within CoDEC.

Making the decision to move to an appropriate level with BIM

The decision to adopt BIM and Linked Data should come from top management. The context of the particular organization (NRA), its vision and organizational strategy should be considered. All management systems, including BIM, should be appropriate to the maturity level of the organization. NRAs should aim for an appropriate level of BIM.

Such a decision should include the involvement of the entire workforce into the BIM management.

Common language - defining the level of detail (LOD) and the level of exchange

In line with the NRAs strategy, organizations should determine needs and expectations and LOD that meet those needs. A variety of measures can be used to do this and industry can provide support.

Define requirements from one world to another

Strategic alignment to a standard based on the needs and requirements of NRAs is considered necessary.

NRAs should expand their own entire infrastructure system to include the other relevant systems, such as various pipelines, to look at an entire relevant infrastructure portfolio.

Information needs to be disseminated systematically to increase awareness on the part of administrations and software companies.

Once we know what both sides want…

Establishing bi-directional communication between Asset Management Systems (AMS) and the BIM software means that the AMS can view the information from BIM and vice versa.

Establish connections and communication between the two worlds to define interfaces / APIs for querying data and making meaningful, fact-based and informed decisions.

Communication needs to be at the database level (data drives decisions) and also ensure the flexibility of that communication. The focus on the data itself drives decisions about "the best tool for the job".

Training the workforce of NRAs

NRAs should invest in training staff to use the tool they have chosen.

Define business processes in a common framework

Asset Management (AM) + Building Information Management (BIM) = Asset Information Management (AIM)

Standardization?

NRAs should step forward and mandate the use of BIM and open data standards while there is no solution for interoperability in sight. This will ensure that standards are based on NRA needs and have the opportunity to evolve, and will push the software industry to keep pace and adopt these standards more quickly.

Augmented reality in infrastructure maintenance

Software vendors must provide for visualization solutions in a BIM environment (examples from CoDEC Pilot Projects 1 and 2) or in a GIS environment (example from CoDEC Pilot Project 3).

7 References

[1] CoDEC D1A Literature Review and Stakeholder Engagement on Legacy Data and the Data Dictionary, June 2020, CoDEC deliverable

[2] Change management, https://en.wikipedia.org/wiki/Change_management , Wikipedia (accessed 16th August 2021)

[3] International Organization for Standardization. Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling (ISO 19650 standard series)

[4] CEDR project INTERLINK: https://www.roadotl.eu/ (accessed 16th August 2021)

[5] INTERLINK D.2 D.3 - WPA & WPB Report Information Management for European Road Infrastructure using Linked Data – Investigating the Requirements, Final Issue, 31st March 2017, INTERLINK deliverable https://www.roadotl.eu/static/media/INTERLINK_D2-D3._Investigating_the_Requirements.pdf (accessed 16th August 2021)

[6] INTERLINK D13 – Implementation plan, 4th October 2018, INTERLINK deliverable https://www.roadotl.eu/static/media/INTERLINK_D13._Implementation_Plan.pdf (accessed 16th August 2021)

[7] CoDEC D3A Pilot projects report and consolidated implementation resources, June 2021, CoDEC deliverable

Appendix 1 Interviews with NRAs

List of supporting questions for conducting interviews with NRAs

Sensors and scanning data

A. How NRAs are using new sensor/scanning technologies in asset management (Satellites and UAVs, LiDAR, Embeddable and fixed sensors, Internet of Things (IoT) and sensor networks, Vehicle fleet data and CAVs, Software solutions)?
    a. Do you use or planning to use any new sensor/scanning technologies in asset management?
    b. What sensor/technology types of that group do you use or plan to use?
    c. For which assets do you use these technologies?
    d. What data type/asset parameter is collected?
    e. How do you store the data?
    f. How this data is used for asset management?
    g. Do you have any relevant reports, publications available and could share with us?
B. What technologic trends (e.g. new sensors, data processing using AI methods, autonomous technologies, 5G, etc) you expect to have a significant impact on current asset management practices? Do you consider these trends in your NRA?

Inventory data

C. How do you store and manage inventory data (the list and characteristic properties of the assets, e.g. road section lengths, road layer materials and thicknesses, type of bridge, length of tunnel, etc.) on the road assets?
D. Is the inventory data shared between different divisions within the NRA?
E. If so, how is the data provided to the different users?
F. If so, is there a data dictionary on these data?
G. Are the results from traditional monitoring devices on roads (e.g. skid resistance, roughness, detected cracking) just used for pavement management or also made available for a wider audience (internally at NRA or externally) ?
H. If shared, how is the data provided to the different users?
I. If shared, is there a data dictionary for that data?
J. Are the results from bridge/tunnel inspections just used for bridge/tunnel management or also made available for a wider audience (internally at NRA or externally) ?
K. If shared, how is the data provided to the different users?
L. If shared, is there a data dictionary for that data?

M. Are the results of data collected with fixed sensors just used for asset management or also made available for a wider audience (internally at NRA or externally) ?
N. If shared, how is the data provided to the different users?
O. If shared, is there a data dictionary for that data?
P. If some of the data is not (yet) shared, for which purposes other than management and maintenance planning of the assets the monitoring data, inspection data, sensor data could be used if the data would be made available to a wider audience? Please list: which kind of data on which asset and for what purpose.
Q. If some of the data are not (yet) shared, is there a data dictionary, standard format, … in use for monitoring data, inspection data, sensor data – or are these data in a format proper to the monitoring devices, inspection methods, sensor equipment? Please list the formats of the data you think could be useful to share.
R. The management of the assets (pavement, bridge, tunnel or other asset) produces a result for maintenance planning. Is this result shared with others?
S. If shared, how is the data provided to the different users?
T. If shared, is there a data dictionary for that data?
U. Is there a specification, a data dictionary, standard format, … for the result or conclusion after interpretation of monitoring data, inspection data, sensor data on any kind of asset (e.g. a standard format for an indicator such as IRI for longitudinal evenness computed from a longitudinal profile measured by a laser profiler installed on a vehicle dedicated to road surface monitoring)?

AMS output display/visualisation

1. Do you visualize outputs of your AM systems (in terms of presenting them on network maps or in 3D models) and which methods do you use?
2. At what stage do you use such visualisation?
3. What type of geodata background layers do you include within your visualisation outputs?
4. Does your AM system allow for importing of IFC format (Industry Foundation Classes or IFC is a standard and open BIM exchange format)?
5. If so, what is purpose of BIM models that you import in AM systems?

BIM (Building Information Modelling/Better Information Management)

6. Are there any government requirement to implement BIM?
7. If yes, please specify: If yes, please specify on what type of project: If yes, please specify on what size of project: Do you see an advantage from implementing BIM?
8. Please share with us where you see advantages of implementing BIM?
9. What data from BIM do you consider to be vital for your AM system?
10. What does your organisation need to get to next level with your BIM? (Additional levels depend on their current maturity level)

11. What are your expectations when you will move to higher levels?
12. What support is needed to move to higher levels?
13. How can this support be provided by software industry?
14. Do you foresee any specific difficulties that might arise while getting connected or engaged with the IT industry with the aim to improve your information management?

Appendix 2 Interviews with software industry

List of supporting questions for conducting interviews with software industry

BIM software industry

A. Do you think NRAs need to get to a higher level with BIM and why so?
B. What do NRAs need to get to a higher level with BIM (your BIM software)?
C. What support can you give them to get to a higher level?
D. Do you foresee any specific difficulties that might arise while getting connected or engaged with NRAs with the aim to improve their information management?
E. Does your BIM software (or the one that you use) support open standards? Which ones?
F. Do you integrate/embrace in your BIM software data from sensors / monitoring devices / inspections? In what format?
G. What data from BIM do you consider to be vital for AMS systems?
H. What do you see as the risks of development of BIM software related to horizontal infrastructure (e.g. roads, bridges, tunnels, water pipes)?
I. What do you see as the advantages of development of BIM software related to horizontal infrastructure?
J. Does your BIM software allow for adapting models / upgrading models / adding elements to models?
    a. Is it possible to attribute these additions with any meaningful information?
K. Does your BIM software support visualization of input data from different sources? Does it include applications (APIs) that support immediate decision making? (e.g. closure of tunnel in case of incident detection)
L. Does your commercial strategy include NRAs? Interoperability with their AMS?
M. Does your vision include NRAs? Interoperability with their AMS?
N. Does your road map include NRAs? Interoperability with their AMS?
O. What steps in a roadmap would be needed for BIM industry to align with NRAs needs?
P. What risks do you see with aligning your strategy/vision/road map with NRAs needs/interoperability with AMS?
Q. What opportunities do you see with aligning your strategy/vision/road map with NRAs needs/interoperability with AMS?
R. The CEDR Interlink project (see https://www.roadotl.eu/ for more information), which was completed in 2018, was an important preliminary step in what CEDR wants to achieve with BIM. What is your level of awareness of the CEDR INTERLINK project?

AMS software industry

1. Is your software following the principles of Linked (Open) Data?
2. Would you expect BIM Software to be following the principles of Linked Data?
3. To what extent is your AMS software using Open Data protocols?
4. What support can you give them to get to a higher level with their information management?
5. Do you foresee any specific difficulties that might arise while getting connected or engaged with NRAs with the aim to improve their information management?
6. Does your commercial strategy include NRAs? And interoperability with their BIM? And why/why not?
7. Does your vision include NRAs? Interoperability with their use of BIM?
8. Does your road map include NRAs? Interoperability with their use of BIM?
9. What steps in a roadmap would be needed for AMS industry to align with NRAs needs in BIM?
10. What risks do you see with aligning your strategy/vision/road map with NRAs needs/interoperability with BIM?
11. What opportunities do you see with aligning your strategy/vision/road map with NRAs needs/interoperability with BIM?

Appendix 3 List of abbreviations

AIM	Asset Information Model or Asset Information Management
AMS	Asset Management System
BIM	Building Information Modelling or Building Information Management
CEDR	Conference of European Directors of Roads
COINS	Standard that provides an information model and exchange format by means of a container for BIM related data
DATEX II	Data exchange standard for exchanging traffic information and traffic data
EUROTL	European Road OTL
GDPR	General Data Protection Regulation (EU) 2016/679
GIS	Geographic information system
ICT	Information and communications technology
IFC	Industry Foundation Classes
ifcOWL	Web Ontology Language (OWL) representation of the Industry Foundation Classes (IFC)
INTERLINK	Information management for European roads using linked data
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information technology
LiDAR	Light Detection and Ranging
LOD	Level of detail
NRA	National Road Authority or National Road Administration
OTL	Object Type Library
PIM	Project Information Model
PMS	Pavement Management System
RWS OTL	Rijkswaterstaat Object Type Library
UAV	Unmanned aerial vehicle