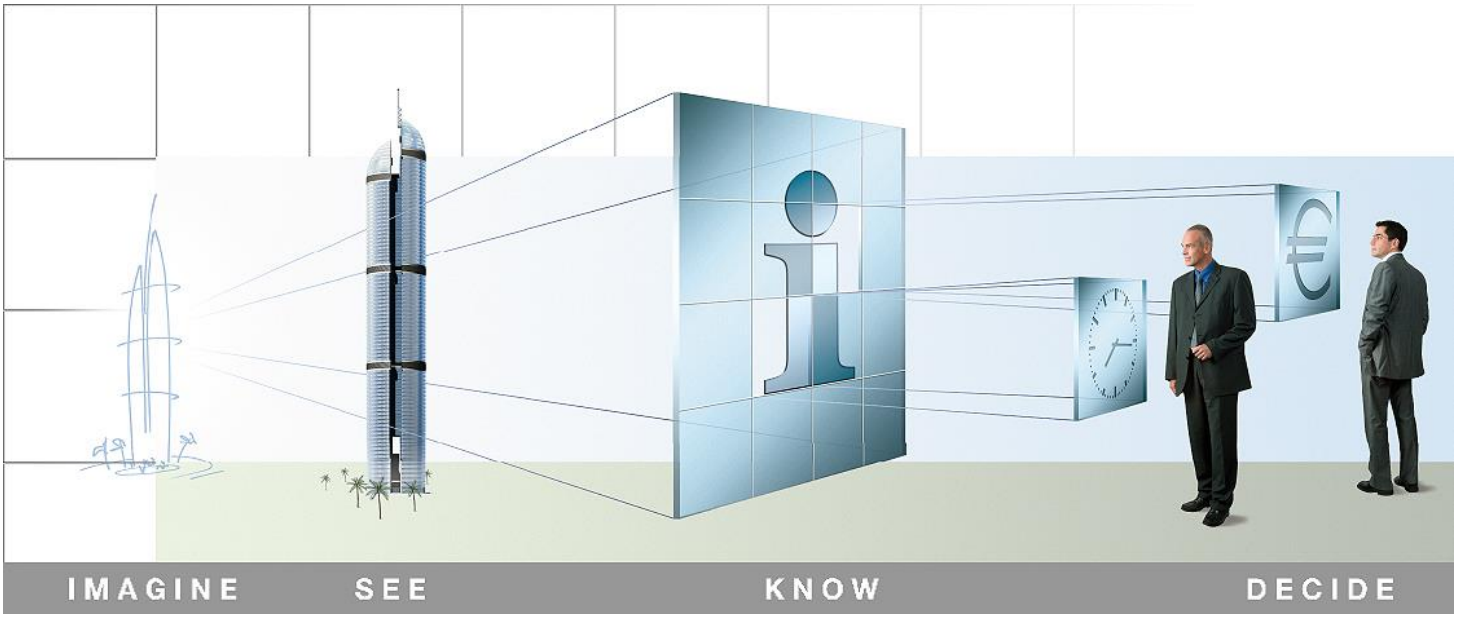

Digital Collaboration and Automized Tracking of information

WP5 Deliverable: Exchange Information Requirements recommendations

Report No.: #WP5-01

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1 Executive summary

The descriptions in this document can be considered as input for developing organization-specific Exchange Information Requirement (EIR) templates. EIRs comprise vital definitions in the context of the organization of information about construction works using Building Information Modeling (BIM).

In particular, the authors of this report assume a broad and industry-wide adoption of the information management principles in accordance with ISO 19650. In essence, information management is needed to steer and control the field of tension between requiring digital information and delivering them in BIM projects. Therefore, this report contextualizes with the principles of ISO 19650 the role of a public authority[1] as the lead appointing party in BIM projects. More precisely, this report elaborates on how such a public authority needs to require information from their suppliers in the right way and quality assure the delivery accordingly in order to comply with international standard mentioned above.

To this end, we analyze how information is currently requested from suppliers and what possible improvements in the light of information management according to ISO 19650 can be implemented. Furthermore, recommendations for requiring and processing information for the BIM-use case “BIM-supported requirements management” are elaborated and documented in the form of a so-called “Information Delivery Manual” (IDM) according to ISO 29481-1. This comprises also the suggestion of a new BIM use case to Trafikverket, which could potentially be implemented in upcoming projects.

Prerequisite for adopting this use case recommendations in future BIM-project is a completed requirements engineering process, including the:

- Definition of the phase when the requirements shall be verified (“during design” vs. “during construction”)
- Allocation of each requirement into a Project Data Structure (PDS) according to the guidelines from the work package 3 (WP3) deliverable of the DCAT project

The evaluation of the used data formats within Trafikverket has revealed that these are not entirely sufficient to fully commit to the ISO 19650 information management principles in the context of information deliveries from the supply chain. Therefore, in addition to enable a BIM-based requirements verification, another objective of this document is to promote the use of open data formats for information exchanges with suppliers.

[1] such as Trafikverket

2 Abbreviations

BIM	Building Information Modelling
EIR	Exchange Information Requirements
PDS	Project Data Structure
BEP	BIM Execution Plan
IFC	Industry Foundation Classes
MVD	Model View Definition
ER	Exchange Requirement
QA	Quality Assurance

3 External references to be considered for this document

- PDS Guidelines (WP3 deliverable)
- Trafikverket existing BIM requirements document (TMALL 0423 PM v1.0)
- International Standards
    - ISO 19650-1: Organization of information about construction works — Information management using building information modelling – Part 1: Concepts and principles
    - ISO 19650-2: Organization of information about construction works — Information management using building information modelling – Part 2: Delivery phase of the assets
    - ISO 17412-1: Building Information Modelling - Level of Information Need - Part 1: Concepts and principles
    - ISO 29481-1: Building information models – Information delivery manual – Part 1: Methodology and format

4 Existing BIM Standards within Trafikverket and recommendations to commit to ISO 19650 in the future

Trafikverket requests from the suppliers BIM models already since a few years back, formulating the so-called BIM requirements (BIM-Kråv in Swedish) within the document TMALL 0423 PM v1.0. In addition, a supplementary document is provided to the suppliers for the locations (subareas and positions) of Ostlänken project, which has been used as reference for the D-CAT project. These two documents have been the basis for the current document's analysis of existing information and BIM standards within the organization of Trafikverket.
The existing BIM standards of Trafikverket, define various requirements related to the BIM data delivery. These include:

- General information related to documentation, as well as advice when parametric design is applied
- Information about data sharing and delivery
- Basic instructions about software
- Main requirements on file formats and exchange
- Elemental Instructions on units
- Terrain and GIS basic instructions
- Essential information on model coordination
- General information on model object types and layers, including required classification
- Information on model revisions
- Instructions of graphical interface and visual appearance

Based on the information included in the above-mentioned BIM standards of Trafikverket, it can be realized that the requirements for the BIM models are not conforming to the ISO 19650 standard series as they do not sufficiently detail out on an object-basis what the required level of information need for the appointing party is. Also, no detailed processes for the information exchanges with the suppliers are prescribed. For the future further development, it is assumed that the ISO 19650 standard will be adopted eventually by Trafikverket as the industry as a whole, including public authorities, shows more and more acceptance and commitment in following the underlying concepts.

ISO 19650 provides basic concepts and guidelines for information management in construction works when BIM is used. Information management therein is defined as management and production of information during the life cycle of built assets when using building information modelling (BIM). Information management is intended to contribute to deliver beneficial business outcomes to asset owners/operators, clients, their supply chains, and those involved in project funding including increase of opportunity, reduction of risk and reduction of cost through the production and use of asset and project information models.

ISO 19650 prescribes the sharing and coordination of information through a Common Data Environment (CDE). The CDE sets the single source of information for the project, used to collect, manage, and disseminate design documentation, the graphical model and non-graphical data for the whole project team. The defined workflows enable all offices, teams, or team members to produce information in the same form and quality in a managed environment. The ISO 19650-based methodology for managing the production, distribution, and quality assurance of graphical and numerical data in the CDE basically includes four stages (see Fig. 1). Each stage follows an approval or authorization gate, which must be passed successfully to transfer data from one stage to another.

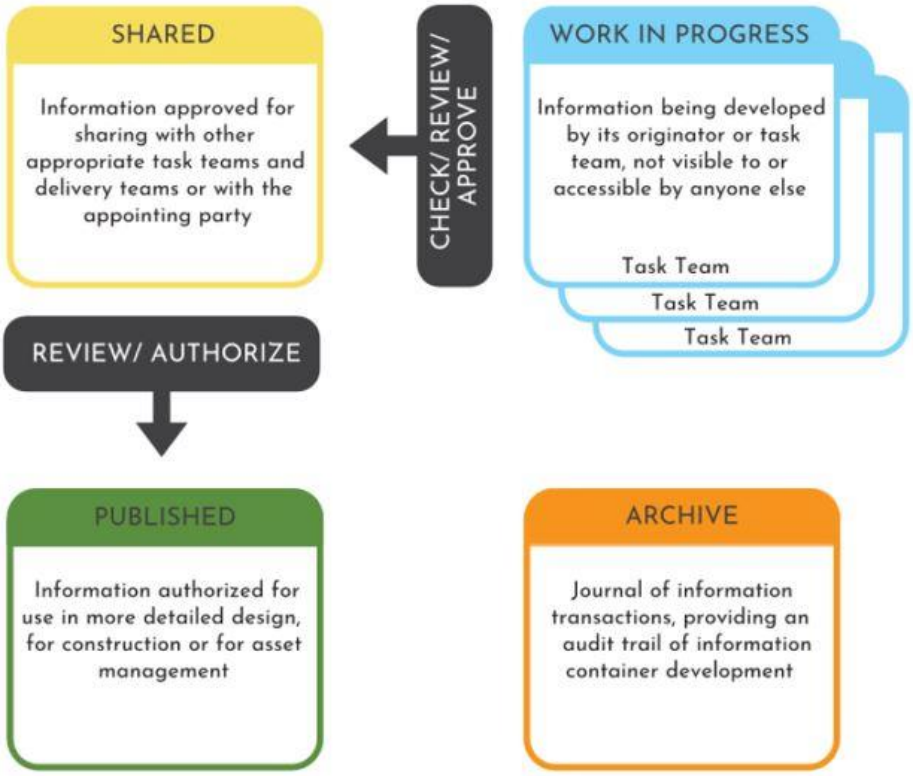

Fig. 1. CDE workflow according to ISO 19650-1

When it comes to information delivery during the project delivery stage (including design and execution), ISO 19650 suggests to clearly establish precise and verifiable information requirements on the client side before appointing other parties like designers or engineers. Information requirements are bundled in a document referred to as Exchange Information Requirements (EIRs) which is composed of asset information requirements, organizational requirements and project specific requirements (see Fig. 2). As the authors of this document assume that ISO 19650 will be a binding document for an organization like Trafikverket, we also strongly suggest to indicate required information from BIM projects to streamline the production of structured and valuable asset information models that will be managed by Trafikverket after project completion. From the perspective of the authors of this document, these indications should follow the concepts for EIRs as outlined in ISO 19650.

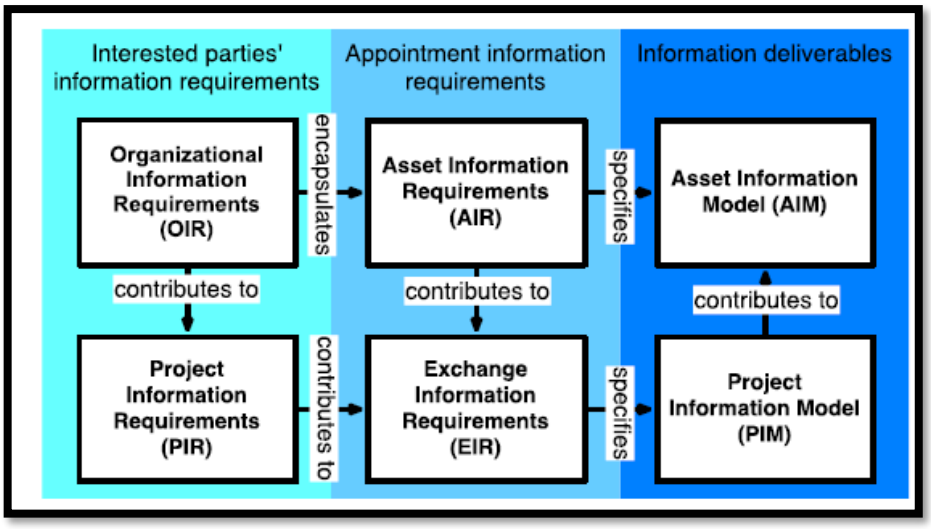

Fig. 2. Hierarchy of information requirements according to ISO 19650-1

EIRs are not the same as technical project requirements like functional requirements (e.g. “railway tracks need to have a certain signaling system”) or geometrical requirements (e.g. “keep a distance of 2 meters between single tracks”). EIRs are rather used to describe what aims the appointing parties pursue with respect to information that is to be delivered. These aims are often referred to as BIM goals and shall be driver for every BIM project. Within an EIR document, BIM goals are usually defined at the beginning and can contain on the hand quite generic and obvious goals like for example “reducing amount of waste during project execution”, “improving the collaboration and communication between stakeholders”, “reducing non-conformity costs during execution” or “reducing project lead times”. Goals of this kind are applicable in each project and could therefore also be considered a standard paragraph of EIRs documents.
On the other hand, BIM goals could be formulated more specifically on an individual project-level. These specific goals could be also referred to as BIM use cases that should be implemented and followed during project delivery. The level of detail of these BIM use case descriptions varies drastically from organization to organization. It can range from a few bullet points (e.g. “we would like to conduct 4D-simulations before execution to assess the constructability of the design”) to full-fledged use case descriptions, following for example ISO 29481-1, and covering aspects like use case content description and process maps with involved stakeholders and relevant information exchanges during the conduction the use. Following the BIM goals and use case part, EIRs usually also include requirements and information on:

- Digital delivery items (information requirements and provision)
- Higher-level processes
- BIM organization and collaboration
- Geometric and alphanumeric levels of detail of models
- Modeling guidelines, including naming conventions and classification systems to be used
- Data exchange, especially exchange formats
- Applying standards (e.g. ISO 19650)

Generally, the EIRs describe in detail the roles, responsibilities, and duties of the appointed parties for the application of the BIM methodology during project delivery. The basic, substantive descriptions of the design services to be provided (e.g., a rail station with 4 tracks is to be designed) is not part of the EIRs. In summary, the EIRs define the following topics:

- The motivation why the appointing party has decided to use BIM, expressed in the form of use cases that the appointing party would like to implement
- Responsibility for the management, production, collection, and control of the information exchanged
- Technical aspects

EIRs become also official part of tender documents and eventually contractual documents. According to ISO 19650 terminology, a company that is participating in BIM-project tenders (and eventually also being awarded with the contract for information delivery) is referred to as an "appointed party". For being selected for appointment they have to indicate in written form how they would meet the requirements formulated in the EIR, which is referred to as the BIM Execution Plan (BEP), which includes:

- How the company will produce what is necessary for the Client
- Definition of the exact responsibility matrix
- The detailed technical aspect (software used, data drops, planning, etc.)

As stated earlier, an EIR document may also contain precise use case descriptions. As one of the contributions of the DCAT research project followed in by BTH and HOCHTIEF ViCon, the project partners have developed a novel BIM-use case for requirements management, which is presented subsequently. The novelty lies in the leverage of BIM data for requirements verification as well as in new approaches for increasing the traceability from requirements to the assets that are supposed to fulfill these requirements.

5 BIM supported requirements management (UC) definition

The BIM Use Case in this document is specified by three components. **(1)** A definition that provides a textual description of the Use Case content and its objectives. **(2)** A process map, illustrated by means of BPMN[2] business modelling language that shows information flows between involved parties for Use Case implementation. The process map indicates where information is being exchanged and when specific prerequisites, such as for example "*Requirements Guidelines*", are used during conduction of the Use Case.
(3) Exchange requirements (ER) that specify, for each information exchange, who is requesting information, **why** in relation to the process, **when** information is exchanged (phase of a project), **what** information is to be exchanged, **who** is receiving the information and **how** it is to be delivered and received. For the Use Case specification, this document conceptually follows ISO 29481-1 Building information models — Information delivery manual — Part 1: Methodology and format. The standard describes a process-oriented methodology, representing a counterpart and complement to the information management approach outlined in the ISO 19650 series (Fig. 3). ISO 29481-1 provides

[2] Business Process Model Notation (BPMN) graphical process modelling language as defined per standard ISO/IEC 19510:2013 - Information technology — Object Management Group Business Process Model and Notation

guidelines for presenting process maps and exchange requirements in BIM Use Cases, and thus, makes information requirements for implementing these Use Cases explicit and verifiable.

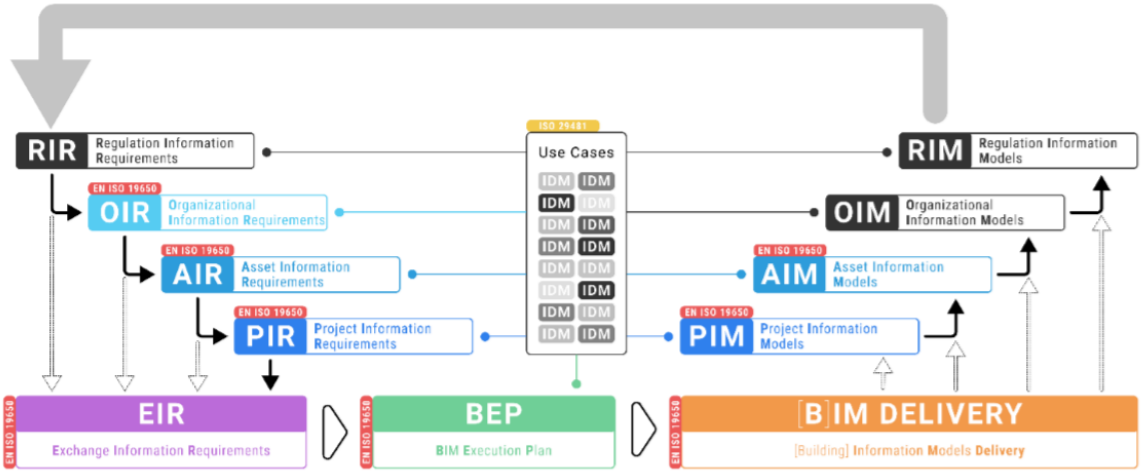

Fig. 3. : Interaction of IDMs and information management according to ISO 19650. Source: WD WI 442023 CEN/TR Guidance for understanding and using EN ISO 29481-1

5.1 Description of the use case

The use case "BIM-supported Requirements Management" is based on the regular requirements management process used by appointing parties for infrastructure measures (Trafikverket). At its core, this process consists of the elicitation of all technical requirements[3] to be applied to a specific project in the form of textual statements (e.g., "the station must contain two platforms"), an indication of who is responsible for verifying the requirement, and a time estimate of the project phase in which a requirement can be verified (design vs. execution stage). There are no further links between the requirement and the assets to be built. This means that explicit trace links between the requirement and the asset responsible for fulfilling the requirement are usually unavailable. This also means that with regards to specific assets (whether digital or physical), it is not immediately clear for what reason these assets are actually there and which requirements they are supposed to fulfill. This, in turn, means that a targeted verification of the requirements becomes difficult for the asset supplier. It is also not clear which information must be available and at which point in time in order to be able to verify the requirements.
Both processes, creating detailed traces from requirements to the digital assets, as well as the verification of all requirements are costly and inefficient if they take place manually and in an ad-hoc fashion. Therefore, structuring the required information could facilitate facing these challenges by bringing automation into the digital verification process.

[3] Not to be confused with exchange information requirements (EIRs) introduced in section 4

This use case is intended to be applied in this problem area and to generate added value through application of structured data and process definitions. The targeted benefits are based on the following hypotheses:

- There exist a semantic relationship between requirements and specific assets to be built, which can be formally described.
- The information required to verify the requirements (graphical, alphanumeric, documents) can be named in relation to the asset (= information requirements).
- The time at which this information must be available can be specified.
- The connection of these artifacts (requirements, (digital) assets represented in BIM models and asset-related information requirements) can be established via a consistent, machine-readable Project Data Structure (PDS).
- A consistent PDS is applied (according to project DCAT WP3 deliverable) to all digital assets in the 3D model as well as in associated documents and requirements.
- The PDS is responsible for the trace links and thus represents a prerequisite for automated verification of requirements.

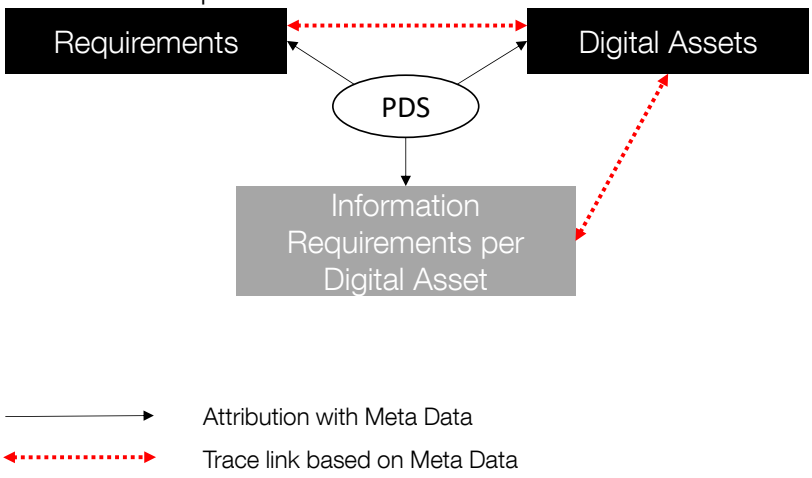

Fig. 4. Traceability concept in Use Case

Based on these hypotheses, the scope of this use case can be described as proposing a concept for linking the information required to verify requirements to the considered requirements. Thus, this concept describes how asset-specific information relevant for requirements verification can be identified automatically. The actual verification of the requirements and its potential automation is out of scope of this use case.
The implementation of this concept includes that at the beginning of a project or during the requirements elicitation process for an existing project idea, the nominated BIM manager is responsible for developing a project-specific PDS in accordance with the PDS Guideline (according to project DCAT WP3 deliverable). This taxonomy, which consists of a location and system breakdown, for example, and can also be based on existing classification systems (e.g. SB11 or CoClass), must then be attributed to the textual requirements as far as possible (see DCAT WP4 deliverable).
In the further process of project delivery, the suppliers appointed with design tasks must be informed about the information requirements of the appointing party (Trafikverket). In accordance with ISO 19650, this should be done via the EIRs as introduced in section 4. Here, the information requirements for the

BIM-supported requirements management shall be addressed. In concrete terms, a request statement needs to be included pointing out that the BIM models which will be delivered and contain the digital assets, shall be attributed according to the PDS guidelines and definitions. This represents the first building block of the traceability concept outlined in Fig. 4. Furthermore, the EIRs must specify which information types and which information level in terms of geometry, alphanumeric metadata as well as documents shall be provided at which point in time per digital asset or asset groups.
For this purpose, it is suggested to use the Level of Information Need (LOIN) concept as introduced in ISO EN 17412.
The LOIN concept provides for the precise description of asset-related information requirements at specific points in time according to an information delivery plan. Thus, a verifiable target can be defined for delivered BIM models and associated documentation (e.g. drawings, data sheets, etc.) (see Fig. 5).

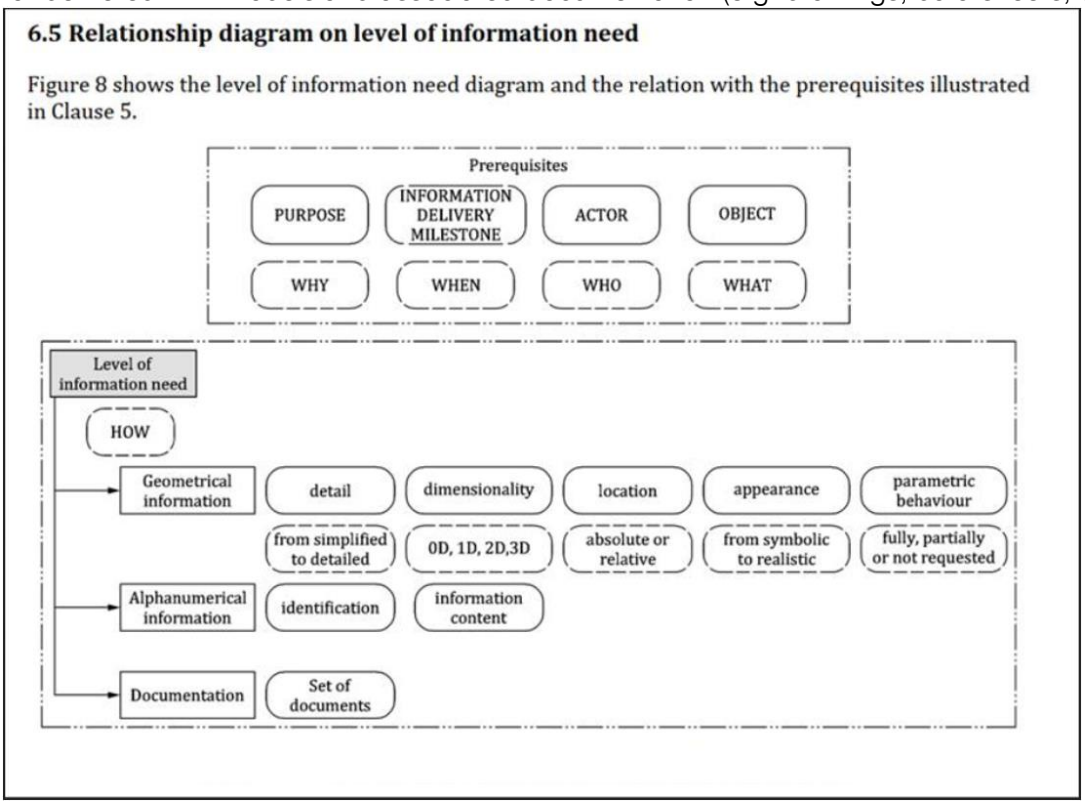

Fig. 5. LOIN concept according to ISO EN 17412

It has to be noted that the LOIN does not define the milestones of information delivery, but that the required depth of information in terms of geometry, alphanumerical data, and documentation can vary for the different milestones. ISO EN 17412 likewise suggests that the asset-related definition of the LOIN should define the purpose of the information delivery, so that the LOIN is only used to fulfill the purpose. This aspect is of particular importance for the use case of BIM-supported requirements management, because a new LOIN purpose is defined here, namely the verifiability of requirements through digital assets and associated information.
When the LOIN is defined, the assets of an information delivery should be identified in a structure plan. It is recommended to create cross-project and project-specific asset structure plans, derived, for example, from existing classification systems (e.g. SB11, CoClass, UniClass). For a given project, a milestone-

related LOIN should then be assigned to each relevant asset, which, among other objectives, serves the purpose of requirements verifiability.
ISO EN 17412 further recommends that LOINs should be represented in a format that is readable by both humans and machines. This standard also explicitly states that the LOIN can support the verification of the presence of assets and their properties in a digital model. This again reinforces the usefulness of using the LOIN concept in the context of BIM-supported requirements management.
In terms of process for the use case of “BIM-supported requirements management”, following receipt of the EIR, which should also include the current "BIM Requirements (BIM Kråv)" regarding model nomenclature rules, the preparation of a BIM Execution Plan (BEP) by the suppliers would be required. Among others, this document should describe to what extent the suppliers would address the required information deliveries and their specifications and how they would realize the quality-assured information delivery.
Upon acceptance of the BEP by Trafikverket, design development on the part of the supplier would begin. After running through a quality assurance process which needs to be defined in more detail (e.g. by means of a CDE process in accordance with ISO 19650) under governance by Trafikverket, the model files would be used to verify asset-related requirements (asset references are created by the PDS).

5.2 Process map and involved Roles

In addition to a textual description, ISO 29481-1 recommends describing use cases by means of a process map in BPMN notation, naming the roles involved (represented as swim lanes) and information exchanges relevant to the process. The process proposed for the use case BIM-supported Requirements as a supplement to the above description is shown in Fig. 6 (larger version can be found in Annex A – Process Map). The roles involved can be seen in the labels of the swim lanes.

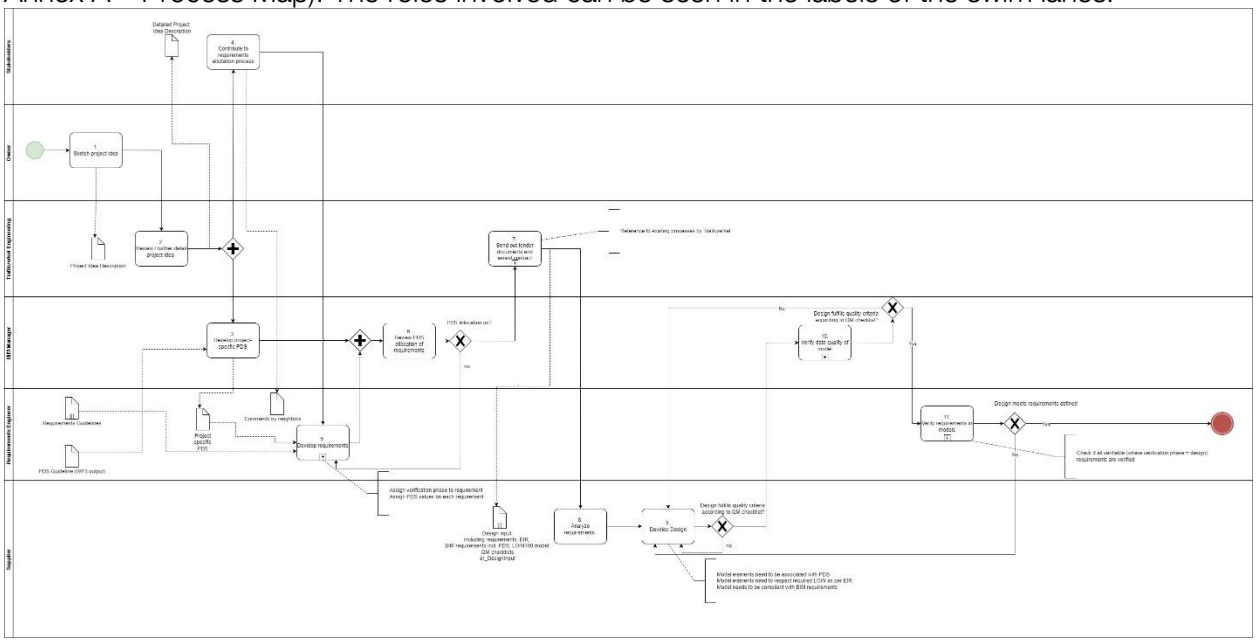

Fig. 6. Suggested process map of the BIM-supported Requirements Management (larger version can be found in Annex A – Process Map)

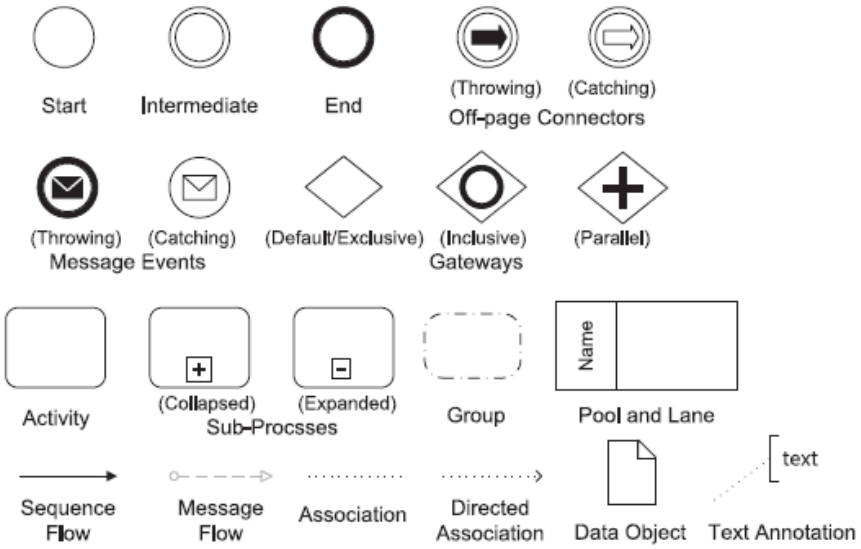

Fig. 7. Legend for relevant BPMN symbols used for use case process modelling

5.3 Exchange Requirements and Functional Parts

Relevant information exchanges within a process map for describing a use case according to ISO 29481-1 are described as "Data Object" symbols that define so-called "Exchange Requirements" within the process. These relevant exchange requirements are identified with "er_NameOfExchange" tags in the process map. Basically, the relevant exchange requirements in this use case are the asset-related LOIN definitions, which should include the request for PDS attribution according to the PDS guideline. These define decisively the expected model quality as well as related documentation. No further textual description of this exchange requirement is provided in this paragraph, but instead reference is made in Annex B to a template provided by buildingSMART[4] for the definition of asset-related LOINs, which can be filled out on an asset-specific basis and used as part of EIRs for different BIM use cases.

6 The role of open data formats for information exchanges

When it comes to the use of open data formats in BIM supported projects, it should not matter what data formats are used. The primary goal is to exchange data for the entire course of the project with all the participants involved via neutral and open interfaces just according to the Open BIM approach. The idea of the Open BIM approach is, to exchange data independent from the software solutions used by the parties involved, in order to monitor construction and all the information linked to it over its whole lifecycle with open data standards. Since many different parties are involved in a project, they do not all work with the same software solution. Hence, open data formats and open standards are important to enable efficient co-operation independently from the tools used.

[4] buildingSMART, as the worldwide operating organization for the development and maintenance of Open BIM standards publishes officially released MVDs here

With reference to information exchanges as introduced in the use case description of “BIM-supported requirements management”, the exchange requirements should be formulated in a way that meeting these requirements is always possible independent from the used data authoring systems. However, the format of information delivery can and should also cover the request for open data formats (e.g. IFC). In common practice, usually information deliverables are requested to be handed over both in the neutral / open formats and native file format from authoring tools (e.g. .rvt file format for Autodesk Revit as an authoring tool).
In the particular case of IFC, the explicit formulation of exchange requirements in BIM use cases and subsequent functional parts could lead to precisely defined so-called Model-View-Definitions (MVD) as subsets of the IFC data model containing only classes that are of relevance for the use case in consideration. When MVDs[5] are availably defined, they could be explicitly required in EIR documents.

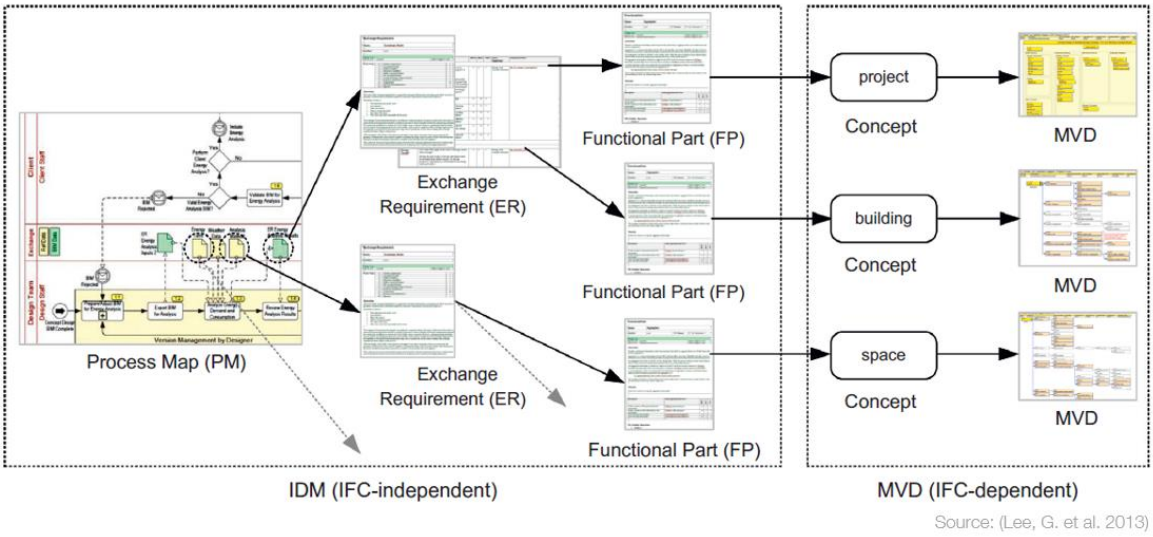

Fig. 8. Conceptual use case description following ISO 29481-1

When working for Trafikverket, suppliers are free to choose the formats in which they want to transmit their data. However most commonly the dwg and dgn formats are requested by Trafikverket.
The downside of requesting solely .dwg files is that information requirements for digital assets can be hardly met by the suppliers as possibilities for using meta data of CAD-objects are poor in comparison with IFC.
It is therefore suggested that Trafikverket also commits to – and hence requires in their BIM projects – the delivery of open formats that are capable of carrying relevant meta information as per BIM use case specifications (e.g. BIM-supported requirements management). If this is not possible, for example because usually used software for infrastructure project design is not capable of exporting to the IFC file format, it has to be made sure that relevant meta data are supplied attached to the design files as external data. This could be realized following the suggested PDS and LOIN concepts. This would mean that suppliers would have to deliver information containers with multiple files that precisely describe the digital assets in the design files according to the information requirements as per LOIN definition.
Delivering information in this way also brings new challenges to the quality assurance process for these supplies that are briefly introduced next.

[5] MVD Database - buildingSMART Technical

7 QA process on data exchanged

The above mentioned challenges which derive as consequence of the proposed concept for data sets deliveries within information containers for the LOIN definitions of the digital assets, bring together chances for the QA process standardization. In fact, the more in detail EIR define what information shall be included in documents and in which format it shall be defined, the more possibilities exist for standardizing the QA process. The main aspects of a standardized QA process should cover:

1. The completeness of the information provided by the supplier in terms of provision of all required documents, all model objects as defined for the under design trades and disciplines, availability of needed metadata and attributes
2. The quality of delivered information, meaning the availability of correct attribution or documentation alongside the deliverables
3. The correctness of delivered BIM objects in terms of spatial position and functionality they are supposed to fulfill
4. The proper granularity of the BIM objects of the digital assets

Moreover, the development of an agile quality checklist shall be the prerequisite for the assurance of the delivered information.
The first quality gate for the supplier as, indicated in the process map (Annex A), requires that the supplier shall ensure the quality of the delivered artifacts by examining whether design fulfills the quality criteria as they are defined in the quality checklist. As a minimum, the supplier shall review the digital artifacts for compliance against the BIM requirements, the model elements need to be associated with the PDS and they need to respect required LOIN as per EIR.
The second quality gate shall include the quality verification of the delivered data by the client's BIM Manager. These verifications shall be based on predefined (semi-) automated quality checks which will take into account the LOIN and shall report the quality of the digital asset against the defined quality checks. An iterative process between the BIM manager and the supplier shall ensure the elimination of potential quality bottlenecks, enhancing the quality and allowing the use of the digital asset of all further scopes as for example the verification of the technical requirements.
The process of establishing the logical syntax and setting up the model checks for the automated verification of the requirements will be extensively explained within the deliverables of the DCAT WP7.

8 Recommendations

Based on the suggested BIM supported use case of Requirements Management and the reviewed documents as received by Trafikverket, the following actions are recommended:

- Develop organisation wide PDS template and define specific PDS for each project
- Annotate the technical requirements which will enable their linking through the PDS to model and facilitate their verification
- Commit to ISO 19650 norm for the structured information exchange processes, including:
    - Setting up CDE standard processes on organizational level

  - Develop EIR overall template which can be adjusted on project scale specific needs
  - Sharpen process definitions for BIM supported Requirements Management UC considering also required roles and functions
  - Mobilise resources and assign BIM roles on organisational as well as project level
  - Develop LOIN definitions for Trafikverket Assets according to ISO 17412 norm and incorporate as part of the EIR that are submitted to the suppliers
- Require information deliveries by Trafikverket suppliers in open formats, which allow for rich metadata assignments and enhance collaboration
- Setup and conduct predefined and structured QA processes on exchanged information
- Consider the implementation of the use case within a pilot project of limited scope for testing and refining the theoretical approach and establish lessons learned mechanisms

9 ANNEX

9.1 A – Process Map

9.2 B – Functional Part template by buildingSMART