The role of Web GIS in project information management aligned with ISO 10650 standards

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June 3, 2021

Acronyms

1 Introduction

In large and complex work such as infrastructure projects, data management is important for collaborative production and sharing of information. The data management processes include storing, exchanging, and distributing information including 2D/3D spatial data. In practice, many organizations have their own and different standards and process for data management which, while collaborating in projects, raises several issues such as efficiency and time and data loss (7.1). After the publication of the British standards PAS 1192 series about the information management in projects, their benefits were internationally recognized and organizations started adopting *PAS 1192-2:2013* in their projects. As a result, the international community approached ISO and demanded elevating PAS 1192 to an international level (Shillcock, 2021). This resulted in the publication of the *ISO 19650 series* which is international standards principles for assets' information management. ISO 19650 series "*Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling (BIM)*" standards offer recommendations and principles for managing information over the whole life cycle of a built asset [1]. ISO 19650 standards consist of 5 parts, each of which focuses on a specific phase of the assets' life cycle management. In 2018, ISO 19650-1:2018 (Part-1) (BS EN ISO 19650-1 - Concepts and principles, 2018) and ISO 19650-2:2018 (Part-2) (BS EN ISO 19650-2 - Delivery phase of the assets, 2018) were released. Part-1, which can be adapted for projects of any scale and complexity, contains recommendations for frameworks to digitally manage information, including exchanging, recording, versioning, and organizing. It outlines clear principles for all parties involved throughout the entire asset life cycle, including owners, leads and non-lead designers, contractors, sub-contractors, manufacturers, investors, end-users, and public authorities. Part-2 specifies information management requirements within the context of a project's delivery phase, from design through to planning, procurement, construction, commissioning, and close-out for built assets [2].

Infrastructure projects involve the usage of BIM data in combination with GIS data which is important for the development of such large-scale projects. The spatial context enables deeper insight for better decision making, communication, and understanding [3]. Moreover, in many projects, the practice is that BIM and GIS data generated throughout the projects end up on Web GIS platform, the environment where the asset is managed for further purposes (Field research, 7.1). Ma and Ren (2017) agree and add that having this data in (Web)-GIS platform is not only important during the project (for the designing, construction, and retrofit phase), it is used for many applications later over the whole life cycle of the asset such as maintenance work, hazard response, risk management, and energy management.

For enabling information management process compliant with ISO 19650-1:2018 & ISO 19650-2:2018 (ISO Series), the EN ISO 19650-1:2018 document contains the concept of a Common Data Environment (CDE) and defines it as "agreed source of information for any given project or asset, for collecting, managing, and disseminating each information container through a managed process". In infrastructure projects, the Web GIS platform is an essential part of the workflow (process) and, therefore, should be part of the CDE technical solution (7.1). Whether data comes from BIM or GIS software as an information container, in Web GIS, this information container is a Web service. In order for a Web GIS platform to be a part of (or as standalone) a

[1] https://www.bsigroup.com/en-GB/iso-19650-BIM/ URL date: 2021-05-16

[2] https://www.bsigroup.com/en-GB/blog/Built-Environment-Blog/iso-19650-parts-1-and-2–things-to-consider-when-implementing-bim-in-your-business/ URL date: 2021-05-16

[3] https://steemit.com/steemstem/@langford/gis-and-it-s-importance-to-civil-engineering URL date: 2021-05-16

project's CDE, it should enable certain functionalities/tools, which are specified in Part-2 clause 5.1.7, for the web services (information containers).

1.1 Scientific relevance

Although Web GIS and the GIS data are essential components of working in infrastructure projects, there are hardly any research on the role of Web GIS and managing GIS data in ISO Series compliant projects. There are also no examples of tools/functionality that enables applying ISO Series information managements standards in projects that include working with GIS and BIM data. Moreover, interviews conducted with parties involved in the Hoogwaterbeschermingprogram (HWBP), such as the Afsluitdijk, showed that there is interest in possible solutions.

2 Background and related work

2.1 ISO Series

Since the release of ISO Series in 2018, there has been some publications regarding the application of these standards for information management process using BIM data. For example, Rudden (2019) addressed the relevance of ISO Series to consulting engineers and the benefits of using them from BIM approach and project management perspective. Oberste-Ufer (2019) describes how ISO Series standards will have an impact on the construction supply industry in three different ways:

- Information delivery: ISO Series set out requirements for information management which is originally a product. Therefore, pressure on the contractor is increased to deliver the correct information at the specified requirements and time.
- Easier optimization: the set of standards is seen as an opportunity for safer, faster, and more flexible information management process overall
- Global adaptability: the clear guidelines offered by ISO Series raise of international awareness of digitally enabled BIM information management processes and will demand parties involved to be prepared for it.

Using the British national annex of (BS EN ISO 19650-2 - Delivery phase of the assets, 2018), (Kemp, 2019) and (Kemp, 2021) present guidance-on-how-to-implement ISO Series information management process for the delivery phase of an asset.

2.1.1 Common data environment (CDE)

The information management process according to ISO Series requires a CDE that facilitates the information workflow. "A CDE workflow describes the process to be used, and a CDE solution might provide the technology to support those processes". The CDE definition holds two parts, the process for collecting, managing, and disseminating information and the technological solutions that support this process (praktijkrechtlijnen, 2020). "A CDE solution could be software, or it could be another form of tool", and "it must be recognized that many different technologies can be used within a single workflow" (Kemp, 2020). Figure 6 shows the concept of CDE and information (containers) workflow. In this regard, (Kemp, 2020) explains the principles of the CDE workflow and the technical requirements for its implementation with examples. Moreover, Shillcock and Suchocki (2019) and Spencer (2019) have provided examples of using the Autodesk software BIM360 Docs as CDE to enable BIM workflows aligning with ISO 19650 standards.

2.2 Web GIS & (I3S) Scene layer (Web service)

Web GIS is a web-based GIS platform that allows users to consume and serve GIS data in the form of Web services such as WFS and WMS. The Indexed 3D scene layer (I3S) service and scene layer package (SLPK) (also referred to as scene layers) formats is an example of Web services that can be consumed and served on Web GIS. (I3S) is an open 3D content delivery format used to rapidly stream and distribute large volumes of 3D GIS data to mobile, web, and desktop users. (I3S) and SLPK are OGC Community Standard based on (I3S) version 1.6 of the Esri openly available specification [4]. It is possible to convert high detailed BIM data (such as (*.ifc)) to (I3S) scene layer (of type 3D Objects) and share it on the web to be used/combined with GIS data.

2.3 Infrastructure projects - Hoogwaterbeschermingprogramma (HWBP)

The Hoogwaterbeschermingprogramma (HWBP) is a prolonged program to reinforce the dykes protecting the Netherlands against water. This program is a collaboration between Rijkswaterstaat (*Dutch Ministry of Infrastructure and Water Management*) and 21 Regional water authorities (waterschappen). Reinforcing the Afsluitdijk [5] is an example of infrastructure projects and activities related to the HWBP where the Rijkswaterstaat is widening the body of the dyke and raising it by 2m. Therefore, construction companies (contractor) such as BAM are assigned for designing or constructing work. Field analysis showed that the Rijkswaterstaat requires the final products (an asset) of a project to be delivered in a GIS software readable format (with specified attributes) to be converted to Web services. This data is stored and managed in their Web GIS (kern GIS) [6] to be used later in different application such as maintenance work and administrative purposes. Besides that, the size and complexity of these projects make it essential to incorporate the Web GIS platform in the information management process and workflow.

3 Research objective and scope

The main research question for this thesis is: *What is the role of Web GIS in information management process of projects aligned with ISO Series standards including GIS & BIM?*

The aim of this thesis is to understand how Web GIS can enable information management aligned with ISO Series standards in infrastructure projects. To achieve this, the following subquestions are relevant:

- How information workflow is managed in infrastructure projects that include working with GIS & BIM?
- What is the role of Web GIS in the current practice?
- What are the challenges/requirements in these information workflows?
- How do these challenges/requirements fit in ISO Series standards as a solution?
- What are the technical requirements (tools or functionalities) to support the ISO Series solution and workflows in Web GIS?
- How can these functionalities be applied on Web services in Web GIS?

[4] http://docs.opengeospatial.org/cs/17-014r5/17-014r5.html
[5] https://www.rijkswaterstaat.nl/en/about-us/gems-of-rijkswaterstaat/afsluitdijk URL date: 2021-05-10
[6] https://www.geomaat.nl/producten/kerngis/ URL date: 2021-05-16

4 Methodology

This thesis employs a combination of literature study and field analysis; figure 1 shows the general guideline of the methodology. The paragraphs below explain the steps in more detail, with preliminary results presented in the section 5.

Infrastructure projects - Hoogwaterbeschermingprogramma (HWBP) are used as a case study in this research. Field analysis is conducted on the information management workflow of the (HWBP) to 1st identify the role of Web GIS and GIS data in infrastructure projects. Recognizing the role of Web GIS in current practice is important to understand what functions Web GIS shall serve in projects aligned with ISO Series standards. 2nd Explore information management requirements and challenges in projects that include working with GIS & BIM data; Since ISO Series standards for information managements are very generic, this step is necessary in order to understand how these standards apply in practice and fit in the identified

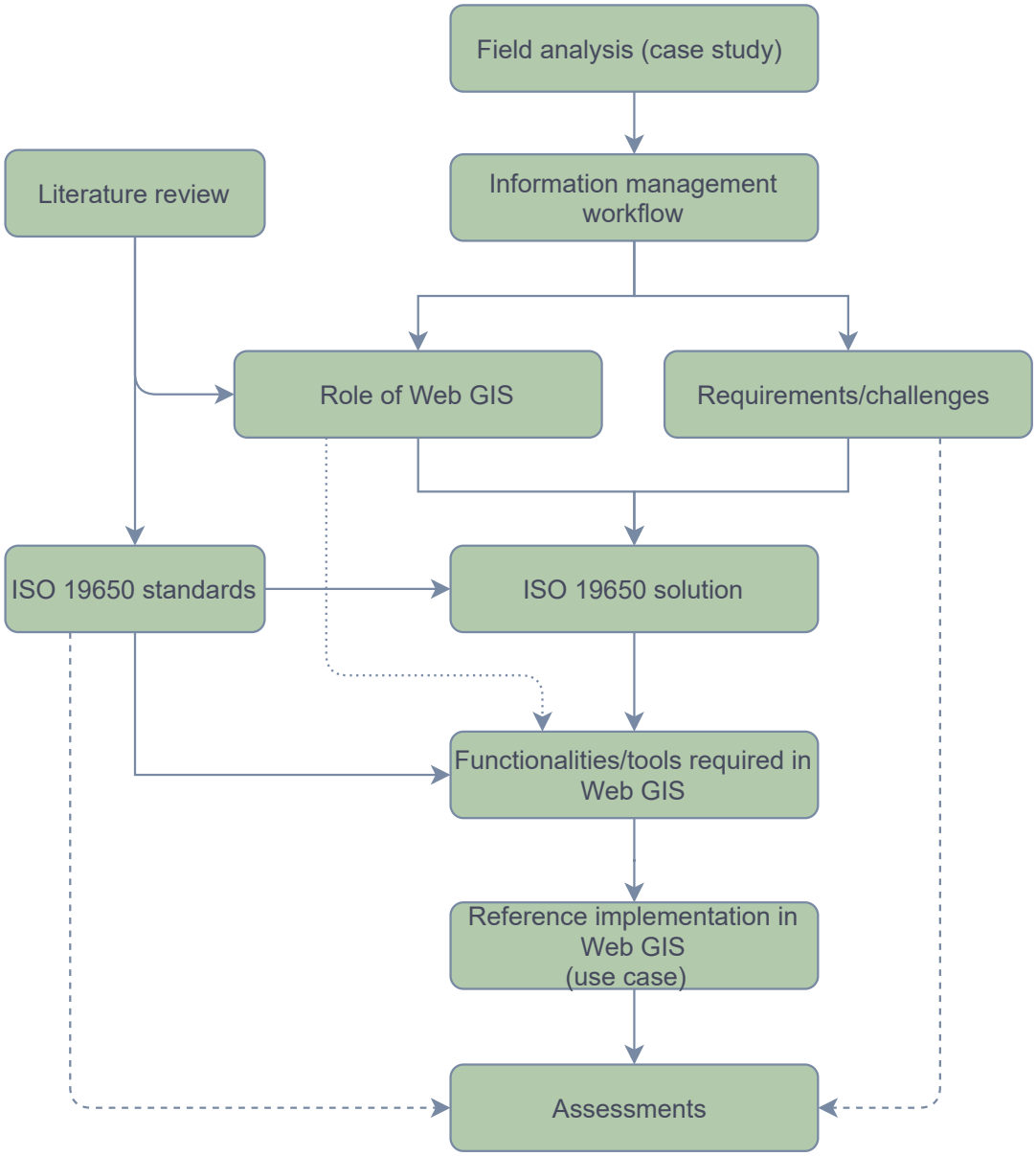


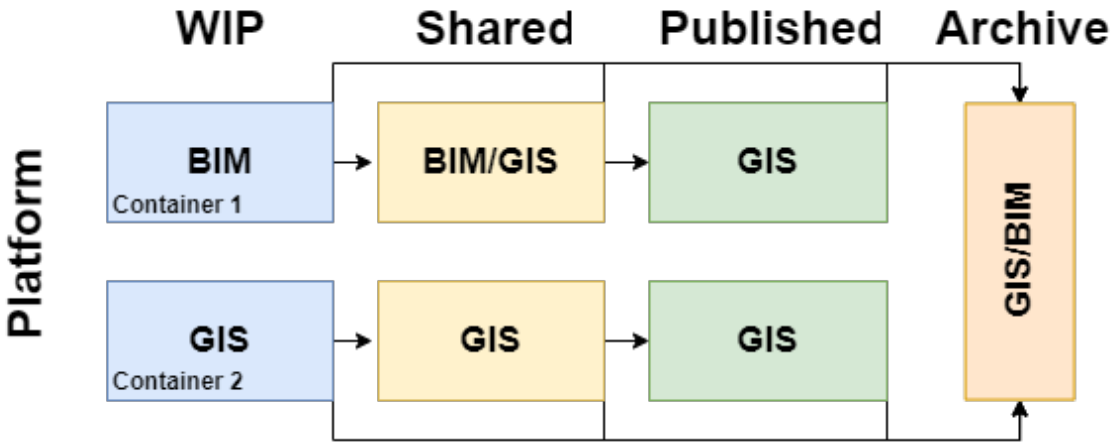
Figure 1: Methodology flowchart

requirements/challenges. For more details and the preliminary results of the field analysis see section 5.1

The literature review discusses the role of Web GIS and its importance in projects and asset's information managements. Furthermore, the study researches ISO Series standards for information management workflow during the delivery phase of an asset (in project-based workflow). For doing so, ISO Series documents and guidance-on-how-to-implement-ISO Series such as (Kemp, 2019), (Kemp, 2021), and (praktijkrechtlijnen, 2020) are used. This step is carried out in order to understand how to apply ISO Series standards (the 8 phases/activities shown in table 1) and recognize the benefits of applying these standards to solve identified requirements/challenges. The findings on the role of Web GIS and information managements requirements are used to develop a scenario (ISO 19650 solution) that complies with ISO Series standards in order to solve those requirements/challenges (see figure 5b for illustration). Section 5.2 contains further details on how ISO Series standards would solve the identified challenges and the suggested solution.

According to Part-2, projects' information workflows are enabled in a CDE (see section 2.1.1). Therefore, the research explores the CDE technical functionalities required in Web GIS to support the information workflow of the proposed solution. The technical requirements are a list of functionalities that a CDE should enable, which are specified in Part-2 clause 5.1.7. The CDE process and technical solution include different types of data formats (files such as *.pdf, word, or other type of data in a database). However, the focus of the investigation is solely on the 3D GIS & BIM spatial data in Web GIS platform, (see figure 2).

For BIM data (container 1 in figure 2), enabling the functionalities requires integration between different platforms, e.g, using API's. This is not within the scope of this research. However, the work will present a workflow (BIM ⇒ File GDB ⇒ (SLPK) ⇒ (I3S)) available and the



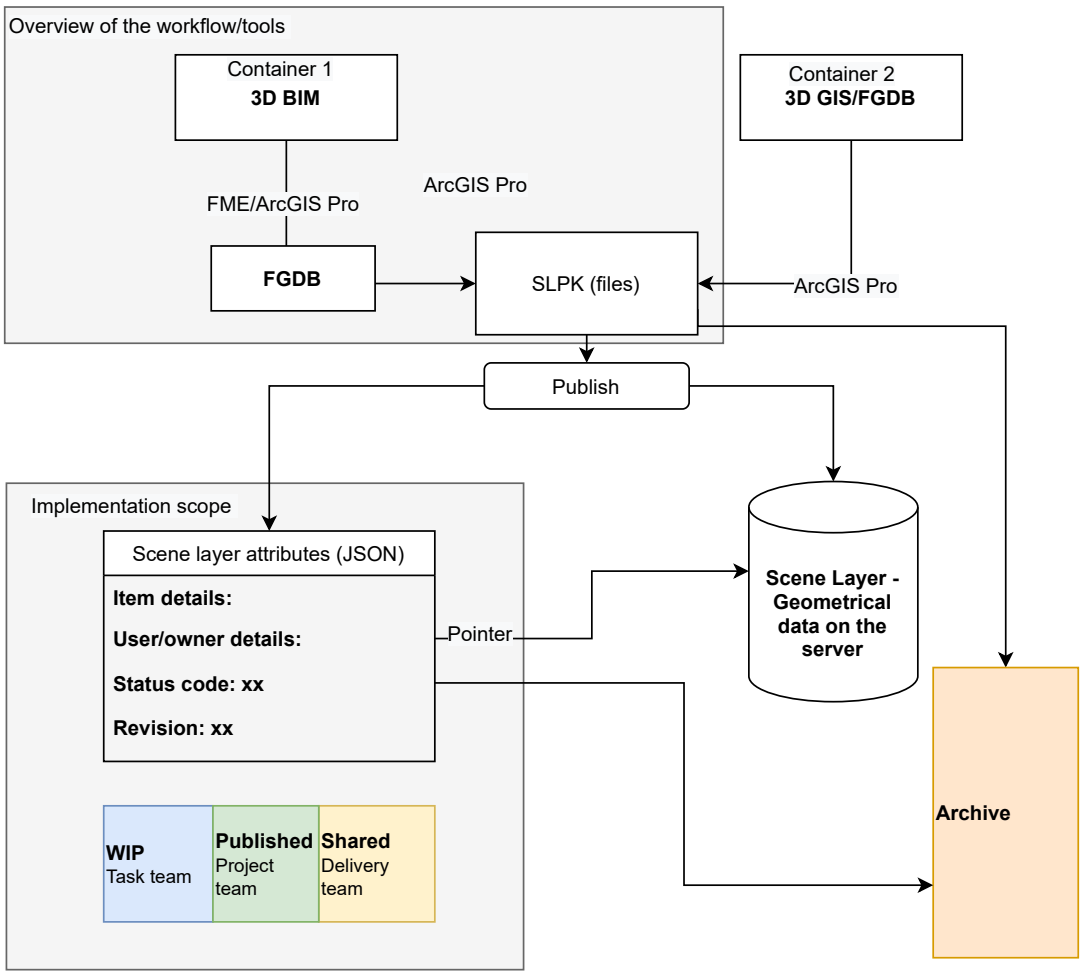
A **container** can be a single object of an asset (object of the soil layer in a dyke) or objects of a discipline or sub-discipline of an asset (soil layer or bottom layers)
container 1: product designed in BIM software and pushed to (Web)GIS platform
container 2: product designed in GIS software and pushed to (Web)GIS platform

Figure 2: GIS & BIM information container workflow in an infrastructure project - transitioning between platforms and CDE status' (projected on the Common data environment (CDE) concept (BS EN ISO 19650-1 - Concepts and principles, 2018), figure 10))

tools necessary for converting BIM data in (*.ifc) format to (I3S) Web services (see section 6).

Whether the data is coming from BIM or (Web)-GIS platform, certain functionalities are required for facilitating the workflow in Web GIS. This work uses the British national annex (BS EN ISO 19650-2 - Delivery phase of the assets, 2018) to discuss the required functionalities in details. Some functionalities are data (case) specific and therefore not considered in this research. Please refer to section 5.2.1 for more details on the functionalities and how they are tackled. Figure 7 shows a container (Web service) workflow within a CDE and attributes attached in accordance with the British national annex.

Implanting a CDE with functionalities according to ISO Series standards for a project differs per platform, data type and format. Therefore, a Web GIS platform is chosen to implement a CDE with (2-3) functionalities out of the list presented in section 5.2.1. For doing so, this thesis compares examples of CDE's implementation on other platforms. Then, the chosen Web GIS platform is expored in order to develop a CDE solution and implement it. This solution enables the workflow (per lead appointed party in table 1) of container 2 in figure 2. Section 6 contains



The implementation scope (lower left box) focuses on functionalities 1 & 2 of the list in section 5.2.1. For the purpose of this thesis, the workflow and tools available for converting an (*.ifc) file to a (SLPK) file is presented (upper left box).

Figure 3: Use case - schema illustrates a solution to meet the requirements of CDE according to ISO Series standards.

further details regarding the choices made and the implantation specifics.

Measuring the results can be done in two ways. First, assessments based on two criteria: solving the challenges identified in the field analysis and compliment with ISO Series standards. Second, requesting the interviewees from the field analysis to assess the functionalities created.

5 Initial results

5.1 The role of Web GIS & the requirements in information management

Since no research has been found on application of ISO 19650 standards for GIS data on the web, this step was necessary to understand how Web GIS fits in the process of information management. Therefore, the goal of the field analysis was to identify the role of Web GIS and requirements in the information workflow of infrastructure projects. Projects and activities related to HWBP are used as a case study in this research (see section 2.3). For understanding what role Web GIS plays in the process, interviews with people in data management roles were conducted. The interviewees were also familiar with ISO Series standards and showed interest in the possible solutions. Regarding the role of Web GIS the interviews concluded that:

- GIS data is an essential part of the design process (e.g. environmental analysis, site management and logistics).
- BIM and GIS data produced throughout the project mostly end up on Web GIS platform to be used later for different application (e.g. Rijkswaterstaat stores the deliverable in a Web GIS Platform called Kern GIS, 2.3).

The analysis also addresses the challenges in infrastructure projects regarding information management. Therefore, with data collected from around 18 stakeholders from different roles, the following requirements/challenges in the information management process have been identified (see figure 5a):

1. There is a general gap between the client waterschappen and the contractor in used technology, data format and the information management standards resulting in a loss in the data and inefficiency (see figure 5a).
2. There are no clear standards for managing information (sharing, exchange, distributing)
    - Difficult access to reliable information available prior to the project (site information, older designs).
    - Difficult access to most up-to-date information produced throughout the project.
3. There is no clear specification for the deliverable, e.g. attributes (semantics), formats, coordinates system (for spatial data), dates, etc.
4. There is no project requirement and clear project plan that can steer the information management process.
5. There is no managed data environment, e.g.
    - No version history of the information.
    - No managed information-flow.

5.2 ISO Series solution for information management process - literature review

The aim of this section is to understand what ISO Series standards are for projects' information management and what the benefits of applying these standards are. Therefore, the study reviewed the 8 activities and stage specified in Part-2 (see table 1) and the responsibilities of the parties involved in an ISO Series compliant projects. The research suggests that an ISO Series compliant workflow (see figure, 5b), would solve the identified challenges by:

- The availability of clear guidelines which leads to better defined roles, responsibilities and activities for the client (appointing party) and contractor (lead-appointed party) throughout the project; solves requirements 1, 3, and 4 in 5.1.
- The ISO Series specifies requirements and standards for information management and the exchange of this information; solves requirement 2 in 5.1.
- The ISO Series specifies requirements and standards for CDE workflow and the technical solution that grants controlled and reliable access to most up-to-date information; solves requirement 5 in 5.1.
- Generally optimized process that saves time and leads to less data loss.
- It is worth noting that, beside these benefits, the research has shown organizations (clients) are interested, and they are requiring the contractors to collaborate according to ISO Series standards.

Given that GIS & BIM data produced throughout the project end up on Web GIS, by projecting the current information workflow (see figure 2) on the activities/stages and responsi-

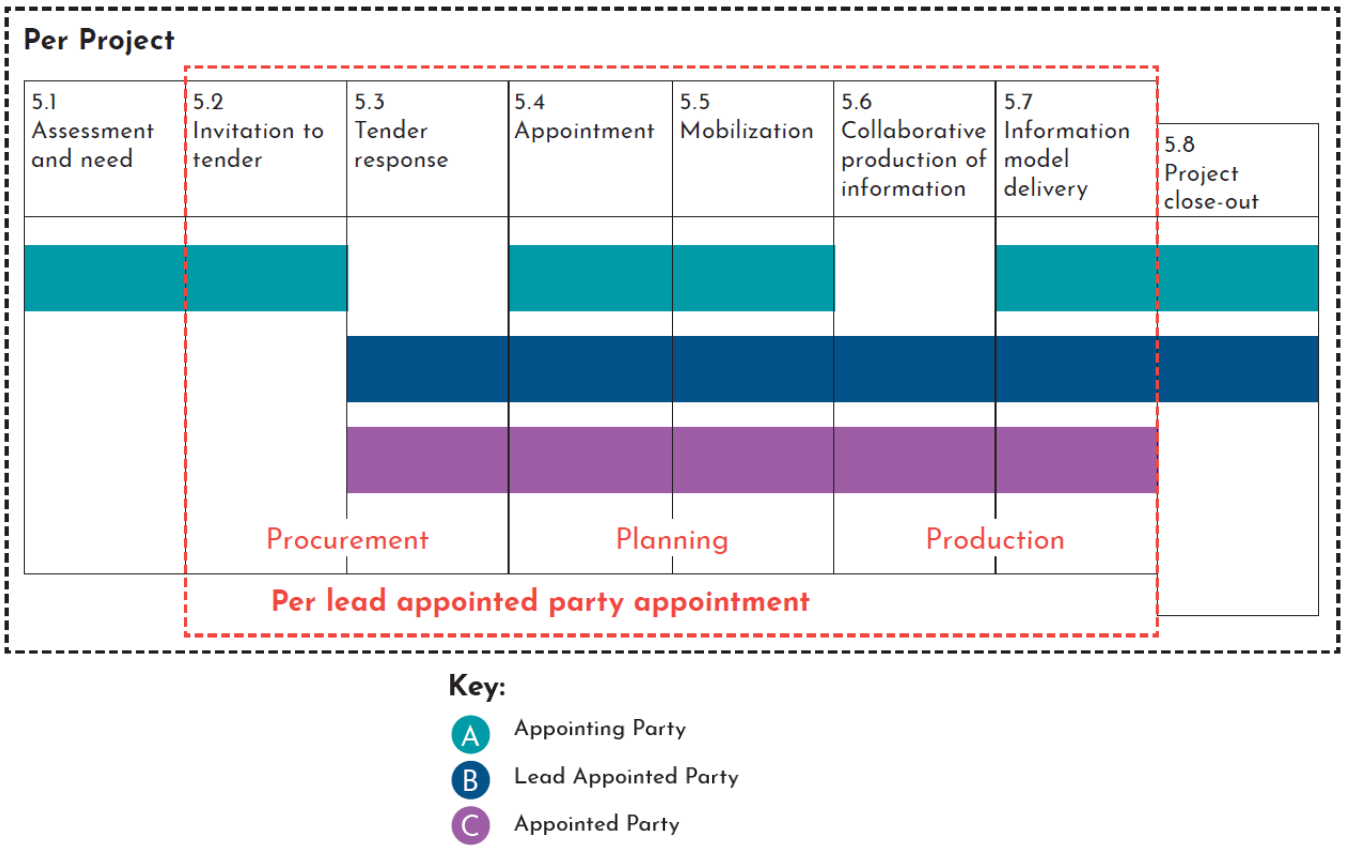


Table 1: Activities and stages, table 2 of (Kemp, 2021)

bilities specified in Part-2 (table 1) a scenario (ISO Series solution) is developed (see figure 5b for illustration)

5.2.1 Common data environment (CDE) requirements & technical solution

As mentioned in section 2.1.1, a CDE describes the workflow of the information and the technology that supports those processes. Part-2 clause 5.1.7 explains that in order for a project's CDE (established by the appointing party) to serve the requirements of a project and the collaborative production, it shall enable specified functionalities/tools. Given that 3D GIS or BIM data end up on Web GIS, the workflow takes place fully or partly on the Web GIS platform. Therefore, Web GIS shall enable those functionalities. The first two are, 1st documented convention for assigning an ID to each container. 2nd assigning each field (object level) from an agreed codification standards. Since those two requirements are case specific, they are not considered in this research. The rest, which are listed here below, are not case specific and therefore are tackled in this research using the British national annex conventions, (figure 7 illustrates the workflow and technical requirements of an information container accordingly).

1. The ability of each information container (Web service on the web) to transition between states (WIP, shared, published)
2. The ability for each information container to have attributes assigned (status, revisions, and classification (see table 2))
3. Recording of user details (name, date) when information container transitioning between states
4. Controlled access at an information container level.
5. Record of version history of an information container.

6 Reference implementation of a CDE in ArcGIS Online

Implementing the functionalities listed in section 5.2.1 to enable the workflow differs per platform and per data type. For example, an option to be used is by simply deploying metadata fields to assign states (WIP, shared, published) and attributes (status, revisions, and classification) to an information container. Another option, which is presented by Shillcock and Suchocki (2019) and Spencer (2019) is by creating folders that represent *WIP, shared, published, archive* for the states; and the files within them are assigned attributes for *status, revisions, and classification*. The reference implementation of this thesis consider creating functionalities that enable the workflow (container 2 in figure 2) for an (I3S) scene layer in Web GIS Platform as a standalone CDE. Esri Nederland, the hosting company of this research, provided data (documents), the necessary tools, and access to ArcGIS platform (Esri's Web GIS platform). Moreover, (I3S) Web service and (SLPK) specification are developed by Esri, hence, they are compatible with ArcGIS Platform. Therefore, the reference implementation of a CDE and functionalities required are carried out in/for ArcGIS Online. Out of the list in section 5.2.1, the focus of the implementation is on functionalities 1 and 2.

For the implementation on ArcGIS Online, the work compares two methods (use cases) to upload (publish in ArcGIS) an (I3S) service to ArcGIS online from 3D *GIS or BIM* data [7].

[7] https://doc.arcgis.com/en/arcgis-online/manage-data/publish-scenes.htm URL date: 2021-05-16

- **Option 1:** ArcGIS Pro, from File GDB using *share as web layer* tools ⇒ Scene layer (I3S) service with associated feature service.
- **Option 2:** ArcGIS Pro, from File GDB using *create-3DSceneLayerPackage* tool ⇒ (SLPK) file ⇒ upload to WebGIS/publish ⇒ Scene layer - (I3S) service.

Option 2, the method illustrated in schema 3, is recommended to guide the implantation for two reasons: 1st the geometrical data are stored in one (SLPK) compressed file which makes it easier to store these data for versioning purposes (one of the functionalities required). 2nd restoring the data from this stored (SLPK) file can be easily done by uploading it to ArcGIS Online and publishing it without the need for any software (unlike option 1 which requires ArcGIS Pro).

When publishing an (SLPK) file to ArcGIS Online the geometrical data are stored in the database on the server and an item (JSON file) is created. This (JSON) file is a pointer to the geometrical data with metadata and additional attributes that control access permissions, categorize the data, adds tags etc. The reference implementation is focused on using those (JSON) files, which are called items in ArcGIS, to create the required functionalities. Note that in the context of ISO Series standards, an item represents an information container. Furthermore, a feature called *Group* in ArcGIS Online is used to represent a CDE (see figure 4). A *Group* is a collection of items usually related to a specific area of interest, [8]).

A *Group* allows its content (items) to be categorized within it per item. Categorizing feature can be used to create different states (WIP, Shared, Published). Subcategories can be used to create a list of suitability codes (S1, S2 etc. see table 2). On the item level, there is an object (attributes) called "snippet" can be used to assign revision and classification metadata (see

[8]https://doc.arcgis.com/en/arcgis-online/share-maps/groups.htm

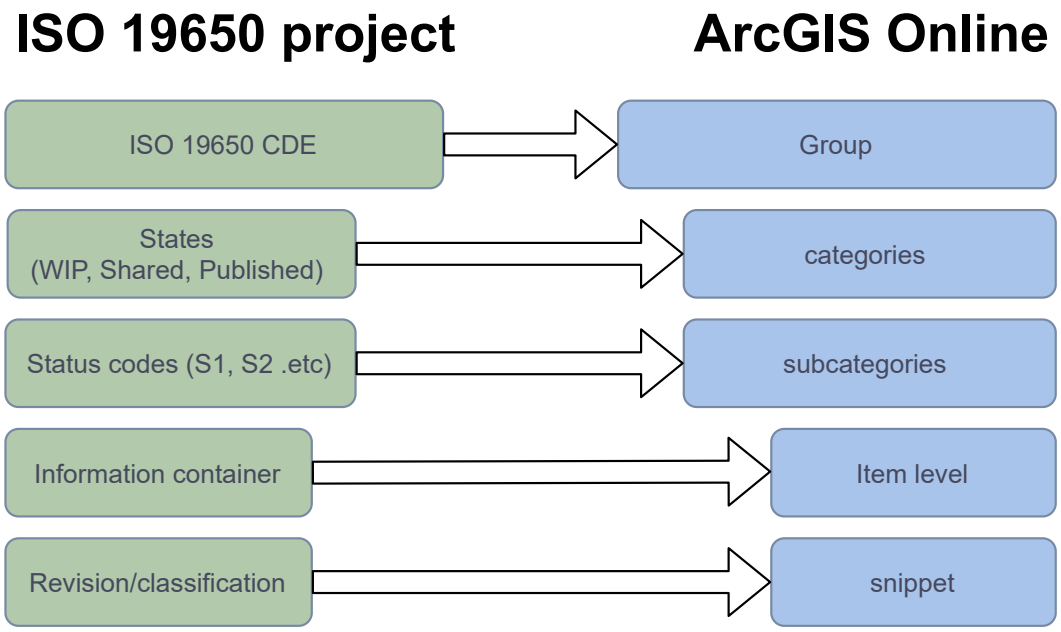


Figure 4: A CDE representated in ArcGIS Online as a Group: metadata required for an information container and how they are assigned partly on a Group level and partly on an item level

figure 4). While this can be done manually, the implementation use Python API to automate the creation of the categories and the process of transiting, between states and the suitability status. The user details of a *Group* are registered when logging in to ArcGIS Online to access the *Group*'s content. The user details with update time can be stored in an archive repository when an action is taken.

A *Group* allows different level of access permissions to the items within it. Beside the access permission levels offered on an item based level, so, different level of access permission according ISO Series standards can be granted (this functionality needs more research). The implementation focuses on the first 2 functionalities (states and attributes) with the possibilities of spending time on the access permission and record of the version history if time allows (schema in figure 3 illustrate the implementation scope and the general proposed approach of the solution).

For BIM data (container 1 in figure 2), as mentioned in the Methodology, it is possible to convert an (*.ifc) file to (I3S) Web services. Although, the workflow of container 1 is not within the scope of this thesis, and not considered in the implementation. An example of the workflow to convert an (*.ifc) file to (I3S) Web services in ArcGIS Pro is presented:
BIM (using *quick import* tool *data interoperability extension*) ⇒ feature classes (3D objects) in File GDB (using *Add 3D Formats to Multipatch* geoprocessing tool) ⇒ 3D object feature class using *Create 3D Object Scene Layer Package* tool (Data Management) ⇒ (SLPK) file (upload to Web GIS and Publish) ⇒ (I3S) Web Service.

6.1 Tools

For the reference implementation of functionalities/tools that enables a CDE workflow in Web GIS, Esri's ArcGIS Online is used as a Web GIS platform. ArcGIS Online provides a feature of group based content (content is accessed by members of a group of users). This feature (Group) which represent a CDE is used. ArcGIS Hub, which is a configurable website interface with embedded scene viewer, is used for visualizing the content of a CDE while testing the created functionalities. GitHub is used for hosting the codes/functionalities which will be made publicly available. ArcGIS API for Python is used as a programming language. If required, ArcGIS Pro (and its FME plugin) can also be used for testing the developing tools and visualizing content.

6.2 Data

For the purposes of this thesis, any data can be used for testing the workflow and the implemented tool. There are Civil 3D (*.dwg) model of a dyke in 2D and 3D related to the HWBP, and authorized for testing. The Civil 3D model is converted to (I3S) web service that will be used for testing the implemented functionalities.

7 Schedule, time planning & activities

The following schedule is set up for carrying out the activities needed to complete the research objectives.

Begin date	*End date*	*Activity*
		P1 - Registration of topic & mentors
3/1/2021	3/12/2021	Exploring graduation topic & choosing a case study
3/15/2021	3/29/2021	Study information workflow - infrastructure projects
3/15/2021	3/22/2021	- Interview & field research
3/22/2021	3/29/2021	- Literature study - role of Web GIS
3/29/2021	4/16/2021	Study ISO 19650 Series standards part 1 & part 2
		P2 - Graduation plan (formal assessment)
4/19/2021	4/27/2021	Field analysis & interviews
4/27/2021	5/19/2021	Study common data environment requirements
5/20/2021	6/9/2021	Study the role/requirements of Web GIS for a CDE
5/17/2021	6/9/2021	Write graduation plan & P2 presentation
		P4 - Formal process assessment
6/10/2021	8/6/2021	Implementation of CDE's functionalities
7/19/2021	7/30/2021	Midterm progress meeting
8/2/2021	8/27/2021	Assessment & final implementation
8/30/2021	10/1/2021	Write thesis & P4 presentation
		P5 - Public presentation and final assessment
10/4/2021	10/22/2021	Finalize thesis
10/26/2021	11/5/2021	Prepare final presentation

The following calendar shows the dates of milestones (P's) of the thesis. The exact dates of P4 and P5 are to-be-defined.

Milestones	date
p1	4/19/2021
p2	6/10/2021
p3	7/19/2021 - 7/30/2021
P4	9/21/2021 - 10/1/2021
P5	10/26/2021 - 11/6/2021

7.1 Meetings

(By)-weekly meeting is held with the supervisors from Tu Delft, dr. Francesca Noardo & Stelios Vitalis. Similarly, for additional guidance on the topic and the materials provided by Esri, meetings are planned by weekly with Niels van der Vaart & Frank de Zoete.

References

BS EN ISO 19650-1 - Concepts and principles. Organization and digitization of information about buildings and civil engineering works, including building information modelling (bim) - information management using building information modelling, 2018. URL https://www.iso.org/standard/68078.html. Url date: 2021-03-08.

BS EN ISO 19650-2 - Delivery phase of the assets. Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling, 2018. URL https://www.iso.org/standard/68080.html. Url date: 2021-03-08.

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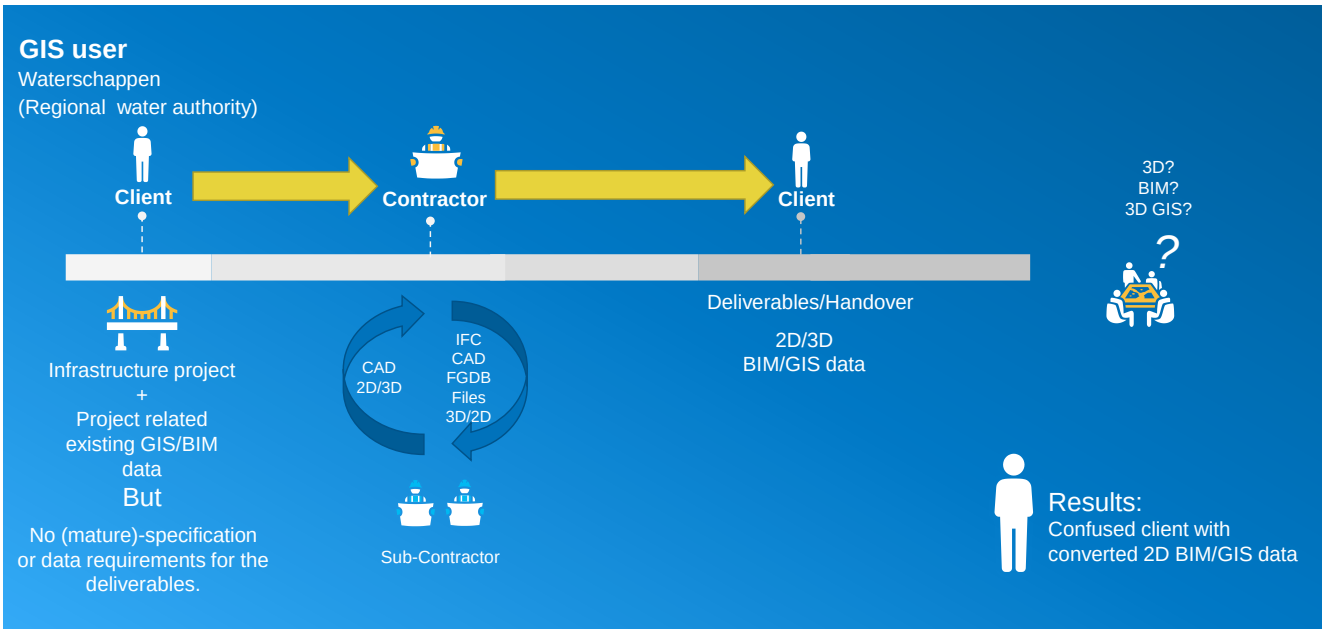
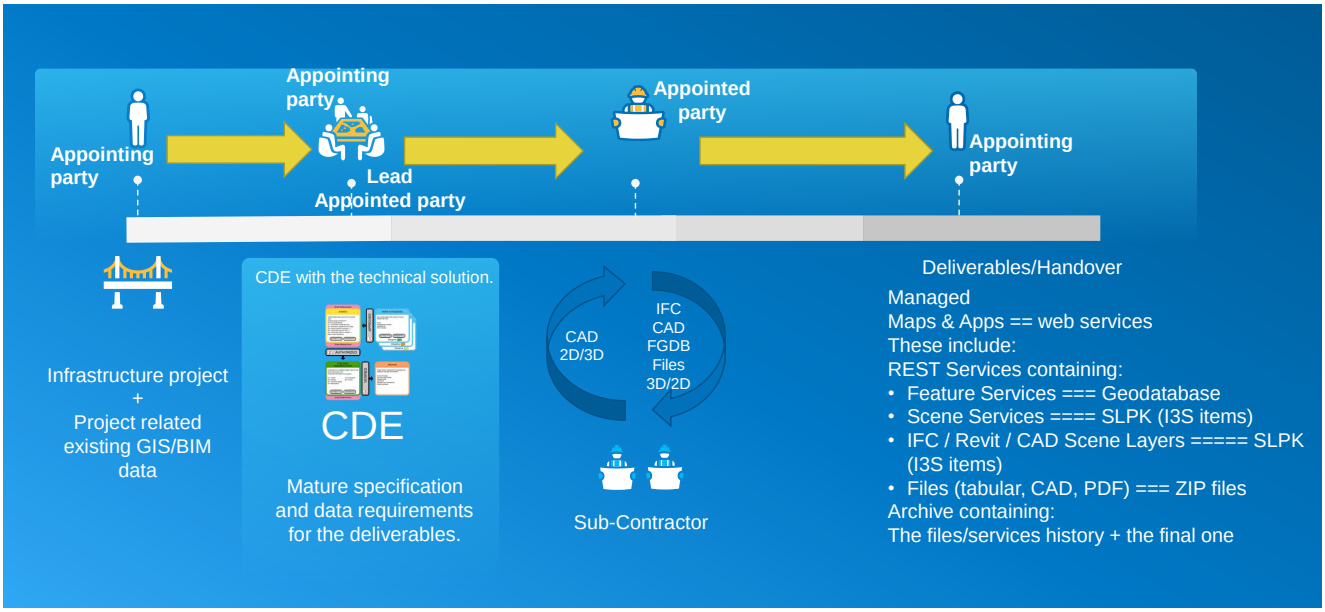
Figures and UML diagrams



(a) Information management process - case study (HWBP).
Results: unmanneged data, time loss, and data loss.



(b) ISO 19650 solution for information management process.
Results: managed data, less time, and less data loss.
ISO Series terms: appointing party = client, (lead)-appointed party = (sub)-contractor

Figure 5: Case study - illustration of the ISO 19650 solution for information management process

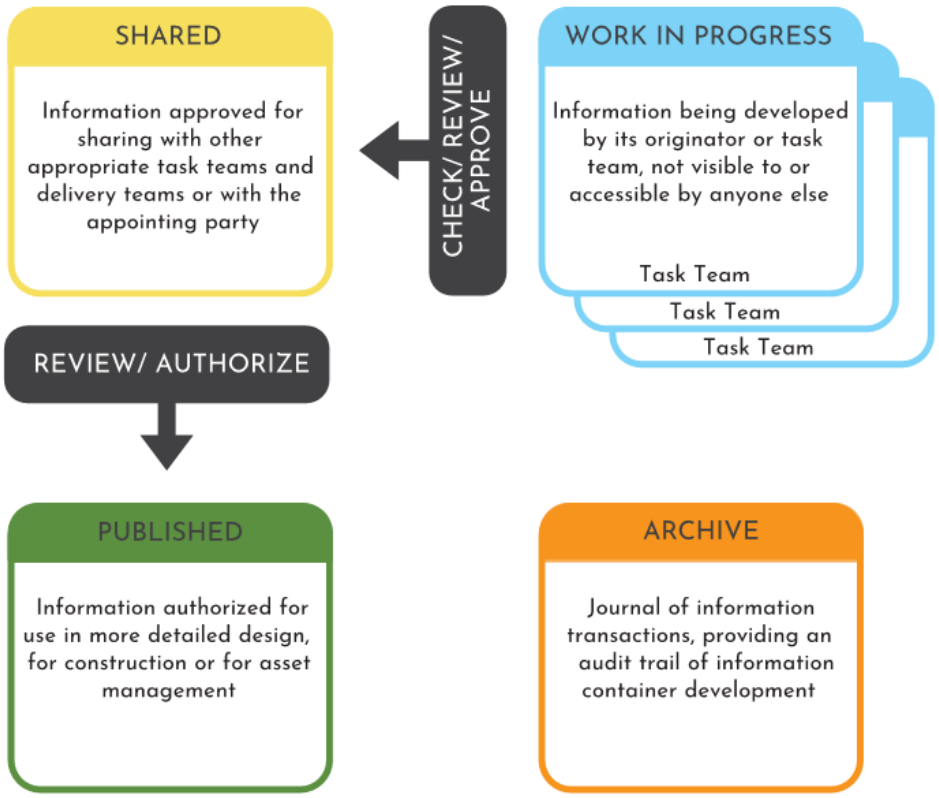


Figure 6: Common data environment (CDE) concept (BS EN ISO 19650-1 - Concepts and principles, 2018), figure 10)

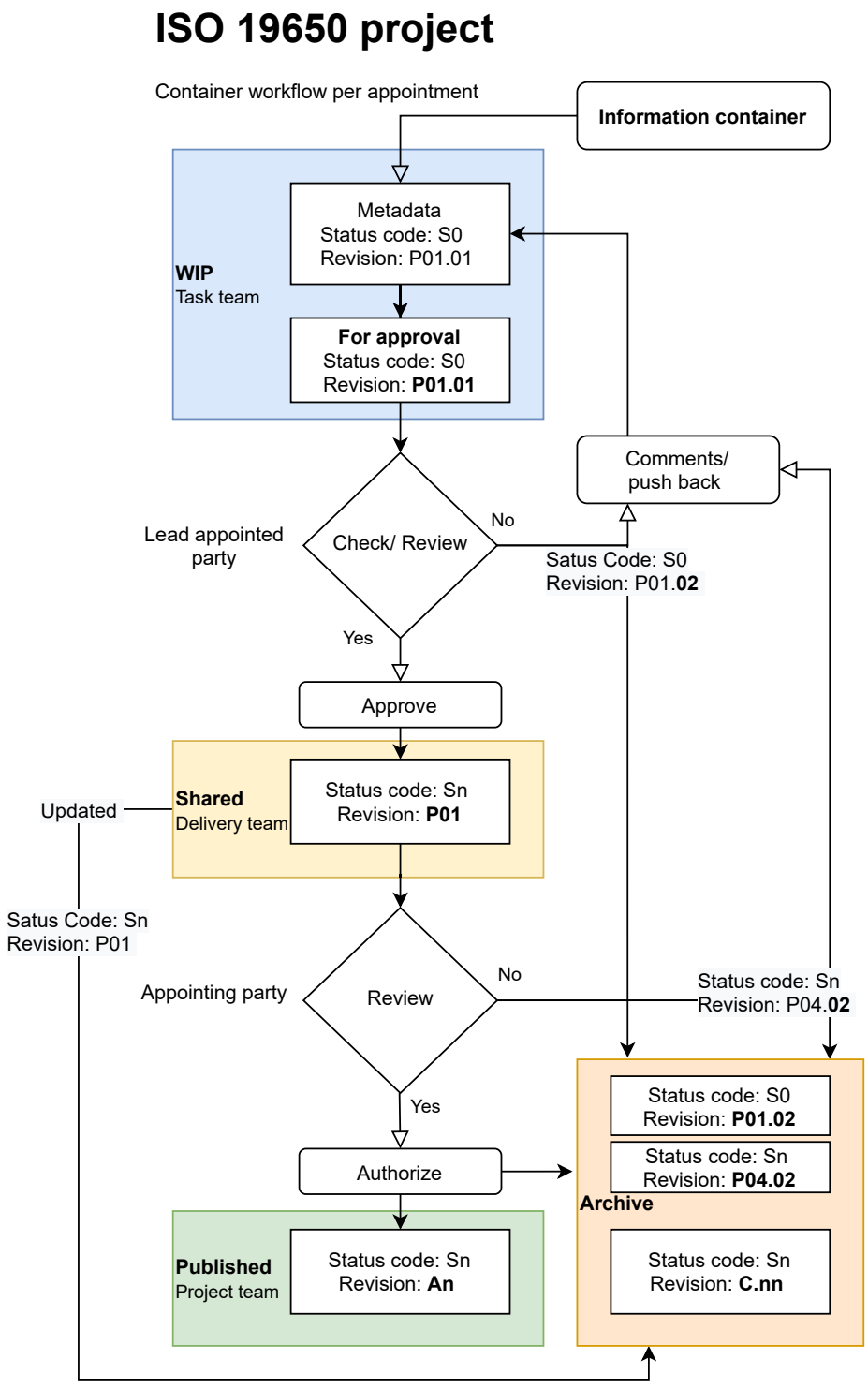


Figure 7: Information container workflow within a CDE according to ISO Series (British national annex conventions), inspired by (SymetriUK, 2020)

Code	Description	Revision
Work in progress (WIP)		
S0	Initial status	Preliminary revision and version
Shared (non-contractual)		
S1	Suitable for coordination	Preliminary revision
S2	Suitable for information	Preliminary revision
S3	Suitable for review and comment	Preliminary revision
S4	Suitable for stage approval	Preliminary revision
S5	Withdrawn*	N/A
S6	Suitable for PIM authorization	Preliminary revision
S7	Suitable for AIM authorization	Preliminary revision
Published (contractual)		
A1, A*n*, *etc.*	Authorized and accepted	Contractual revision
B1, B*n*, *etc.*	Partial sign-off (with comments)	Preliminary revision
Published (for AIM acceptance)		
CR	As constructed record document	Contractual revision

Table 2: ISO 19650-2 Table NA.1 - Status codes for information containers within a CDE (Kemp, 2020)

Interviews and (preliminary)-field analysis

Innovation sprint HWBP

In the week of 15-19 March 2021, Esri Nederland organized an event called innovation sprint. The topic of the sprint was *Information Management with a focus on the HWBP*. The event is a week-long program in which the participants brainstorm innovative ideas to optimize workflows related to the topic of the sprint. Throughout the week, the participants work on realizing these ideas with the technologies available. Stakeholders and parties involved in the HWBP participated in this event and provided valuable input. During the kick-off meeting, the participants, given their roles, identified their requirements/needs as what they would like to achieve at the end of the sprint in an affinity diagram, 8. The following requests were submitted:

- Related to ISO 19650 standards
  - Achterhalen welke data gedeeld wordt en of dat gestandaardiseerd kan
  - Als ingenieursbureau wil ik een uitwisselstandaard voor CAD/GIS zodat ik snel een ontwerp kan converteren, visualiseren en analyseren voor mijn project.
  - Als aannemer wil ik toegang tot de meest actuele en complete data (CAD GIS en etc.) zodat ik tot een weloverwogen en betrouwbare aanbieding kan maken.
  - Als gegevensbeheer wil ik mijn kering in 3d visualiseren zodat ik beter inzicht krijg in de opbouw van de kering en beter aansluit bij de werkelijke kering
  - Hoe kan een waterschap meer met de aangeleverde 3d data?
  - Als gegevensbeheerder wil ik op een eenvoudige manier extra informatie toevoegen zodat ik deze informatie kan gebruiken bij het instant houden van de kering
  - Als gegevensbeheer wil ik op een eenvoudige en eenduidige manier de informatie vanuit het HWPB programma opnemen in mijn beheerregister zodat er geen informatie verloren gaat.
  - Als gegevensmanager wil ik een eenduidige informatievoorziening dit aansluit op de werkprocessen rondom de werkprocessen rondom de primaire keringen zodat ik de informatie vanuit de verschillende werkprocessen kan hergebruiken.
  - als toekomstige beheerder bij WS wil ik dat ik snap waarom een kering is zoals hij is (rekenmodellen, uitkomsten) zodat ik heel veel toekomstige onderzoekstijd kan besparen
  - Wat is er al beschikbaar via services voor een projectomgeving?
  - Voorbeeld projecten vergelijken, waar zitten de overeenkomsten en waar de verschillen?
  - Als informatiemanager wil ik volledige, betrouwbaarder en actuele informatie over de staat van het traject zodat bij aanvang van het project meteen met de goede informatie gewerkt wordt.
  - Als projectmedewerker wil ik een duidelijk verschil tussen schetsen en vastgestelde data en dat vooral de vastgestelde data beschikbaar is voor alle betrokkenen.
  - Wat is er al aan standaarden? Wat is minimaal? Waar het niet voldoet, wat moet er aangepast worden?
  - Op kenmerken data leveren

- Als PD van het HWBP wil ik actuele, gestandaardiseerde data van alle projecten zodat ik overzichtelijk heb wat overal gebeurt en dit met elkaar kan vergelijken.
- Als adviseur ingenieursbureau wil ik vooraf inzicht in de te volgen informatiestandaarden en afgeleide eisen aan ieder door mij uit te werken product zodat ik inzicht heb in de benodigde inrichting van gedeeld kaart-, model- en tekenwerk.
- Als adviseur ingenieursbureau wil ik een dekkend beeld van de bestaande situatie bij start betrokkenheid op een HWBP project. Eenzelfde uitgangspunt op basis beschikbare bronnen, zodat ik lopende het project discussies rond (data)uitgangspunten voorkom of vlot kan duiden.
- Als adviseur ingenieursbureau wil ik onze diverse interne werkomgevingen zelf in kunnen richten op basis van eigen behoeften en (interne)standaarden zodat medewerkers productief en kwalitatief werk kunnen leveren in een bekende omgeving/met set tools onafhankelijk van de keuzen op een individueel project.
- Als waterschap wil ik een standaard samenwerkingsplatform om informatie rondom het project te kunnen delen met de andere stakeholders.
- (middel) Als Informatiemanagement wil ik een gestandaardiseerd platform aan de projectenorganisatie (interne projectorganisatie plus externe betrokkenen zoals ingenieursbureau, aannemers, ...) kunnen aanbieden waarin het projectgebied wordt geduid gepresenteerd (wat ik wel weet en niet weet) zodat ik (informatievoorziening) een goede dienstverlening kan leveren.
- Als ontwerper wil ik graag alle benodigde (ontwerp)gegevens van onze primaire kering makkelijk en overzichtelijk in beeld hebben, zodat er minder tijd en discussie nodig is voor het verzamelen van de meest actuele gegevens.
- Als rayonbeheer wil ik de informatie voorzien rondom de primaire keringen ook meenemen het veld in zodat ik het veld goede keuze kan maken.
- Waterschap/Adviesbureau – initiatie/ verkenning: Als technisch manager van een HWBP project wil ik Inzicht in de technische opgave vanuit de beoordeling van de keringen op kaart. Zodat ik goed weet waar welke technische opgave ligt.
- Als waterschapper wil ik dat alle verzamelde informatie gedurende het project ook beschikbaar is buiten het project.
- Als dijkbeheerder wil ik inzicht in ontwerpbeslissingen zodat ik kan controleren op beheerbaarheid van de toekomstige dijk
- Waterschap/adviesbureau Als omgevingsmanager Wil ik inzicht in stakeholders (perceels-eigenaren), plannen van andere overheden (ruimtelijke plannen, beleid), kabels leidingen, vergunningen. En wil ik per eigenaar op kaart kunnen status kunnen bijhouden. Zodat ik een goed beeld van de omgeving en de knelpunten heb en delen aan anderen betrokkenen.
- Als gegevens beheerder wil ik de revisie gegevens in juiste formaat aangeleverd hebben met de juiste administratieve gegevens, zodat de bestekswijzigingen tijdens het werk ook meegenomen zijn en minder fouten gemaakt kunnen worden. Omdat de gegevensbeheerder niet op het werk aanwezig is en niet van alles op de hoogte is.
- Als omwonende/waterschap/aannemer wil ik up-to-date data zodat ik niet naar verouderde informatie kijk
- (data) Als Informatiemanagement wil ik leunen op gestandaardiseerde afspraken m.b.t. data uitwisselingsformaten (standaard ILS) zodat ik geen verrassingen creëer

ten aanzien van de markt.(*daar waar kan gebruik maken opendata) Doelgroepen in de Hub

  - Als aannemer wil ik de opdrachtgever inzicht geven in de status van het beheer en onderhoud zodat de Asset owner/Asset manager zijn rol goed kan vervullen.
  - Als adviseur ingenieursbureau wil ik een dekkend beeld van de bestaande situatie bij start betrokkenheid op een HWBP project. Eenzelfde uitgangspunt op basis beschikbare bronnen, zodat ik lopende het project discussies rond (data)uitgangspunten voorkom of vlot kan duiden.

- Unrelated to ISO 19650 standards
  - Als informatiemanager wil ik dat GISsers en CADders werken op zelfde dataformat zodat geen conversies meer nodig zijn en ik geen vertraging en geen inforamtieverlies ondervindt
  - Als adviseur techniek kennis en innovatie, wil ik graag een evenwichtig beeld van de (innovatieve)projecten in Nederland in de verschillende fases + de kwalificatie van de info, maar ook de witte vlekken (innovatiekansen) om een actueel beeld te hebben van de waterveiligheidsprojecten in Nederland en lopende innovaties. Graag wil ik het verhaal van de dijk zien.
  - Als bestuurder/programmamanager/Interne opdrachtgever/communicatie bij een waterschap Wil ik op kaart eenduidig actueel inzicht in de ligging, fase, planning, projectorganisatie van de HWBP projecten op hoofdlijnen. Zodat ik het overzicht houdt op waar wanneer welk traject wordt gerealiseerd. (op programma management niveau)
  - Als Geoteam binnen het waterschap willen we actuele geo-informatie op een eenduidige manier inzichtelijk maken, zodat dit in verschillende projecten eenvoudiger en sneller kan worden gedeeld
  - Als omwonende wil ik snel en duidelijk kunnen zien wat de plannen zijn zodat ik snap wat voor effect dit op mij heeft
  - Als omwonende wil ik weten wat er in mijn omgeving gaat gebeuren zodat ik weet wanneer ik hinder ga ondervinden

The innovation sprint event was held in Dutch and here is a summary of the outcome in a context related to this thesis:

- Stakeholders who participated in the event come from different parties such as watershapers (waterboards of The Netherlands), Rijkswaterstaat, engineering/construction companies such as Dura Vermeer and Tauw.
- Stakeholders who participated in the event come from different roles such as information managers, designers, contractors, engineers, administration managers, GIS specialists, BIM specialists.

For the purpose of this thesis, the requirements of the participants were divided into:

- Requirements unrelated to ISO 19650 standards (around 20% of the requests)
- Requirements related to ISO 19650 standards (around 80% of the requests) which are summarized in the following list:
  - Multiple stakeholders - standardized way of exchanging information and clear specification for delivering 2D/3D GIS/BIM data (visual information).

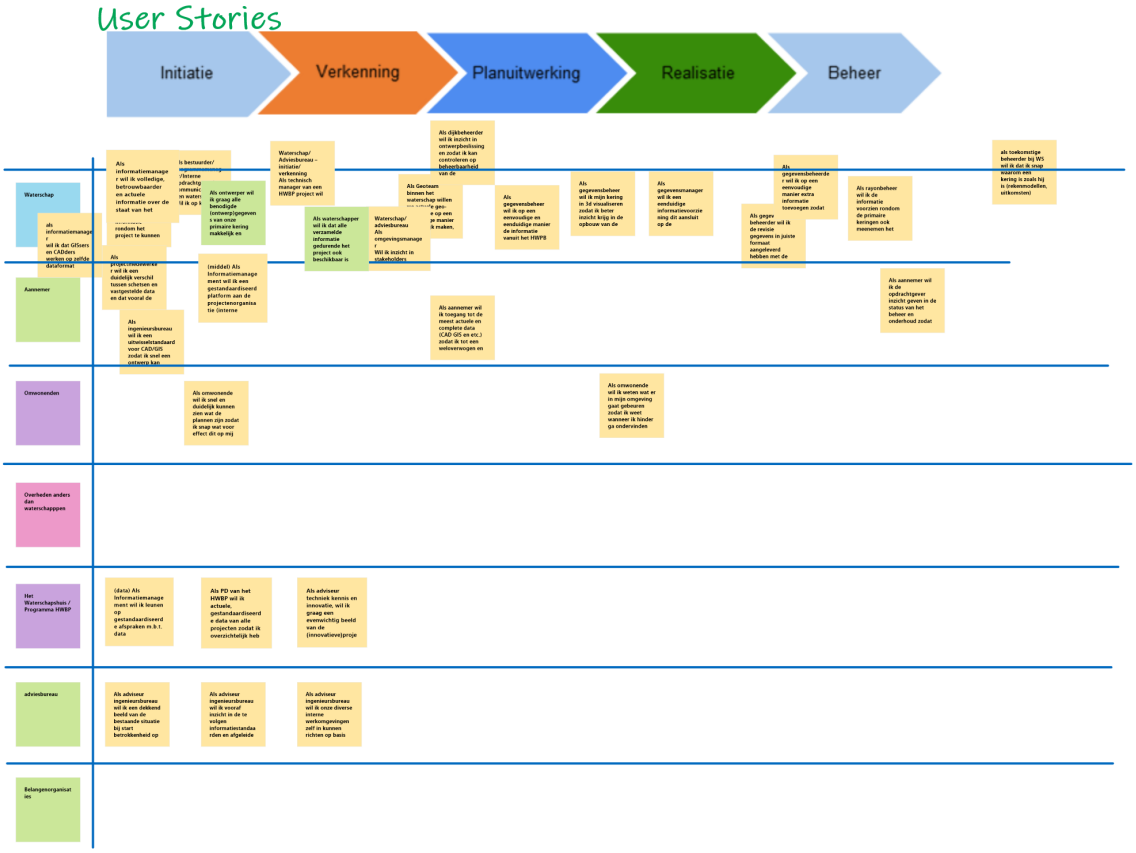


Figure 8: Affinity diagram - the Kick-off meeting of the innovation sprint of the week 15-19 March 2021

- Designers/engineers - easy and reliable access to the most up-to-date data.
- Contractors - a defined source of the reliable and actual up-to-date information/data related to the incident project.
- Clients - having an overview of the progress over the ongoing projects related to the HWBP.
- Contractors - having a clear overview of the specified requirements of the design to avoid wasting time on discussion and looking for information.
- Contractors - the ability to offer the client an overview over an ongoing project status

Interviews

Interviews with stakeholders were conducted for understanding workflows and requirements from practice. The aim of the interviews are:

- Investigating what is the practice in terms of the information management standards.
- Identifying the challenges, both practical and technical, in the current practice.
- Understanding the role of WebGIS in infrastructure projects (with focus on HWBP).
- Exploring the amount of interest in ISO Series standards for information management workflow in infrastructure projects.

Questions asked at the interviews

- What is your role/position at your organization? Does it involve (GIS/BIM) data management? And is it project-based?
- What is the role of GIS platforms/software/data at your work/in this story? And is BIM data used on GIS platforms?
- Does the company have projects related to the HWBP?
- Which software/platform are used within the company?
- If there is any, what are the protocols/standards for data managements adopted for projects at your company? does it include standards for GIS/BIM data?
- Is there are any predefined specifications/requirements for the handed-over information (including visual information GIS/BIM) through the phases of a project?
- Have you heard about ISO 19650 standards for information managements in projects/assets life cycle? if yes, would you want it to be adopted at/in your work(flows)?
- Do you have and make a common data environment (CDE - Hub/repository) available for (GIS/BIM)-information/data related to a project?
- How important is managing GIS/BIM data? Do you think that ISO 19650 standards should be adopted for large projects between and within organizations?

The following paragraphs are summaries of the interviews conducted with stakeholders. The way in which the interviews were summarized tried to keep the wording used by the interviewees.

Meeting with V, N - Product manager at Tauw

V, N is a Product manager BIM at Tauw operate as a data consultant/information management consultant. Sometimes, we have project-based work mainly related to infrastructures like HWBP, or road projects. The role of the GIS platform differs per project, for example, GIS viewer for shared or indoor published information. It helps the information team to have spatial context for doing geo-analysis, (We have a saying at the company *everything starts and end on the map*, so the project closeout with spatially enables data actually). For some projects, GIS software is not used however the spatial data like point cloud is used in BIM/CAD software (plan 3D, Revit and Civil 3D). Relatics is used as a requirements managing tool or for specified databases. GIS is more interesting in infrastructure projects (such as HWBP projects) where environmental complexity is higher. There are different setups depending on the project requirements, ambitions and goals. Sometimes, the model from BIM software is automatically updated on the GIS platform every other week. Sometimes, we use the two platform in a standalone (independent) work environment. For example, the BIM models are only updated to the GIS platform at the end of a phase.

GIS data provides context to the design, sometimes the model is updated to the GIS platform or GIS data are imported to BIM platforms for technical design level. Sometimes, the model is only delivered as part of the GIS data (in the published state) as this can be a clause in the contract. This is mainly for governmental organization, in this case, the design files (Revit/CAD) do not really leave the company, these files are not really part of the deliverable. Mainly the project requirements define what combination of platforms are used and in which set up. But, sometimes, during the project, smarter decisions are made for this purpose so we adjust the set-up. It is never one environment or one fixed set-up for managing the project information. But even BIM 360 is not entirely aligned with ISO standards. And we are trying to comply with ISO principles but we do not actually fully comply with them. Even within BIM 360 on the technical aspect, it is not fully aligned with ISO standards. Bentley is working on or already is complied with ISO 19650 standards. Autodesk is promising us to fully comply with ISO 19650 standards soon.

Here in Touw, we also have our own internally used standards, and these are different per environment(GIS, BIM or a combination of both). Often, we get the information specification for the deliverable. And we actually want to have these, however, government clients have only requirements for 2D CAD data. So what we do is that we advance the requirements ourselves make them applicable to this new world of 3D CAD and GIS data. This is to guide us through the design process. We do not aim to be ISO 19650 certified. However, some companies, like Sweco, worked with clients who required working with an ISO 19650 certified company. I use ISO 19650 terms like shared information or published information. What I find important is that the process is managed, practically working on a project level and that we have clarity on what information is stored where like incoming information or GIS/CAD data and what is the status of this information. And obviously versioning and other aspects. But it is never one database, for example, some projects are 80% in BIM 360 and 20% is in Relatics environment which does not comply with the idea of ISO 19650 but we use for information requirement management. Different type of alphanumeric data is stored in Relatics to support the design for example meetings conclusion or design information are registered in that environment. We always, for best practice, try to have a clear BIM execution plan that contains project and information requirements. In some case this kind of document is missing so we work according to our standards. It is important that there is a function that helps to manage information. The function that makes sure that everything is delivered in time. But it can also go to having a whole information management team with different roles, GIS special-

ist or BIM specialist. Usually, the piratical needs drive us to develop information management process/tool. And we use ISO 19650 standards for ideas. As a company, we do not focus on developing a technical tool. We focus on developing standards, process and templates in different setups with the tools we have in the house. Managing data is not only a technical challenge, it is also a process and contractual. These are important aspects on the organizational level. Sometimes there are subcontractors who develop or design different part of the model. For this there are different scenarios, for example, we get an update every week, or only at the end of a phase. This is already a big difference for the project. For this, it is important to manage the process and to come to an agreement. ISO 19650 standards and good practices could help us very well.

Some challenges lie within getting information requirement on the technical level. Often the client delivers a high-level requirement and these should be translated to practical technical requirement. Furthermore, when technology evolves it hard to come to an agreement that deploys this technology for a better workflow. For example, the 3D GIS, we use for underground subsoil. But on a lot of HWBP projects, there is no need or requirement for this. So no clear specification for working with 3D, so it becomes rough.

Meeting with B, M - Programma Manager Digital Construction at BAM Infra Nederland

There are three kinds of certification that you can obtain from .bsi. One for a year, and one for three years that is applicable on projects that include BIM. Now it is a work in progress for .bsi to be able to grant certifications for companies. BAM has been certified for the design and construction process of asset management, however, they are not yet. For some processes, we are still certified according to pas1192-3 (operational phase of construction) and we are working towards transforming this certificate into ISO 19650 (delivery phase of an asset) later this year. We have The Afsluitdijk which is part of HWBP, however, this project is with the Rijkswaterstaat. Besides the protection from the sea, the work on the Afsluitdijk includes pumping the water from the riverside to the sea. The biggest change is that we come from a document-based process and not from an information data-based process. So we mainly the difference in ISO 19650 and the other ISO 9001. For example, in the document-based processes we hand in CAD drawings and not in data. What we see is that lots of companies ask us to deliver 2D CAD files and these are more drawings than data (it is not very smart data). And our client puts them in GIS systems then add all kind of metadata to it.

That's the change that the ISO came far with. So, at the start of the project, the client defines what kind of information or data they want to have and not what kind of document (drawings). Data means is not only geometrical data but all kind of structured, not geometrical data that comes with it (attributes). Kadaster, for example, each object in their GIS has a unique number that refers to information in the database (e.g. owner and the value of properties). So the goal would be that when clicking on an object, you get the geometrical drawings with these structures non-geometrical data on one (*.pdf) document. This is how it should be, for example, the Rijkswaterstaat has so-called ELS (information delivery specification) which describes what metadata they want to have with the geometrical data in the delivery. The best example of this process is Kern GIS which is the GIS database Rijkswaterstaat use for their asset management work. An example of work we do is pavements, for that they do not only want the geometrical situation of it (where it is) but also what kind of materials were used and the date when it was placed. This information is required for future maintenance work in 5 or 10 years. This allows them to ask the system when they have questions about their pavements. We use GIS for many years already, I mean, the delivered products are in GIS readable formats. Around 10 years ago, the companies started to ask for deliverable's to be stored in

their GIS system which was the reason why BAM started using GIS as well. At the end of the project, we should deliver GIS data (for Kern GIS) and they set requirements on how the data should be delivered.

In the construction phase we use BIM software Autodesk mainly and Bentley and sometimes some metadata. But it is really hard to convert and store this data directly in Kern GIS because it is a 2D database and has a different object structure. Therefore, manual work is always required. They use 2D data for 10 years now, and they are searching on what to do with 3D BIM models. That's why they don't ask for the 3D data we have to be used in the maintenance phase ISO is part of the solution, it is a process to help get data delivered as required. But it does not guide on how to structure the data.

It is good that Esri is researching how their system can be applied for the CDE solution complied with ISO standards. Therefore, you need a controlled data environment. The version is very important and part of the ISO 19650, so you can see if you have the latest version of the data set. And the approval process is important, *where is the data stored? and how can it be shared(in shared status?* these things are missing in the GIS system. Most important is finding a way to give the user the ability to check if the version at hand is the last up to date version (approved shared and status), e.g. if they are on the construction site or somewhere else on their IPad, and they are checking a file or a GIS item. Especially to be able to see that the client has approved the asset. It can be very difficult, but a very easy step (this was our first step) was just using folders for *WIP, shared, published*. The second step we did was having the metadata in a column where you see the status so the versioning method is pushing away (to the archive) the older version and only keep the usable ones. Versioning and the status are important and also the suitability status (what for the data can be used) is also very important. These are specified in the ISO document. For example, it is suitable for calculation, construction or maybe only for a rough sketch with the client. So if these three can be made available by Esri, the process according to ISO standards is then possible. The rest of the things are in the process such as the standards and object code, these things differ per company and projects. The CDE is not one system, there are many systems but each handles a different kind of data. There is Relatics system for structured non-geographical data to put the requirements of the client, SharePoint for the documents and BIM360 for BIM models. So, the easier the system can provide the functionalities for ISO standards the easier it can be engaged in the ISO solution as CDE. In our implementation of ISO 19650's CDE, BIM360 and SharePoint are involved and this year! We are planning to add the GIS system to it. It is already possible actually, but there are lots of manual work that depends on people. For example, for versioning, a person does the save as and delete the item and replace it with the new one. From our GIS team, I heard that the challenge now is in the versioning where lots of manual work is required. We are at the start now, so we don't know if it is achievable at the moment are we postpone the work until an update from esri. The idea is GIS is our main system for asset management projects. So we use only GIS in these projects and BIM software are not involved. So, as we asked the BIM modeller how do you keep a version of the model and how do you see if you have the latest version, and we ask the same for the GIS employees. At the moment these processes are supported in BIM for a file, so we only can say that this file is the latest file. But it would be a huge achievement if the process can support this for objects within the drawings.

You must know that, in huge projects such as the Afsluitdijk, so it is chunked into small pieces with all kinds of something that is already finalized and something has to start still. So we have a big coordination model with the models in it. So we chunk it into files to get them into the workflow of WIP shared published. So the Afsluitdijk is a couple of hundred models

that altogether stitched in a coordination model. Probably it is easier to do it in a GIS system that the workflow goes for an object and not for a whole model. There is a lot of discussion about the naming conventions, so you should have one, but my opinion is that it should be left open. Here we have our own, so we used naming conventions that used to have on drawings in the past. So we adhere to the principle but not the British one. The naming conventions in the British national annexe can be good to show an example but if it is only based on that, then it is limited, If the client can configure their own, then they can easily integrate GIS with other systems they have such as SharePoint. Most of the time, what a container is (in terms of what data each container has) depends on the contract. So, sometimes we use geographical structure: this means that the model is divided per few km, for example, the Afsluitdijk is very long, this means that every container has all discipline but with few km. So nothing is fixed, also in the same project (Afsluitdijk) the road is one container. Because it is one objects whereas, for the pumps, each pump is one container and the lock of pumps is one container. This can be seen as a project within a project. So really everything depends on the planning, logistics and what kind of infrastructure you have. In practice, some things are discussed within the teams for the information workflow. It is hard to get all functionalities that comply 100% with ISO 19650 standards. What important is that the process of ISO 19650 is clear to parties involved.