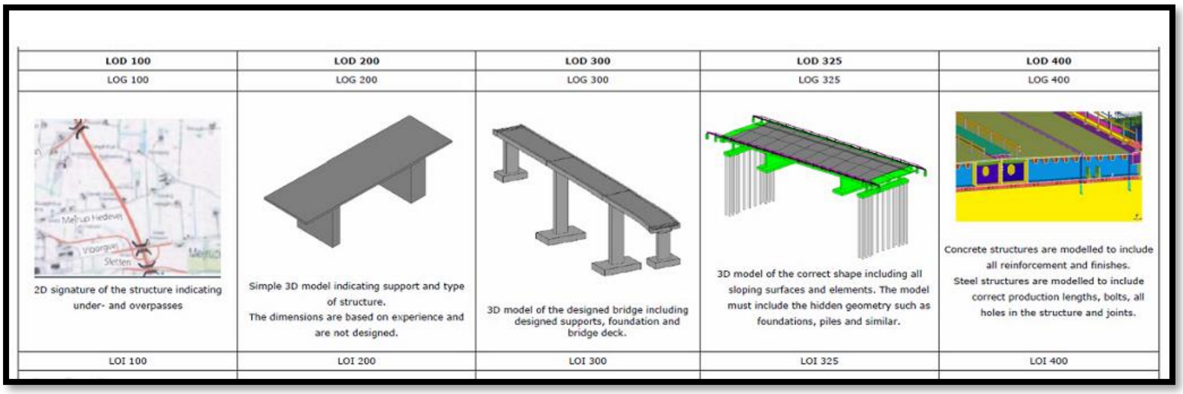
Nordic Road & Rail
BIM Collaboration

REPORT

Status of LOD and related work at Nordic Infrastructure Clients

December 2022
Version 1.0



LOD 100	LOD 200	LOD 300	LOD 325	LOD 400
LOG 100	LOG 200	LOG 300	LOG 325	LOG 400
2D signature of the structure indicating under- and overpasses	Simple 3D model indicating support and type of structure. The dimensions are based on experience and are not designed.	3D model of the designed bridge including designed supports, foundation and bridge deck.	3D model of the correct shape including all sloping surfaces and elements. The model must include the hidden geometry such as foundations, piles and similar.	Concrete structures are modelled to include all reinforcement and finishes. Steel structures are modelled to include correct production lengths, bolts, all holes in the structure and joints.
LOI 100	LOI 200	LOI 300	LOI 325	LOI 400

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Table of Content

1 Background

There is great uncertainty about what information the digital models should contain in what phase. There is a need for common understanding and finding a structure to automate more and check against database.

Many contractors work across borders and are in need of common ground to make their working methods more efficient. Therefor there is a need for at least the Nordic public owners in infrastructure to agree on common guidelines and levels for information in digital models.

The Nordic Road and Rail BIM Collaboration (NBC) was established in 2015. A Memorandum of Understanding was signed in 2017. In November 2019 a working group[1] for LOD was formed during a workshop in Copenhagen. The task was to investigate if it was possible to reach a common Nordic standard. The working group has been discussing issues of what LOD is in addition to keeping all informed on the status of work in the Nordic countries and what they all planning to do. An important task has also been keeping up with ongoing international standards and projects.

The working group has had several virtual workshops during the Covid pandemic and also paused for some time in 2020 to wait for an on-going development in Denmark that is further described in chapter 6.1

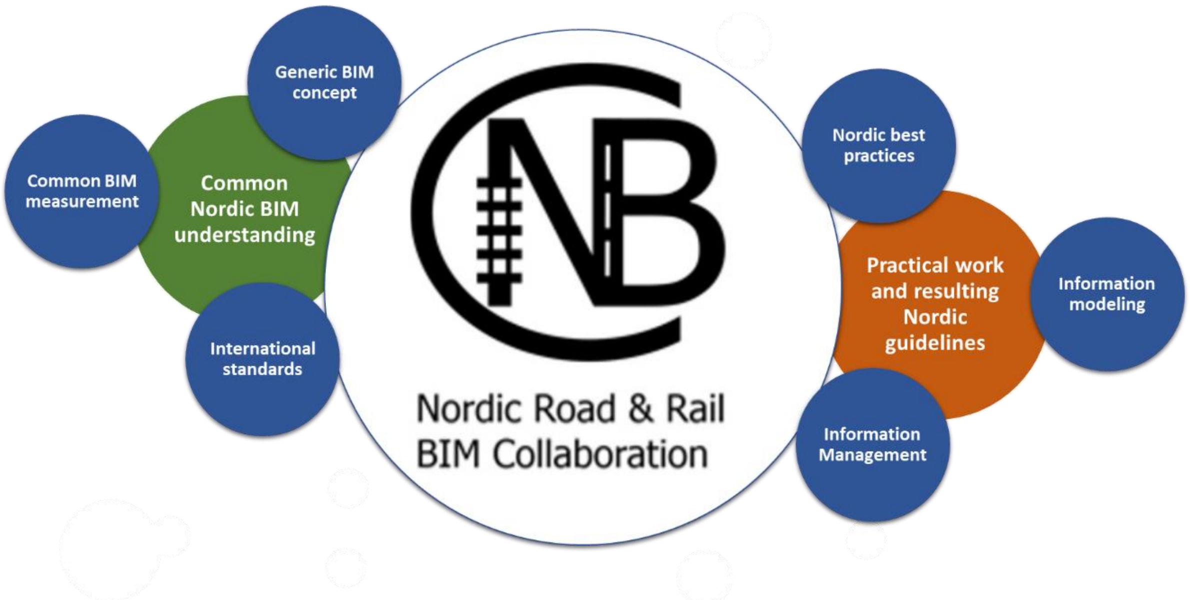

***Figure 1 -** Collaboration to manage common Nordic BIM understanding and guidelines*

[1] See participants list in appendix B

2 Definitions

Table 1 - *Definitions and abbreviations*

Abbreviation	Description
NRA	National Road Authorities
STA	Swedish Transport Administration
FTIA	Finnish Transport Infrastructure Agency
NPRA	Norwegian Public Road Authority
DRD	Danish Road Directorate
Bane NOR	Norwegian Rail Authority
Banedanmark	Danish Rail Authority
NBC	The Nordic Road and Rail BIM Collaboration
DiKon	Digital Konvergens
ISO / IEC	The International Organization for Standardization / International Electro technical Commission
EN / CEN	European Standard / European Committee for Standardization
TC	Technical Committee
SC	Standards Committee
TS	Technical Specification
LOD	Level of development/details/geometry/information/reliability
LOIN	Level of Information Need
MMI	Maturity Model Index
MM	Model Maturity
CDE	Common Data Environment
IDM	Information Delivery Manuals
ICDD	Information container for linked document delivery

3 Purpose, goals and limitations

Goal overall work

The goal of the workgroup is to analyse and identify previous and ongoing standardisation as a way to agree on a common baseline for LOD, for the Nordic public owners for road and rail, NBC.

Goal for this paper

The goal of the paper is to document the work done by the workgroup in analysing and identifying national and international standards and industry initiatives in relation to LOD. Work that is documented is either connected or has an interface to the groups work.

Based on this the workgroups goal is to agree on a Nordic baseline for LOD between the members of NBC.

Stakeholders

Stakeholders for this paper is the Nordic public owners for road and rail as well as software developers, consultants and contractors that work for these public owners.

Limitations

This report describes the work done in the workgroup and how the work is connected to a limited number of international standards and ongoing industry initiatives in the Nordics. It does not describe the standards.

4 International standards

The following chapter has been incorporated to provide a backdrop to the reader with regards to the different aspects of international standardisation.

Major standardisation organisations like ISO/IEC and CEN provide standards, specifications and reports that concern various topics of interest for public stakeholders like the members of NBC. The work is usually done by volunteering experts of different fields, financed through membership fees, and selling of standards as such, in some cases the government would add additional funding. All standardisation work must be kept strictly separate from any political agenda.

The Vienna Agreement - CEN Cooperation with ISO

CEN has an agreement for technical co-operation with the International Organization for Standardization (ISO). Through the involvement of experts in Technical Committees, European and national expertise is involved and recognized globally.

The Vienna Agreement, signed in 1991, was drawn up with the aim of preventing duplication of effort and reducing time when preparing standards. As a result, new standards projects are jointly planned between CEN and ISO. Provided that international standards meet European legislative and marked requirements, and that global stakeholders outside of Europe also implement these standards appropriate priority is given to cooperation with ISO.

The Vienna Agreement allows expertise to be focused and used in an efficient way to the benefit of international standardization. It is completed by jointly developed Guidelines supporting the practical implementation.
The EN ISO 19650, like several others, has been developed by CEN and ISO in parallel under the umbrella of the "Vienna Agreement". That also includes the ISO TC 59/SC 13/ WG 13 that is conducting the work in CEN. CEN will publish the standards as a European Norm (EN) making the document mandatory for public stakeholders across the European Union.

Implementing the standards

There is a general understanding that standards as such are never mandatory unless by contractual agreement. Public clients within the European Union are supposed to implement European Standards without hesitancy, while ISO/IEC standards are rather informative in nature.

Experience shows that the implementation of standards could conflict with the existing code of practice of public stakeholders, thereby resulting in either tremendous costs or a severe lack of implementation.

The low degree of alignment between standards and the current modus operandi is caused in part by historically different necessities in national and organisational contexts resulting in huge amounts of legacy data and systems which do not conform to EN or ISO standards. Another reason might be found in an insufficient involvement in standardisation by public stakeholders.

Even more reason to get familiar with the world of European and international standards when engaging in future development endeavours in order to avoid deviations.

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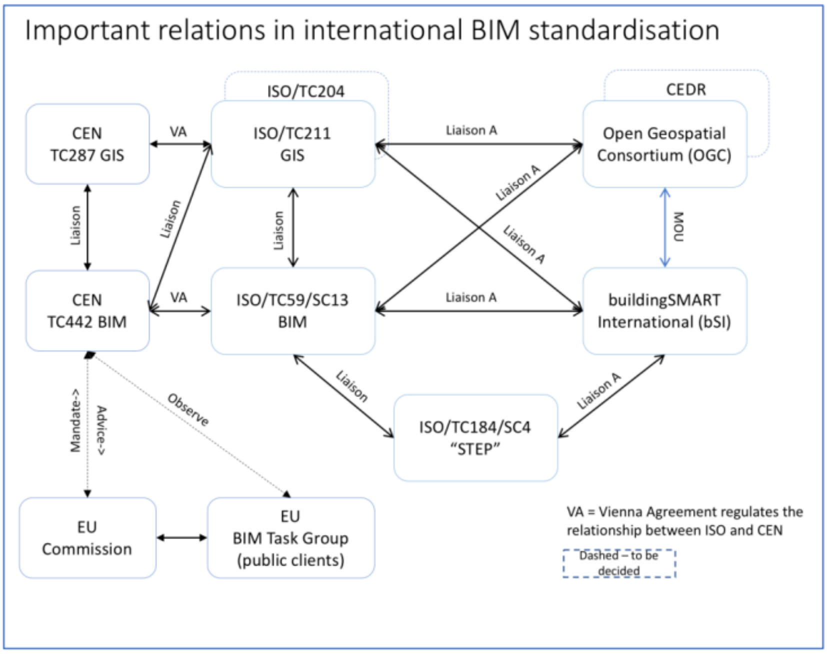


Figure 2 - *Important relations in international BIM standardization (source: CEN/TC 442 Business Plan, Building Information Modelling Version 2020-12-15, 1991542.pdf cencenelec.eu)*

4.1 ISO 19650

The EN ISO 19650 standard is an international standard for information management within the lifecycle of an asset. The EN ISO 19650-series consists currently of 5 parts with the 6^{th} in development.

The EN ISO 19650-series can be applied during planning, design, and the operational phase. It describes the information management process and the relation between organizational information requirements (OIR), project information requirements (PIR) and asset information requirements (AIR), as well as the Project information Model (PIM) and the Asset Information Model (AIM), for collecting, managing, and disseminating information for any given purpose.

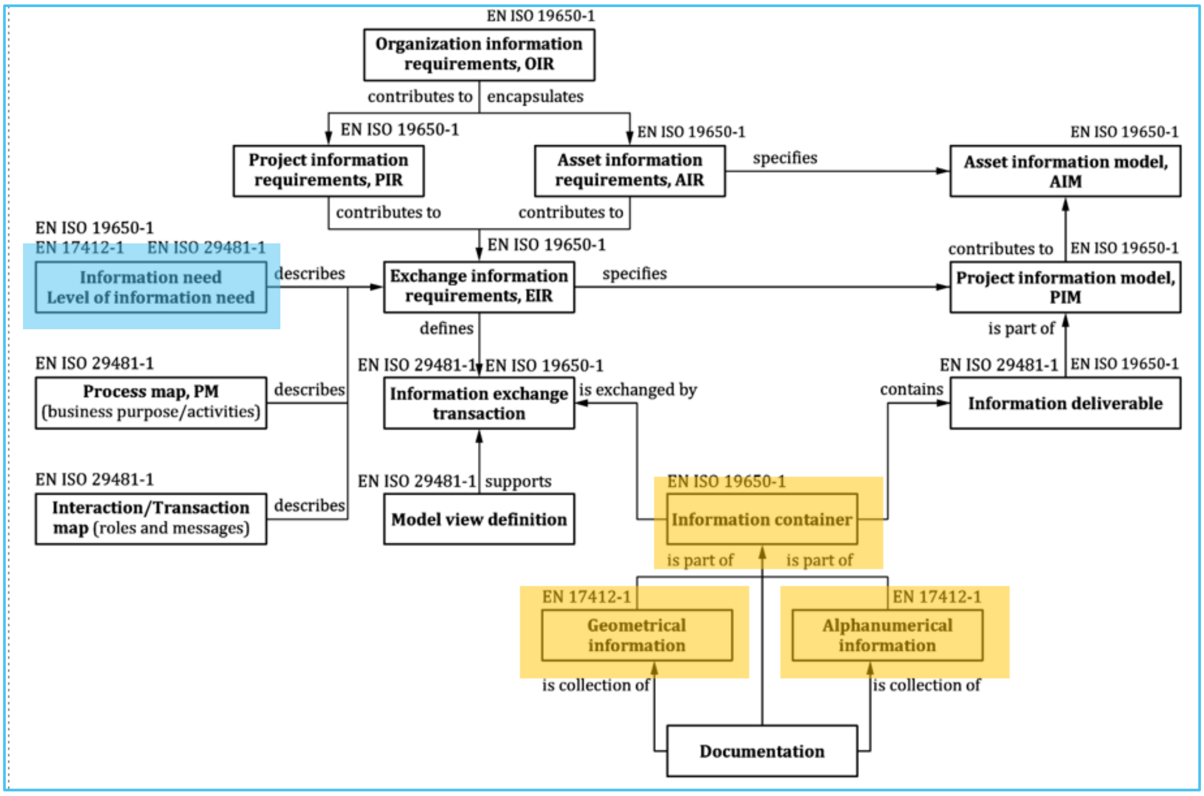


Figure 3 - *Shows the conceptual relationships between EN ISO 19650-1 and EN ISO 29481-1 (Information Delivery Manual) (Source: ISO 19650-1:2018)*

The standard includes these publications:

- EN ISO 19650-1: Concepts and principles (2018)
- EN ISO 19650-2: Delivery phase of the assets (2018)
- EN ISO 19650-3: Operational phase of the assets (2020)
- EN ISO 19650-4: Information Exchange (2022)
- EN ISO 19650-5: Security-minded approach to information management (2020)
- EN ISO 19650-6: Health and safety (under development) (2023)

Key

A start of delivery phase — transfer of relevant information from AIM to PIM

B progressive development of the design intent model into the virtual construction model (see 3.3.10, Note 1 to entry)

C end of delivery phase — transfer of relevant information from PIM to AIM

Figure 4 - *Generic project and asset information management life cycle (shows how Information Management is embedded in ISO 55000 and ISO 9001) (Source: ISO 19650-1:2018)*

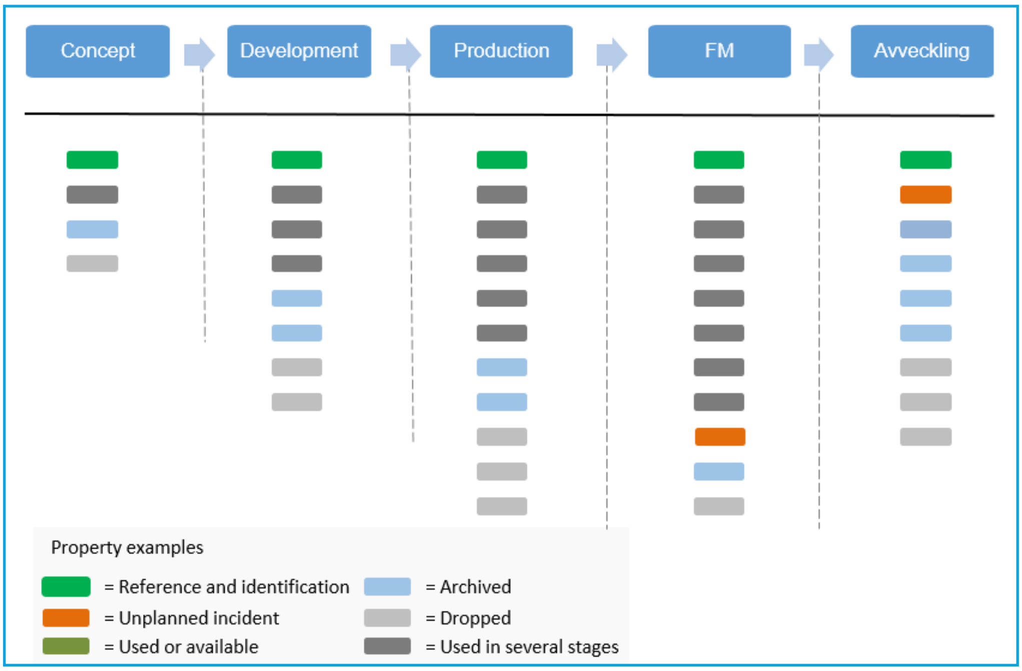


Figure 5 - *Shows how information can be built up and vary over time (Avveckling = Decommissioning)*

EN ISO 19650 parts 1-3 Concepts and principles + delivery and operational phase of the assets require the sharing of project and asset information as part of collaborative and convergent processes. These provide the governance and strategy around the execution of both the delivery phase and operational phase of information management.

The term "information container" is introduced and the requirement stated that the status is to be stated on container level. The LOD development in NBC is one way to meet that requirement.

It should be made clear that a second concept is introduced by way of "Common data environment (CDE)" where the status of an information container within a workflow is stated. The distinction is that the while the content of the information container may have an early stage of maturity, it may reach the state "published" or even archived.

Another major benefit is a set of definitions that are to be applied in projects where the standard is considered a requirement. Reducing the eminent problem of misunderstanding due to different understanding of technical terms and definitions. A managed approach to information production and delivery generates the need for a change in understanding of the obligations of everybody involved in a project, including a public client. Employees and project staff with a different kind of skill set may be required to enable the delivery team to work in accordance with the 19650 standard.

EN ISO 19650-4 Information Exchange complements parts 1-3 by providing the process and criteria for an individual information exchange. The intention is to secure the benefits arising from collaborative and interoperable Building Information Modelling (BIM) and choosing 'open' schemas and data formats and conventions whilst defining when alternatives may be appropriate.
It provides the detailed process and criteria for the decision points when executing an information exchange as defined by EN ISO 19650 so as to ensure the quality of the resulting project or asset information model. It promotes a proportional and sustainable approach to information exchange where the immediate delivery of information does not limit its future use.

EN ISO 19650-5 Security-minded approach to information management addresses the challenges arising by project teams assembled by several organisations and how to maintain a reasonable level of security, especially regarding sensitive infrastructure. By that the standard fills a gap left by the EN ISO 21000-series which addresses a similar topic but within a company or a department within a company. The point of origin would be risk assessment as known from the ISO 31000 and others to form a reliable base for the security minded approach.

EN ISO 19650-6 Health and safety is under development (2023).

4.2 ISO 12911 TS

Framework for specification of building information modelling implementation from 2012 revised and renamed. Final hearing 2022

From scope: "This standard establishes a framework for providing specification for the internal commissioning of building information modelling (BIM during both delivery and in-use phases).

The standard is applicable to building, infrastructure, facilities and managed landscapes, of any size or complexity.

Authors of the BIM implementation specifications, including international and national institutions as well as individual organisations, can use this framework to document their expectations in a way that is clear, concise and checkable. Those supporting specific software application usage can also follow the framework.

Implementers of information management processes will benefit from the clear structure and the ability to compare and merge BIM implementation specifications, potentially from multiple sources, to mobilize execute and check their internal BIM implementations."

The general idea behind this specification lies in the checking of conformity of deliverables to ensure usability of models and information containers within the appointing parties environment. The human- as well as machine-readable nature of a specification which is in compliance with TS 12911 enables involvement of reasonable stakeholders within an organisation as well as efficient conformance checking, enabling the delivery teams to check deliverables against requirements.

The TS 12911 as such is structured in a way that makes it both machine and human readable, elevating the document to its own proof of concept. The business logic behind is the RASE method, which is sufficiently explained in the document, and which utilizes Requirements, Applicability, Selection and Exception (R_A_S_E) to specify requirements and verify deliverables.

A BIM implementation specification according to TS 12911 would support the creation of structured, checkable technical specifications for process of inputs and outputs described in BIM Execution Plan about data exchange.

Regarding LOD, Annex B contains examples of how a managed BIM implementation enables consistent and reliable data for i.e., quantity take off, geometric dimensions, process, naming & classification of objects to group according to type and construction.

Data used to create common quantity report, which contains information to identify the required resources and tools to realize the desired outcome, e.g., common level of information like geometric measurements as properties that are accurate and expressed as required.

ISO 12911 is relating to ISO 19650, delivery of data according to figure 2 in 12911 (information model input and outcomes) and figure 4 in 19650-1 (PIM delivery to AIM and then back to PIM).

4.3 LOIN – CEN/TC 442 - EN 17412

CEN is a European standardisation organisation that support the work with European BIM standardization and ISO 19650 through Technical Committees (TC). TC 442 - Building Information Modelling (BIM) is developing a structured set of standards, specifications and reports which specify methodologies to define, describe, exchange, monitor, record and securely handle asset data, semantics and processes with links to geospatial and other external data that other TC can relate on.

CEN/TC 442 - Building Information Modelling (BIM) (iteh.ai)

EN 17412 Building Information Modelling - Level of Information Need will specify the characteristics of different levels used for defining the detail and extent of information required to be exchanged and delivered throughout the life cycle of built assets. It gives guidelines for principles required to specify information needs. The thought behind the standard is to avoid using a lot of energy and time on information that is not needed in the project or at that point in the project, and make sure that the important information is included.

The level of information need provides methods for describing information to be exchanged according to exchange information requirements. The exchange information requirements specify the wanted information exchange.

The work is divided into 3 parts where part 2 and 3 will be an ISO standard with another number:

- EN 17412-1:2020 Building Information Modelling - Level of Information Need *- Part 1*: *Concepts and principles* is approved both as an ISO standard, ISO7817 and as an EN standard, EN 17412. The standard will get a new common standard number.
- LOIN - Part 2: Guidance for application is under work in TC442 WG2, project leader is Marcia Bolpagni. As of now a date for completion is not known.
- LOIN - Part 3: Data schema is under work in TC442 WG2, project leader is Marcia Bolpagni. As of now a date for completion is not known.

4.4 bSDD – buildingSMART International

The buildingSMART Data Dictionary (bSDD) is an online service that hosts classifications and their properties, allowed values, units and translations. The bSDD allows linking between all the content inside the database. It provides a standardized workflow to guarantee data quality and information consistency.

Pilots have been initiated in the Nordics (specifically at the FTIA) to look how bSDD can be utilised to define and standardize the data content. The main purpose is to evaluate whether the bSDD could be used as a distribution channel for different properties and to see if it is possible to jointly use the system to collect and share data.

4.5 IDM – ISO 29481

Information delivery manual (IDM) is a methodology that can be used to document existing or new processes and describe the associated information that have to be exchanged between parties. The output from the standard can afterwards then been used to specify a more detailed specification that if necessary can form the basis for a software development process.
It is important to state that in order to make an information delivery manual (IDM) operational it has to be supported by software. The main purpose of an information delivery manual is to

make sure that the relevant data are communicate in such a way they can be interpreted by the software at the receiving side.

In some cases it is necessary to have the IDM development work followed by a software development phase. This means that if the software development is non-existent it will not be possible to get the expected results. It is therefore crucial to make sure that the initiator behind an IDM has a clear strategy on how to get the IDM implemented in software solutions.
The methodology is today accepted as an ISO standard. **ISO 29481-1:2016** Building information models — Information delivery manual — Part 1: Methodology and format

ISO 29481-1:2016 is intended to facilitate interoperability between software applications used during all stages of the life cycle of construction works, including briefing, design, documentation, construction, operation and maintenance, and demolition. It promotes digital collaboration between actors in the construction process and provides a basis for accurate, reliable, repeatable and high-quality information exchange.

4.6 ICDD – ISO 21597

The ISO 21597 series has been developed in response to a recognized need within the construction industry to be able to handle multiple documents as one information delivery.

Information deliveries are often a combination of drawings, information models (representing built or natural assets in the physical world), text documents, spreadsheets, photos, videos, audio files, etc. Increasingly, this may also include datasets based on any ontology. An ability to specify relationships using links between information elements in those separate documents can contribute significantly to the value of an information delivery. The composition of such a package arises both from the requirements of the process, e.g. delivery of as-built information, and from the specific functional purpose e.g. performing a quantity take-off or communication about issues in 3D models.

The container format includes a header file and optional link files that define relationships by including references to the documents, or to elements within them. The header file uniquely identifies the container and its contractual or collaborative intention. This information is defined using the RDF, RDFS and OWL semantic web standards.

The header file, along with any additional RDF(S)/OWL files or resources, forms a suite that may be directly queried by software. The link references may be interpreted by the recipient applications or reviewed interactively by the recipient. Where it includes link references into the content of documents that don't support standardized querying mechanisms, their resolution may depend on third party interpreters.

The format can also be used to deliver multiple versions of the same document. ISO - ISO 21597-1:2020 - Information container for linked document delivery — Exchange specification — Part 1: Container

4.7 IFC – ISO 16739

IFC (Industry Foundation Classes) is a neutral and open file format that enables the free exchange of structured and object-oriented information between CAD software and other software and systems. IFC is used in planning, design and construction of houses and facilities and the most recent development of IFC contain also infrastructure assets. The standard is also useful for archiving model data in a way that is sustainable over time. In recent years, IFC v4.3 has also developed to include support for bridges, ports and waterways and elongated objects such as roads and railways (implementation in software is ongoing).

IFC export and import is today available in a number of software and enables the exchange of digital models and information for different areas of use, such as visualization, quantity, simulations of various kinds, quality assurance. With IFC, the model's objects are given unique identities that follow them throughout the lifecycle in the various programs and databases where they are used. An IFC file contains standardized object types and for each type a basic set of properties. IFC itself has only a simple type classification of objects such as IfcWall or IfcDoor, and must therefore be supplemented with an appropriate classification.

ISO - ISO 16739:2013 - Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries

4.8 US Standards

Level of Development is an American standard for the level of detail, information, and replicability by the levels 100,200,300, 350 and 400. This is one of the first standards to describe the model levels independently from the project phases and on an object level.

The levels are descripted for a long variant of object types used in building projects in "the LOD specification" first published by BIM forum in 2013 which expands upon the LOD schema developed by the American Institute of Architects (AIA) in 2009. The specification is updated yearly and is working together with ISO to be compatible with their standards.

https://bimforum.org/lod/

This standard is made for the vertical building industry and does therefore only include object types used in these kinds of projects. Even though many construction parts of an infrastructure project will be found in this standard, most elements of a linear infrastructure project will not be covered. Therefore, this standard cannot directly be used in infrastructure projects but will need an expansion with new object types before being used.

5 Industry initiatives, concepts and definitions

The LOD workgroup in NBC started their work the autumn in 2019 with a workshop in Copenhagen. In this workshop we shared information on ongoing and planned initiatives in our separate organisations. The workshop concluded that we wanted to continue the workgroup to see if it would be possible to have common NBC standard for LOD. At this time we named the workgroup LoX as we didn't want to limit the work to the definition of LOD at the time.

The most interesting initiative at that time was the Dikon7 work that was ongoing in Denmark. We decided to wait for this work to complete and not start a Nordic initiative that could possibly compete.

Due to the pandemic we were limited to several short digital workshops in 2020.

The workgroup started up their work again when Dikon7 completed their first version the summer 2021. During this time several new initiatives had started or been further developed in our separate organisations. The group decided that we needed a report that described LOD in NBC interfaced with international and national standardisations and initiatives. One major goal of the report is to identify interfaces and conflicts as well as pros and cons with both international initiatives as well as different national or organisation developments and standardization work.

5.1 LOD

As construction parts (objects) and associated information (property data) created within infrastructure models become increasingly important for project parties, there is a need to unambiguously describe the content of a building model in relation to the building part's reliability, geometric representation and associated property data. The need typically arises in two situations:

- In contractual situations where parties must be unequivocal about the reliability of building parts, geometric representation and associated property data at a given time. This is typically agreed and documented in a model delivery specification.

- Support of the project process, where there is a need to clarify when to deliver which information in the process and by whom.

This overview is a prerequisite for the use of models for specific purposes, as well as clarification of responsibility for a specific object within a model. Level of Development (LOD) explicitly describes which information about building parts must be present in a building model at different times during the design and execution processes.

LOD for building parts consists of:

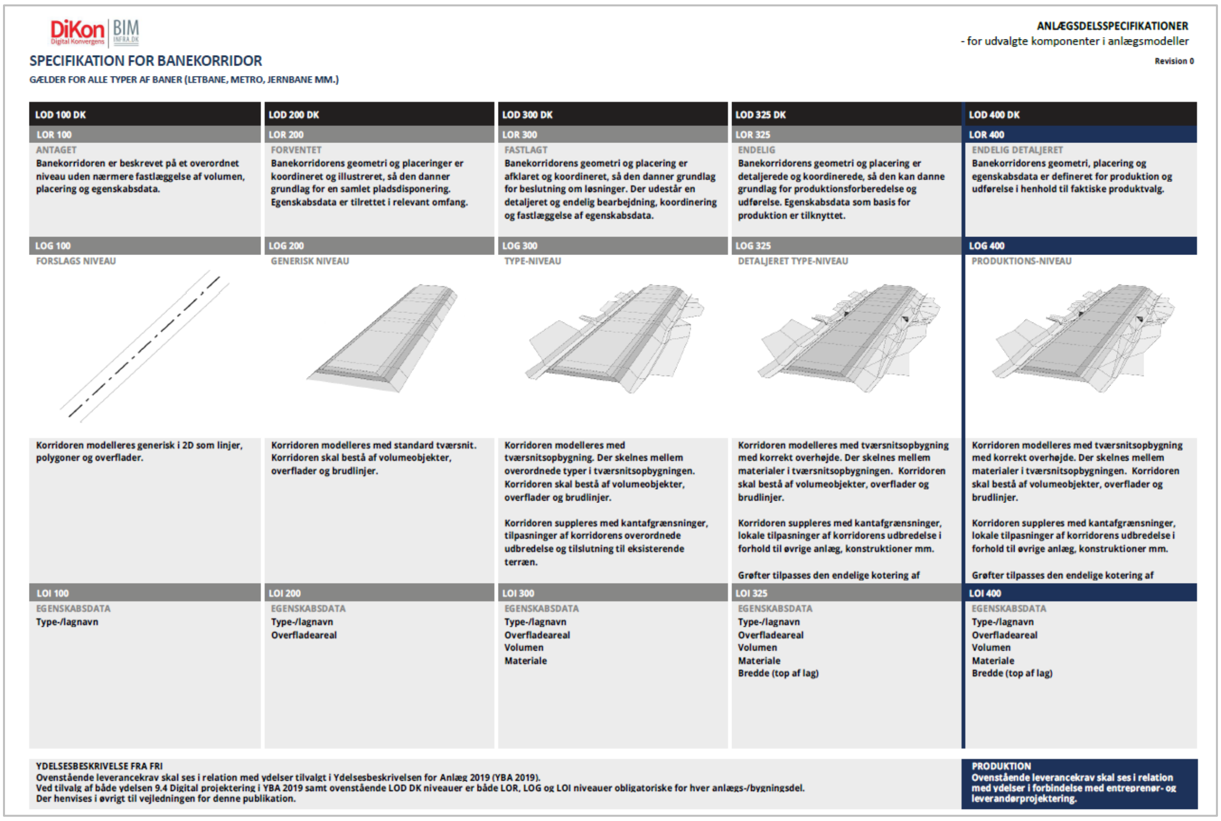
- Level of Reliability (LOR), which describes the reliability of information specified for the building part's geometry and associated property data.
- Level of Geometry (LOG), which describes the building part's geometric representation and extent of included components.

- Level of Information (LOI) that describes associated property data linked to building parts either embedded, linked or otherwise related.

A given LOD level thus indicates both the level of the geometric representation, property data and the reliability of these. LOD levels consist of a predefined composition of a matching level for LOR, LOG and LOI. For example, LOD 200 consists of LOR 200, LOG 200 and LOI 200.

It is possible to combine LOR, LOG and LOI across levels if, for example, is the need for increased geometric representation and an increased range of properties. In that case, the LOD level is described with the following syntax: |200|325|300|, where the first digit (here 200) indicates the LOR level, the next digit (here 325) indicates the LOG level and the last digit (here 300) indicates the LOI level. Note that it is thus the LOR level that governs the reliability of both LOG and LOI.

LOD levels are not linked to specific phases i.e. in a given phase, different building parts can be at different LOD levels. For selected building parts, specifications for LOR, LOG and LOI have been drawn up for LOD 200, 300, 325 and 400. In some cases, the specification deals with a specific building part, while in other cases it deals with a group of building parts that are described in the same way. LOD 200, 300 and 325 can be directly related to design services, while LOD 400 is relevant for actual production and execution of building parts.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ANLÆGSDELSSPECIFIKATIONER
- for udvalgte komponenter i anlægsmodeller
Revision 0

SPECIFIKATION FOR BANEKORRIDOR
GÆLDER FOR ALLE TYPER AF BANER (LETBANE, METRO, JERNBANE MM.)

LOD 100 DK	LOD 200 DK	LOD 300 DK	LOD 325 DK	LOD 400 DK
LOR 100	LOR 200	LOR 300	LOR 325	LOR 400
ANTAGET Banekorridoren er beskrevet på et overordnet niveau uden nærmere fastlæggelse af volumen, placering og egenskabsdata.	FORVENTET Banekorridorens geometri og placeringer er koordineret og illustreret, så den danner grundlag for en samlet pladsdisponering. Egenskabsdata er tilrettet i relevant omfang.	FASTLAGT Banekorridorens geometri og placering er afklaret og koordineret, så den danner grundlag for beslutning om løsninger. Der udestår en detaljeret og endelig bearbejdning, koordinering og fastlæggelse af egenskabsdata.	ENDELIG Banekorridorens geometri og placering er detaljerede og koordinerede, så den kan danne grundlag for produktionsforberedelse og udførelse. Egenskabsdata som basis for produktion er tilknyttet.	ENDELIG DETALJERET Banekorridorens geometri, placering og egenskabsdata er defineret for produktion og udførelse i henhold til faktiske produktvalg.
LOG 100	LOG 200	LOG 300	LOG 325	LOG 400
FORSLAGS NIVEAU	GENERISK NIVEAU	TYPE-NIVEAU	DETALJERET TYPE-NIVEAU	PRODUKTIONS-NIVEAU
Korridoren modelleres generisk i 2D som linjer, polygoner og overflader.	Korridoren modelleres med standard tværsnit. Korridoren skal bestå af volumeobjekter, overflader og brudlinjer.	Korridoren modelleres med tværsnitsopbygning. Der skelnes mellem overordnede typer i tværsnitsopbygningen. Korridoren skal bestå af volumeobjekter, overflader og brudlinjer. Korridoren suppleres med kantafgrænsninger, tilpasninger af korridorens overordnede udbredelse og tilslutning til eksisterende terræn.	Korridoren modelleres med tværsnitsopbygning med korrekt overhøjde. Der skelnes mellem materialer i tværsnitsopbygningen. Korridoren skal bestå af volumeobjekter, overflader og brudlinjer. Korridoren suppleres med kantafgrænsninger, lokale tilpasninger af korridorens udbredelse i forhold til øvrige anlæg, konstruktioner mm. Grøfter tilpasses den endelige kotering af	Korridoren modelleres med tværsnitsopbygning med korrekt overhøjde. Der skelnes mellem materialer i tværsnitsopbygningen. Korridoren skal bestå af volumeobjekter, overflader og brudlinjer. Korridoren suppleres med kantafgrænsninger, lokale tilpasninger af korridorens udbredelse i forhold til øvrige anlæg, konstruktioner mm. Grøfter tilpasses den endelige kotering af
LOI 100	LOI 200	LOI 300	LOI 325	LOI 400
EGENSKABSDATA Type-/lagnavn	EGENSKABSDATA Type-/lagnavn Overfladeareal	EGENSKABSDATA Type-/lagnavn Overfladeareal Volumen Materiale	EGENSKABSDATA Type-/lagnavn Overfladeareal Volumen Materiale Bredde (top af lag)	EGENSKABSDATA Type-/lagnavn Overfladeareal Volumen Materiale Bredde (top af lag)

YDELSESBESKRIVELSE FRA FRI
Ovenstående leverancekrav skal ses i relation med ydelser tilvalgt i Ydelsesbeskrivelsen for Anlæg 2019 (YBA 2019).
Ved tilvalg af både ydelsen 9.4 Digital projektering i YBA 2019 samt ovenstående LOD DK niveauer er både LOR, LOG og LOI niveauer obligatoriske for hver anlægs-/bygningsdel.
Der henvises i øvrigt til vejledningen for denne publikation.

PRODUKTION
Ovenstående leverancekrav skal ses i relation med ydelser i forbindelse med entreprenør- og leverandørprojektering.

Figure 6 - *Specification of levels for LOD for foundation in Dikon.info*

Usage of LOD levels and definitions – an example

The benefits and usage of LOD should be seen in the context of the digital transformation going from a document and drawing based information process to a model based process where the information has to be defined in a much more precise way than before. The LOD levels and methods can in this context be used as a formalized process for a better common understanding and common view between contractor and asset owner/client. Today, the designer is in many cases not guided enough regarding object structure and details when designing e.g. a bridge and the maturity of the client regarding requirements for a model based process is sometimes low.

In order to have a more efficient delivery process, the connections between requirements and delivered products must be more traceable than what is often the case today. To reach a connected process we need machine readable requirements and methods to automatically verify at least the formal parts of delivered results according to the requirements, see figure 7. There are some existing tools today, such as mvdXML for IFC, but used in very limited scale.

The LOD concept is one of the key parts for achieving a standardised delivery process and it is favourable if the Nordic countries have a similar way of expressing LOD, especially regarding the geometric level of detail. Establishing OTL:s with an object type structure, properties, property sets and geometric/graphic levels based on a common LOD model will increase the interoperability and competition between contractors working in the Nordic countries.

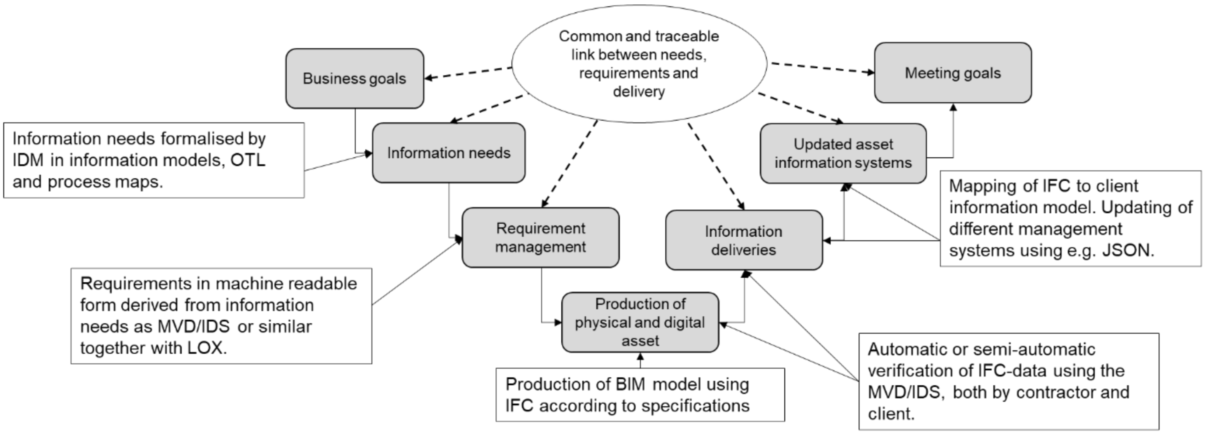


Figure 7 - *Connecting information needs, requirements and deliveries*

An important issue to address is the level of granularity/break down level and how to handle and store needed information and data more detailed than a required LOD. It can be e.g. assembly instructions, bolt dimensions and similar. In many cases this information will not be stored as objects in the model but should be linked in a standardised way.

The usability and utility of a common LOD concept will be more evident when implemented in an OTL and expressed as requirements in a machine readable form. This could be a field for further and future collaborative work within the NBC group.

A practical example on how LOD is done in contracts in Denmark

The LOD levels does not directly correspond to a specific project phase, since different projects and organisation will have different needs and requirements. Sometimes you will even need to have one geometrical level and another information level. This means that each project and organisation will need to have an overview of what should be delivered, in which detail and when. As an appendix to the contract on a project there with be a excel sheet (Leverancespecifikation) defining which levels should be delivered in each phase for which kind of civil works an on which object specification should this civil work follow.

Leverancespecifikation, Banedanmark

Rådgiver (-
Bygherre (BY
Entreprenør (E

Civil Works /Building Part *Anlægs- / Bygningsdel*	Anlægs- / Bygningsdelsspecifikationer* *Civil Works / Building Part Specification*	Level Of Development Denmark (LOD DK) Nivauer er enten beskrevet som en samlet LOD eller som LOG|LOI *Levels is either descriped as one combined LOD or as LOG|LOI*					Kommentar *Comment*
		Scope fase *Scope phase*	Programfase *Preliminary design*	Projekteringsfasen *Detailed design*	Udførelsesprojekt *Construction*	Som udført *As-built*	
Noise Barrier	Støjskærm	-	200	325	-	325	
Foundation	Fundament (BYG)	-	200	325	-	325	
Sign	Tavler	-	200	300	-	300	
Column	Master og Portaler	-	200	300	-	300	
Foundation	Fundament (BYG)	-	200	300	-	300	Stationering/kilometering skal leveres
Sign	Tavler	-	200	325	-	325	
Gantry	Master og Portaler	-	200	325	-	325	
Foundation	Fundament (BYG)	-	200	300	-	300	Stationering/kilometering skal leveres
Signal	El-komponenter (BYG)	-	200	325	-	325	
Signal pole	Master og Portaler	-	200	300|325	-	300|325	LOI 325 da Stationering/kilometering skal leveres
Foundation	Fundament (BYG)	-	200	300	-	300	Stationering/kilometering skal leveres
Luminaire	El-komponenter (BYG)	-	200	325	-	325	
Bracket arm	Stålbjælke (BYG)	-	200	300	-	300	
Lighting column	Master og Portaler	-	200	300|325	-	300|325	LOI 325 da Stationering/kilometering skal leveres
Foundation	Fundament (BYG)	-	200	300	-	300	Stationering/kilometering skal leveres

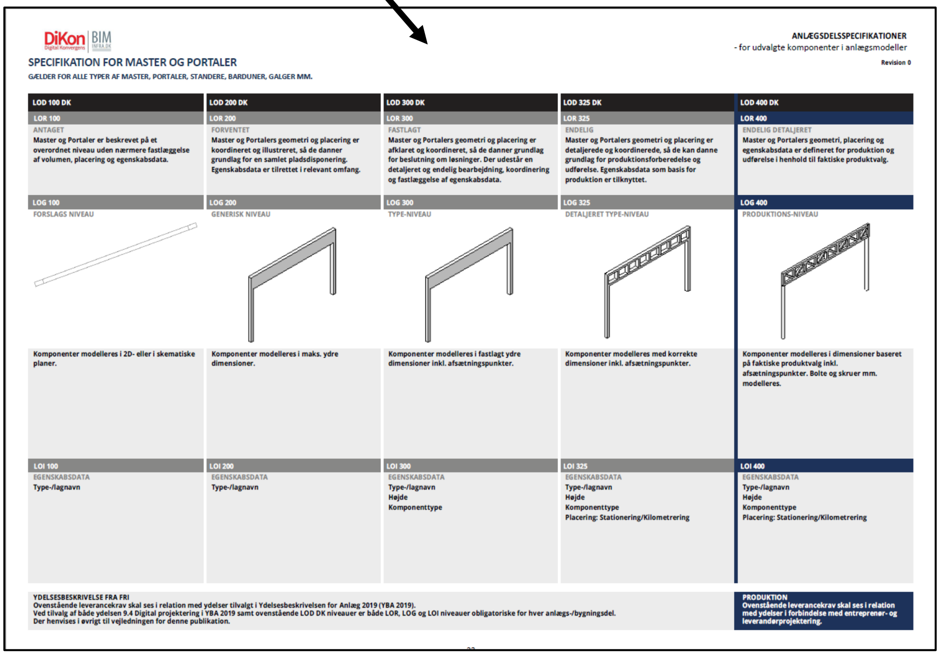


Figure 8 *– Each object type (part) specified within the delivery specification corresponds and refers to a specified LOD, as found in the parts specification, covering LOR, LOG and LOI.*

5.2 MMI – Maturity Model Index

MMI (Maturity Model Index) started in 2018 as a standard in the building industry in Norway as a cooperation between the organisations for consultants, contractors and architects. In 2020 came a similar standard for the infrastructure industry.

A working group has started on a common guidelines for MMI for both building and infrastructure, and will be possible to use in all plan phases and is set up as codes for the lifecycle of a project. this new guidelines is published here: https://www.mmi-veilederen.no/

While LOD is the requirements MMI is a process on how to achieve the requirements and communicate to every party in the project how far in the process object and/or models are.

The MMI guidelines is a combination of values and colours and are divided into these categories:

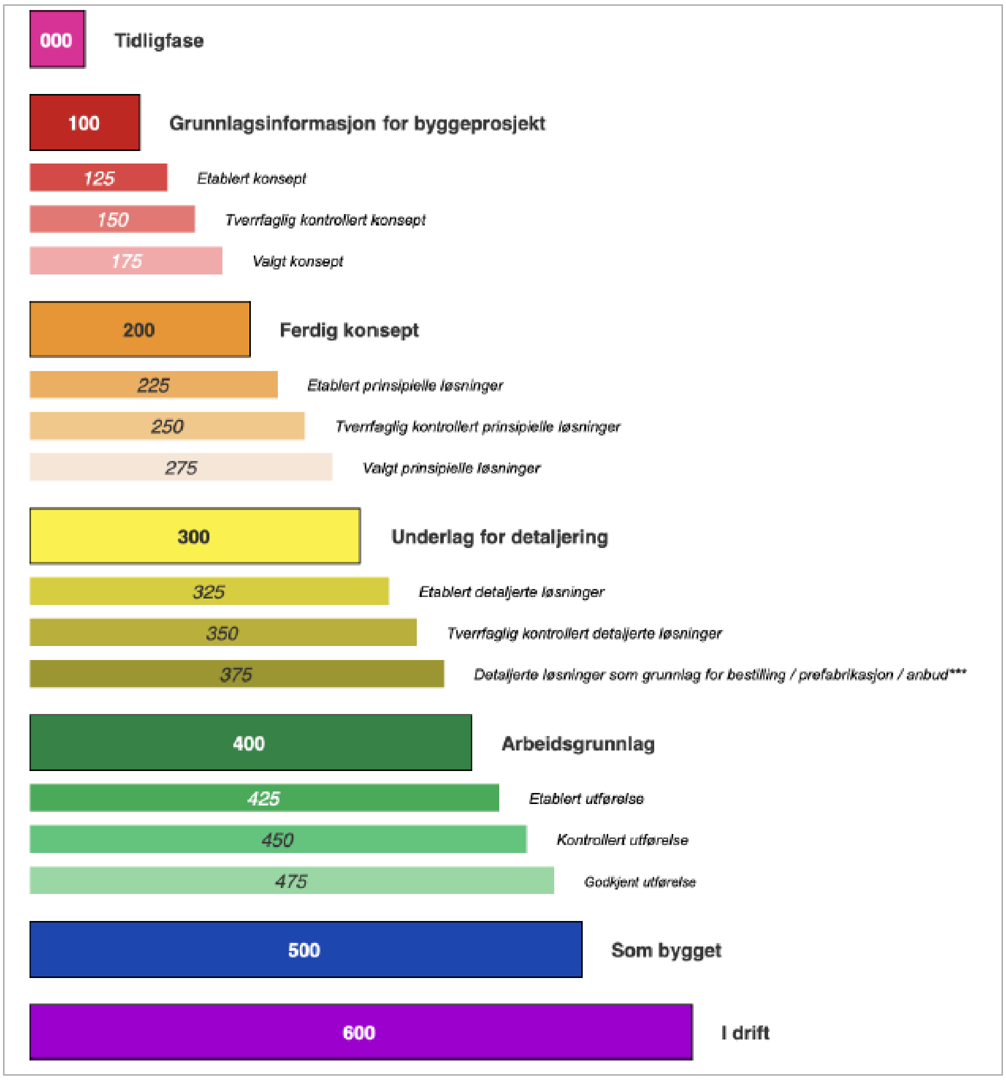


***Figure 9 -** MMI – color-coded status in a model*

The colour coding is often implemented in the coordination model for an easy viewing of MMI status and progress in interdisciplinary models.

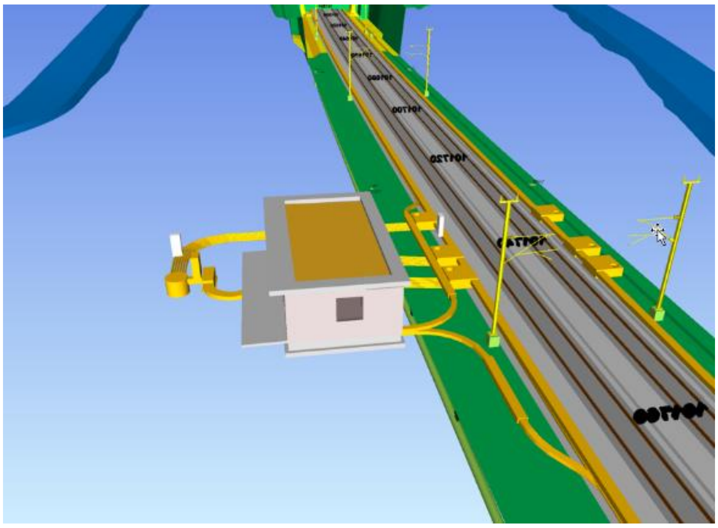


Figure 10 *- MMI - status in a model, example from Nykirke-Barkåker*

5.3 MM – Maturity Model

The BIM levels can be descripted as *"definition of what criteria are required to be deemed BIM-compliant, by seeing the adoption process as the next steps in a journey that has taken the industry from the drawing board to the computer and, ultimately, into the digital age."*

There are different maturity models with fewer or more levels and different focus on the steps than moving from the old way of working with paper and pen to a fully integrated and collaborative process.

Table 2 - *NBC Agreed table as published in 2020-12-10*

	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
CONTENT **... in the model(s)** Combined information which constitutes the information model	Digital lines, text, blocks and symbols in 2D	Simple 3D objects	3D building objects with unspecified information	3D building objects with requirements to objects, properties and ID	Manufacturer's 3D objects with properties for operation	All project, operational documentation and history are linked to objects in the model
DIGITIZATION **...of workflows** Digitalization and automation of workflows	Drawings made with 2D CAD.	Drawings made with 3D CAD/BIM.	Drawings / model views from BIM-tools. Digital management and documentation of Workflows	BIM-models viewable with mobile devices. Model data used for project management	BIM including dimensioning viewable in real time. Model driven production and assembly	BIM with all operational information and history viewable in real time
INTEROPERABILITY **...of information** Information flow between stakeholders	Work on 2D -CAD files. Background information from drawings or text reports	Work on 3D CAD files. Background information from disciplines in CAD.	File based sharing of open BIM (IFC/inframodel e.g.), models accessed through a common data environment	Non graphical Information is connected to objects. Common data environment supports unique object	The objects contain documentation & issue handling	Linked data between the model and other functional systems.
COLLABORATION **...within the project** Data availability and utilization	Digital data stays within the individual discipline. Coordination is done through drawings	3D visualization, systematic visual controls in modeling tools.	Model coordination, clash detection and quantity take off.	Interface handling in BIM. Advanced cross disciplinary simulations. Integrated Project Delivery (IPD).	Data transfers between phases, e.g. from construction to maintenance. operation.	Model used by operations, employees, users and the public.
DELIVERY METHOD of project information The delivery of finished project content (e.g. designs, as-built)	Digital 2D drawings lines, text, blocks and symbols in CAD or PDF/TIFF format	Simple 3D models and 2D drawings without references in CAD, PDF/TIFF format	File based sharing of information consisting of e.g open, native and proprietary formats	Server based sharing of open BIM (IFC/inframodel eg.). Sharing of graphic and non-graphic information	Automatic data transfer between phases, e.g. from construction to maintenance.	Continuous electronic data transfer in all project and business tasks. Project integration with information from other sectors
COST ESTIMATION Relation of cost estimations to project materials and/or content	Cost estimation is not linked to the model.	Simple data reports from model, like mass quantities.	Reliable data reports from models and support from a cost estimation database.	Calculating life cycle costs from the model.	Models include all necessary cost information linked to other functions.	Cost estimation is a clear fifth dimension. (3D + 4D time + 5D).

5.4 Model Uses

BIM - or Model uses is a way of descripting all the ways the BIM model is worked with and how they can be used in a unified way. Including when in a project is this use relevant, what does it require and what is the benefit of this use.

When talking about model uses, Penn States work on the area is often what is referred to, but there are many studies on this area and not all of them describes and categorize the uses in the same way.

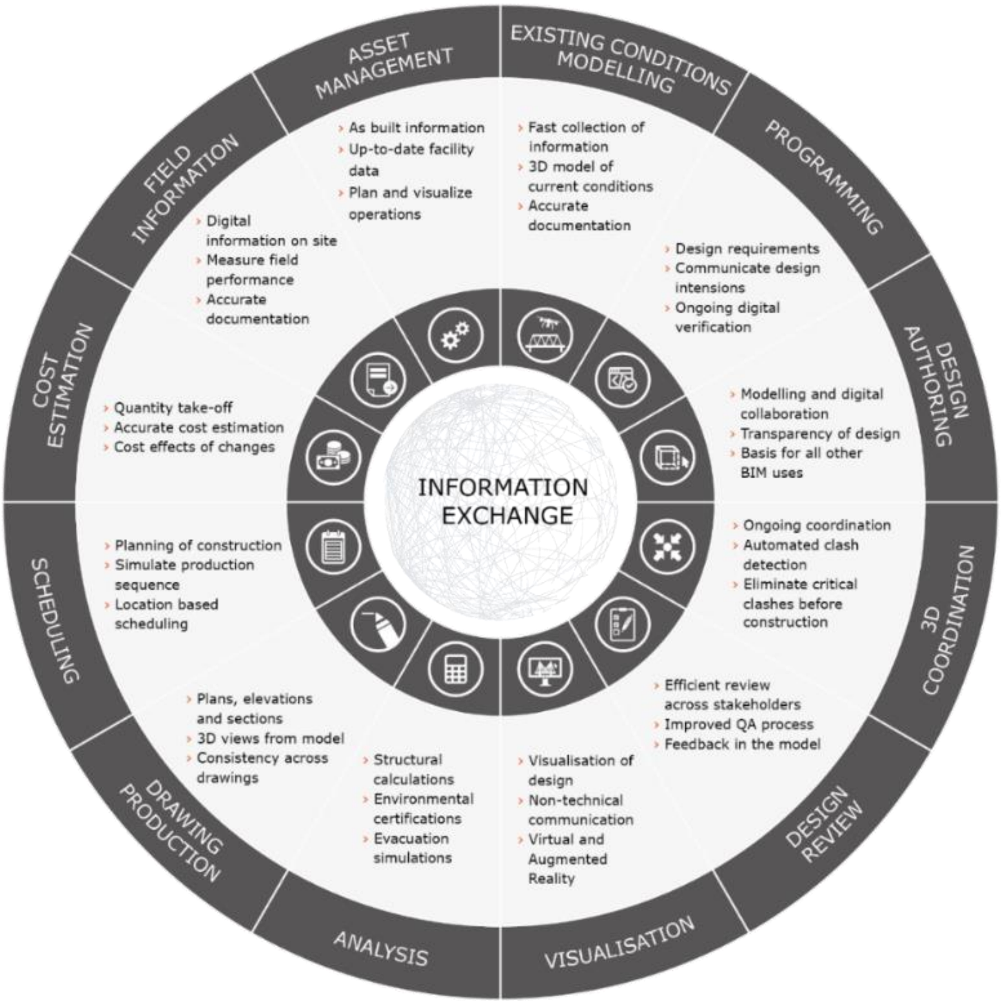


Figure 11 - *Way of illustrating different uses of BIM, courtesy of Danish engineering consultancy COWI. All uses in the wheel is mapped to the 24 Penn state uses.*

The uses change as our tools, maturity and way of working changes, so the descriptions from Penn State have been updated multiple time, in the link here you can read the newest version of their publication.

https://psu.pb.unizin.org/bimprojectexecutionplanning/back-matter/bim-use-descriptions/

5.5 OTL - Object Type Library

An object type library in general is an abstract, simplified view of a part in the physical world that is to be represented for some purpose. An OTL provides a description of built environment concepts – both physical and spatial - from which this information is derived. The purpose of an OTL is to support a common understanding between people and computers of the information required for the design, construction, operation and maintenance of infrastructure assets.

An object type library contains a standardized definition of object types of all the components, facility parts and structural systems that composes a facility or a building (e.g. road, bridge, foundation etc.) with property requirements attached to it. An object is described based on its object type data, geometry data and metadata. Metadata is needed because each object type has its own properties. Using an object type library describes assets with a standard language, syntax and semantics, which are required for a reliable exchange of information. An example of metadata for an object type can be when and by which data was the object type last revised.

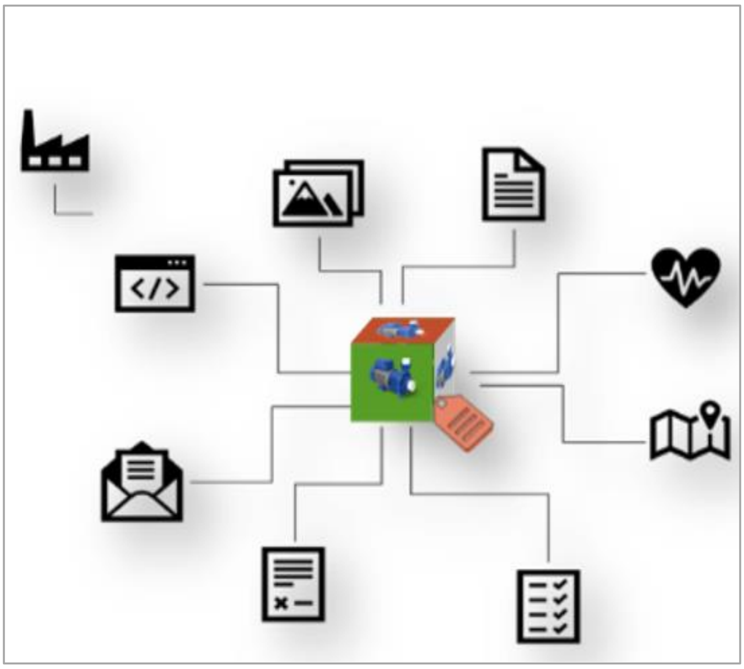


Figure 12 - *Object-oriented data structure*

The object type library defines the data structure and the variables (attributes) to be filled in at different stages in the asset's lifetime, often in connection with associated open data standards.

This also applies to information about a facility or structure, where all information throughout the life cycle must be digital. This is to be easily accessible and to be reusable and refined through the life cycle instead of being recreated. Crucial to this transformation is that the information is objectified and that the processes go from physical documents to digital automated information flows where the asset (construction or facility) is in focus, and not the document (see figure 12). By classifying the object and assigning attributes (or properties), an unbroken flow of information enables parts of the process, such as verification and reports, to be automated.

5.6 Requirement Databases

A requirement is a capability to which a project outcome should conform to. As very large clients in infrastructure, we deal with many requirements. A process for managing requirements is therefore needed to document, analyse, trace, prioritize and agree on requirements and then to control change and communicate to relevant stakeholders. It is a continuous process throughout a project.

In requirement management a database is often used as a tool to get control over your requirements and contributes to work more systematically and automated. The requirement database is therefore important to achieve the overall goal of using the possibilities of digitization and automation.

As clients one of our main task is to perform quality assurance and quality control of project deliveries. In this work, the requirements are a fundamental prerequisite. If it is possible to control the designs automatically against the requirement database, the database fulfils yet another purpose. To succeed, the requirements has to be adjusted and made machine readable if possible. There are different types of requirements and some of them will never fit to be automatically accountable.

Today many clients use requirement databases but not for quality control of designs, object-oriented information models. For this a definition of levels and information need is important to set and agree upon. As an example Statsbygg in Norway has a requirement database to check IFC-models and there are also some ongoing test projects in Sweden. Read more in chapter 0about what's been done in the Nordic countries.

Also see research report: Quality & Digital Models - Integrated Quality Assurance and Automated Quality Control. (Swedish only)

6 Status Nordic Countries

This chapter gives a short overview from each Nordic country regarding LOD/LOIN, MMI, Maturity Model, Model Uses, ISO 19650, IFC, Requirement DB and OTL.

6.1 Denmark

LOD/ LOIN

In 2018 **Vejdirektoratet** and **Banedanmark** decided to adopt the same LOD standard. The standard chosen was a Danish adaptation of the American Level of Development, called LOD DK. LOD DK was already used in the Danish building industry and Vejdirektoratet and Banedanmark made a version for infrastructure projects, working on a discipline model level. Since then, a focused industry collaboration (DiKon) has continued the LOD work on an object type level, a standard also developed for the building industry. The biggest change compared to the American standard is that instead of LOD350, LOD325 is used.

The DiKon work for infrastructure was published in early March 2022. Banedanmark has just adapted its CAD manual and ICT contract to accommodate the DiKon-work while Vejdirektoratet is in progress of adopting the standard. Banedanmarks revised CAD manual came out late May 2022.

https://www.bane.dk/Leverandoer/Krav/CAD/CAD-manual

http://digitalvej.vejdirektoratet.dk/modelstandard/Sider/default.aspx

https://www.dikon.info/

MMI

The MMI term is not currently in use in Denmark. However, through the use of the Task Information Delivery Plan/Leverancespecifikation as well as post-award BEPs, called process manuals in the Danish context, an approach to follow each delivery process will be set in place, through structured quality assurance, as project information matures into outputs. This may catalyse the future use of MMI, given the need for an established system to ascertain the maturity and status of a process by which a delivery is handed over to us, as the appointing party.

Maturity Model

We generally refer to the Nordic Maturity Model as shown in table 2 of this document. The Maturity Model has subsequently been expanded upon by BIM Infra.dk, for the Appointing party/client to be able to evaluate the maturity of a project organization, to discuss and evaluate which competences or methods have to be implemented for a project to be aligned with a specific level of maturity. Please refer to the link below:

https://biminfra.dk/testmodel/wp-content/uploads/2021/04/BIMInfra-Maturity-Measure-ver.1_english_22042021.xlsx

Model Uses

BIM Infra.dk has worked extensively with the concept of BIM Uses and although we are using a slightly different term, the concept is identical. We are using the term in project planning, but the implementation into contractual documents is lagging somewhat behind. However, model uses are an integrated part of how we specify the base level of usability/applicability of discipline specific information models.

ISO19650

In Banedanmark charts/metrics define the level of information for geometrical and non-geometrical content in terms of quality, data extraction possibilities and granularity needed across the entire design and/or asset delivery phases. These needs are described clearly within the PIR and EIR, which Banedanmark specifies through the so-called task information delivery plan (TIDP) or in Danish "leverancespecifikation". It has taken design and maintenance phases into consideration to get the right level of non-geometrical as well as geometrical, to avoid information exceeding the required level.
The process is adopted in May 2022, currently being tested on projects to get input from external as well as internal users. To maintain the AIM (maintenance) upholding the agreed level of information, project information is delivered from the design phase to execution and then as a document of the final state of the physical asset, with requirements, to establish the information to be captured during the response to the trigger event by the appointing party.
Reviewing and authorizing the LOD in models are to be required processes.

IFC

IFC 4.3 will, at a currently unknown time, become the standard format through which all tender, procurement and asset information is exchanged and delivered. As such, given the current uncertainty as to when our current practice (using proprietary formats) is phased out, we are in a standstill until ISO 16739 is formally amended and republished. With this in mind we are counting on/expecting our software vendors to code and implement reliable exporters in the interim. However, if the software vendors implement exporters before ISO 16739 is amended, we will begin using IFC 4.3 as our primary data format at that time.

Requirement DB

At Banedanmark, we are in the process of ascertaining the need for a requirement database in relation to quality control of information deliverables. This work, however, is still in its starting/definition phase and we do not currently have a finished concept with which to proceed. At Vejdirektoratet, one project has been carried out using a requirements database. Please refer to the following link to the tender documents:

http://lp.vejdirektoratet.dk/DA/vejsektor/leverandoerportal/Sider/nht.aspx

OTL

Our current classification work, with lists of component types and their class, delineates some of the work that will eventually lead to a comprehensive OTL, but the information within pertains to type coding/naming and some attributes. It can therefore not be said to be a full OTL, but rather a start of one, to be built out when we have more standard objects, in the form geometric solids, that can be applied to project work. With the uptake of IFC, we see a great opportunity to build a full OTL.

6.2 Sweden

LOD/ LOIN

The Swedish Transport Administration (STA) has not yet adapted a common LOD/LOIN standard. As for today there are only a few requirements for defining levels for details and information. They mainly say that the Cad layers/levels need to correspond to the content of the current phase, product and application. Requirements are vague which results in differences in deliveries and quality. There is therefore a need for a common specification.

Various pilot projects are running today within STA, where project specific requirements for LOD is being implemented for example in the East link railway project and in the project Tunnel of Varberg. Also some of the technical disciplines have specified different levels to describe both the geometrical representation as well as the need for information. One example is the geotechnical discipline that defines three different levels depending on the complexity and need of the project.

In the internal project *Technical Platform*, STA will be using the concept of LOIN-packages. A LOIN-Package is a group of different requirements, properties etc. that are connected to a building element/entity based on the methods described in the EU standard EN-17412-1. The different building element/entity will be used to model a facility and are grouped under the following categories:

- Infrastructure complexes (e.g. road, rail)
- Construction entity (e.g. railway tunnel, railway bridge, railway station)
- Constructive system (e.g. track substructure, track superstructure)
- Components (e.g. rail, grinder, switch)

The different building element/entity included in the model will functions as a placeholder for all property sets (information) that may be needed for different purposes (requirements, management, simulation, design), required by a different actor and delivered in different millstone.

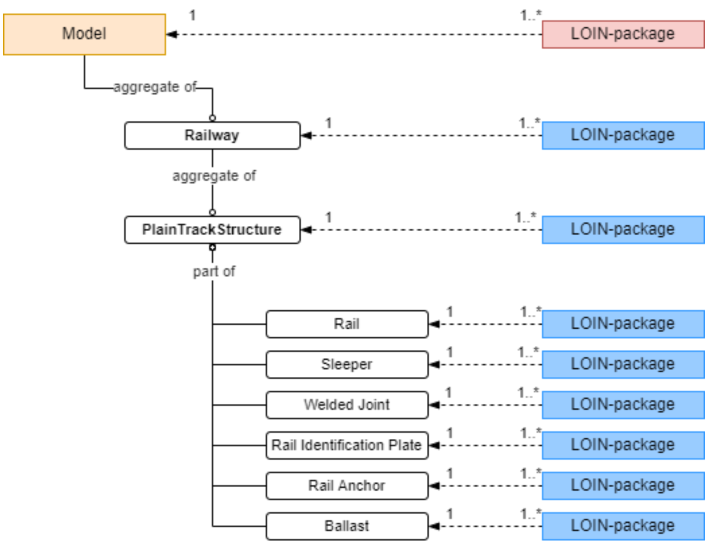


***Figure 13 -** LOIN-Packages for the different building element/entity in the model (STA project Technical Platform)*

Worth mentioning are some national initiatives in the building industry, like the National guidelines https://www.nationella-riktlinjer.se/ and the BEAst standard: https://beast.se/standarder/beast-bim/.

The purpose of the National Guidelines is to simplify, streamline and harmonize the requirements and management of digital information for the built environment. BEAst is also working to standardize and harmonize the industry and is a non-profit association that develops common standards and working methods for digital communication in collaboration with Nordic and international organizations.

MMI

MMI is not a widely used standard in Sweden today. Currently, status in models are usually placed on CAD-layers and as metadata. Moving forward, this will change when implementing requirements for object based properties and the IFC-format.

There are some initiatives from Swedish industry to develop a Swedish version of the guideline for MMI. It's based on the Norwegian guideline but simplified and a level 600 has been added for maintenance (as ATU and Stanford University).

Model Uses

This work has only just started and a workshop to establish definitions and priorities uses is being planned before the end of 2022. An activity collecting previous work from around the world is initiated. The input for this work is taken from bSI IFC 4.3 projects requirements analysis phases, the Model maturity matrix work, Penn state, DiKon and many more. The bSI UCM tool is also an interested place to look for inspiration.

Maturity Model

The Nordic maturity model has been used as a base for a new adjusted maturity model. The suggested model will have five levels instead of six and the categories has been changed to organization, process, product, information exchange and applications (BIM Uses) see Table 3 - *Swedish development of a maturity* model. The matrix will enable us to identify the current situation for where we are in the implementation of BIM, within a specific project or within an organization. It will also provide an overview of the possible steps that needs to be taken for a future desired situation. This would facilitate planning as well as follow-up and development of BIM in the construction industry.

The adjusted model will be tested within STA as a method to follow-up projects and as a tool for strategic development of BIM Uses and applications in projects. Possibly it will also contribute to the STA goal of increasing the digital capability and to identify activities that benefit the business.

Table 3 - *Swedish development of a maturity model*

Description	Category	Level 0 - Initial	Level 1 - Definied	Level 2 - Managed	Level 3 - Integrated	Level 4 - Optimized
Describes how we communicate and collaborate. *Describe the clarity achieved in the organization in terms of roles, responsibilities and mandate.*	**ORGANIZATION**	Collaboration is not established and clear definitions of roles, responsibilities and mandates are missing. Communication plan not established.	Collaboration with other parties is to some extent established and is based on simple routines. Roles, mandates and responsibilities are documented.	Collaboration is well established and is based on agreed basic principles. Roles with clear responsibilities and mandates are well defined and documented.	Collaboration is based on full integration with common project goals. Communication plan established. A high level of cooperation is required by contract.	Collaboration is optimized and well-defined. Systematic management of risks, requirements and quality is applied that enables automation.
Describes how we work with quality-assured information and how it is integrated into various decision-making processes. *Describe how well processes are documented and implemented and at what level experience feedback and improvement of processes takes place.*	**PROCESS**	Information from models is not used and has not been integrated into any processes. Overall strategies are lacking and the processes are not defined or documented.	Majority of main processes are well documented and experience feedback has been implemented, but the potential of digital information is not yet exploited. Clients and suppliers lack common processes and agreed routines.	Common main processes are applied to a certain extent and are governed by agreed, simple routines for the project.	The processes are fully integrated between the various actors. All actors use the digital information and processes are continuously validated. A common workspace is used to share and communicate the processes.	Digital information is used as a critical part of the decision-making process regarding assets and risk management and is also an important part of creating a common digital society. Processes are evaluated and optimized continuously.
Describes how we work with the product's geometric information, structure and required properties.	**PRODUCT**	Objects and their properties are represented geometrically in 2D according to drawing standards. Classification is limited to include CAD layers as information carrier. Presentation technique for the result is based on traditional drawing production.	Objects are also reported geometrically in 3D. Classification is supplemented and may include multiple information carriers. Presentation technique is supplemented with models for visualization.	Geometric information is adapted to the product's purpose and needs. Properties of objects (types) are defined and based on requirements. Requirements allow open formats. The model forms the basis for the development of various products where 2D and 3D information complement each other.	The product must correspond to the physical facility with the content needed for the specific purpose at a given time. There are requirements for special applications where the model must be used and integrated into the process. Open formats are required. Presentation of result is based on the model and information in the various products is linked.	The product is valid as a legal document and constitutes the common database that forms the basis for automation and control of processes. Requirements are machine readable and linked to objects. The models are integrated with sensors and other data sources and are updated in real time.
Describes how we exchange object-oriented information between different parties; the formats and systems used for handling and information transfer.	**INFORMATION EXCHANGE**	No exchange of model-based information takes place. Communication takes place via locked export format (pdf).	Object-oriented information is shared with exchange formats that are not based on an open standard. Data is shared via a simple and common web interface.	Information is shared with both open formats and exported exchange formats. Shared server is used as workspace and for exchange.	Information is always shared with open formats. Exported exchange formats only occur in cases where other alternatives are missing. Table data for objects is stored in database, graphical information is stored in models. Work takes place via a common server where data is updated in real time.	Information is handled from a life cycle perspective and shared via information systems where data is available and refined. Work takes place in a common database where all data is updated in real time. Both table data for objects and graphical information are handled in the database.
Describes overall how and to what extent object-oriented information is applied	**APPLICATION**	Object-oriented information may exist but is not used.	Object-oriented information is used to visualize the product.	Object-oriented information is used in a few applications for simpler visual analyzes and measurements	Object-oriented information is applied for deeper analyzes. The information is not linked to the end result and is not updated automatically.	Object-oriented information is integrated and constitutes an obvious part of the processes. Information is updated automatically.

ISO19650

SS-EN ISO 19650 is regarded as a supplement to the Swedish Transport Administration's management system standards to control the organization of information about infrastructure and facilities in their common life cycle for all actors involved. ISO 19650 was the main guiding principle when developing the internal document TDOK 2019: 0082, Management of information of facility assets.

There is currently no decision taken whether to have a formal decision placing ISO 19650 as one of the basic management system standards or to let ISO 19650 be more of an informal guiding standard.

A new strategy for Asset Information is under development in close cooperation with the Asset Management group at the Swedish Transport Administration. ISO 19650 will be one of the main guiding documents for this strategy.

A new development program for Asset information has been initiated and will be started Q3 2022. ISO 19650 will be one of the main guiding documents for the program.

IFC

The Swedish Transport Administration has made a joint policy decision where IFC is pointed out as the central standard for the exchange of data of the physical road and railway facility. The decision refers to the ISO standard SS-EN ISO 16739-1, Industry Foundation Classes (IFC), as an open format for deliveries and exchange of structured asset-related data in order to obtain uniform information deliveries and eventually machine-readable delivery requirements and automated delivery control.

The policy decision applies to all activities where structured data about the physical facility is to be communicated with internal systems, external suppliers and users, e.g. production of procurement / requirements documents, IT systems and business development. The decision is in line with TDOK 2019: 0082, Management of information of facility assets, chapter 4.8 Selection of standards for the physical road and railway facility.

The policy decision means that where applicable, IFC shall be the first choice in e.g. business development, revisions of requirements documents and preparation of tender documents. Through this decision, the Swedish Transport Administration shows that IFC is a long-term chosen solution that will be an important part of the Swedish Transport Administration's ability to effectively exchange facility-related information between systems, actors and stages.

In addition to decisions on IFC, similar decisions were also made on railML and RSM (RailSystemModel). Both of these standards only concern railway-related data.

Requirement Databases

The Swedish Transport Administration have collected almost all requirements in requirements databases. The same system is used for all databases and to manage the requirements Systematic Requirements Management as a method are often used. Today, however, not all the possibilities that a database can support are applied, for example such as follow-up of projects and control of compliance between design and requirements.

There is a need to structure the regulations so that it can be used to enrich the models. For example the LOD levels are here important to establish (figure 6) to be able to facilitate automation, validation and further on make some of the requirements machine-readable.

There is some ongoing projects at STA that use a requirement database more broadly. In the project New Main Lines, structural requirements for information models is stored in a database. The database gives more possibilities to analysing, tracing, prioritizing and agreeing on requirements and also makes it easier to control changes. Advice and motive are connected to each requirement to make it easier to share resources. The database can be used for following-up projects and because the requirements are tagged with for example phase the possibility to automatically export procurement documents are used.

Additional internal projects like Technical platform for maintenance and a development project looking at handover from projects to FM, includes structures for IFC-models. The plan is to develop a database for semi-automatic checking of IFC-models for quality control at deliveries like the SIMBA and KIM databases in Norway (chapter 6.4). Pilots are running to demonstrate how we can derive requirements from the database and compile these into delivery specifications that can be exported and utilized directly in the design applications. The same specification should also be used for automated validation of the requirements to make sure the information delivered is complete and compliant.

OTL

Within the project Technical Platform, The Swedish Transport Administration are creating a common object type library for Railway facilities. The objective of the program is to collect objects (CAD-objects) used in previous projects and assign to them a semantic definition, a classification (using CoClass), an Ifc entity class and the relevant LOIN-Packages. The Swedish Transport Administration plans to make the OTL available for future projects and for that multiple system and IT-solutions will be tested to determine the proper workflow for the management and the distribution process.

6.3 Finland

The Finnish Transport Infrastructure Agency (FTIA) has required a BIM-based project delivery since 2014. Currently the requirements for the hand over material are based on the use of open data formats such as IFC, LandXML (in its's Finnish extension Inframodel https://buildingsmart.fi/infra/inframodel/index.html), InfraBIM classification and national as well as FTIA's guidelines. FTIA has released guidelines for roads, railways, waterways as well as bridges and engineering structures.

A key principle for FTIA is to continue to rely strongly on international standardisation work. With this in mind, FTIA is exploring opportunities to link concepts such as IDM, IDS, bSDD, etc. to project delivery, maintenance systems and asset management.

LOD/ LOIN

The infrastructure BIM requirements of FTIA are not aligned to a named LOD standard or framework. The level of information for geometrical and non-geometrical content is defined both in the national InfraBIM requirements (YIV) and in more detail in FTIA's own requirements for the BIM delivery of road- rail- and waterway projects. The latter document is currently being revised and will include an annex setting out the requirements for both data content and geometry by sub-model and project stage. The table includes project phases from preliminary design to as-built models.

The intention is to update the requirements in the future to comply with a LOD standard.

Table 4 - *LOI Requirements through the stages of railway projects*

SUUNNITELMAMALLIT

Osamallit	Yleissuunnitelma		Ratasuunnitelma		Rakentamissuunnitelma		Rakentaminen		Toteuma	
	Tiedon esittäminen / geometria		Tiedon esittäminen / geometria		Tiedon esittäminen / geometria		Tiedon esittäminen / geometria		Tiedon esittäminen / geometria	
Geometrialinjat	Pituusmittausraide, vaaka- ja pystygeometria sisältäen alustavat kallistustiedot, vaihteiden tiedot, kilometripaalutus	*esimerkkikuva*	Pituusmittausraide, vaaka- ja pystygeometria sisältäen kallistustiedot, vaihteiden tiedot, kilometripaalutus	*esimerkkikuva*	Pituusmittausraide, vaaka- ja pystygeometria sisältäen kallistustiedot, vaihteiden tiedot, kilometripaalutus	*esimerkkikuva*	Rakentamissuunnitelmamalli	*esimerkkikuva*	Toteumamittaukset	*esimerkkikuva*
Radan ylin ja alinyhdistelmäpinta	Ylin yhdistelmäpinta	*esimerkkikuva*	Ylin yhdistelmäpinta Alin yhdistelmäpinta	*esimerkkikuva*	Ylin yhdistelmäpinta Alin yhdistelmäpinta	*esimerkkikuva*	Laadunvarmistus ja poikkeamamallien ylläpito	*esimerkkikuva*	Rakentamissuunnitelman mukainen malli + toleranssista poikettaessa poikkeamamalli yhdistettynä toteumamalliksi	*esimerkkikuva*
Radan rakennepinnat	Ei mallinneta		Rakennekerrosten pinnat	*esimerkkikuva*	Rakennekerrosten pinnat	*esimerkkikuva*	Laadunvarmistus ja poikkeamamallien ylläpito	*esimerkkikuva*	Rakentamissuunnitelman mukainen malli + toleranssista poikettaessa poikkeamamalli yhdistettynä toteumamalliksi	*esimerkkikuva*
Radan päällysrakenne ja vaihteet	Ei mallinneta		3D objektit	*esimerkkikuva*	3D objektit	*esimerkkikuva*	Laadunvarmistus ja poikkeamamallien ylläpito	*esimerkkikuva*	Rakentamissuunnitelman mukainen malli + toleranssista poikettaessa poikkeamamalli yhdistettynä toteumamalliksi	*esimerkkikuva*
Radan routaeristykset	Ei mallinneta		2D esitys radan routasuojauksesta	*esimerkkikuva*	3D esitys radan routasuojauksesta	*esimerkkikuva*	Laadunvarmistus ja poikkeamamallien ylläpito	*esimerkkikuva*	Rakentamissuunnitelman mukainen malli + toleranssista poikettaessa poikkeamamalli yhdistettynä toteumamalliksi	*esimerkkikuva*

MMI

FTIA is currently not using a formal definition of the Model Maturity Index. Some aspects of the MMI are covered in the national and FTIA's InfraBIM requirements. The requirements demand the preparation of a separate document indicating the content and level of maturity of the models.

Nordic Road & Rail
BIM Collaboration

Maturity Model

The Nordic Maturity Model is in use after being slightly modified to better suit the use as an evaluation tool for FTIA projects. In interviews that use the MM as a discussion and evaluation basis, 29 projects have been analyzed in 2022. The evaluation covered all types of fairways and project phases, from preliminary design to construction. Based on this analysis, future development measures to improve the BIM maturity of projects and processes can be targeted in the most effective way.

Model Uses

The FTIA has identified several of the Penn State Model Uses as relevant. Below a table with information about the status of different BIM Uses from the FTIA perspective.

In addition to the above mentioned, FTIA will focus on the use of BIM in the future especially in asset management and maintenance.

Table 5 *- FTIA BIM uses*

Penn State BIM Uses	Currently used at FTIA	Usage planned at FTIA	Currently not relevant
Analyze Energy Performance			x
Analyze Lighting Performance		x	
Analyze Program Requirements			x
Analyze Structural Performance			x
Analyze Sustainability Performance		x	
Author 4D Model	x		
Author Construction Site Logistics Model	x		
Author Cost Estimate	x		
Author Design Model	x		
Author Temporary Construction Systems Model	x		
Capture Existing Conditions	x		
Code Validation		x	
Compile Record Model			x
Coordinate Design Models	x		
Disaster Planning			x
Draw Construction Documents	x		
Engineering Analysis			x
Fabricate Products	x		
Layout Construction Work			x
Monitor Assets		x	
Monitor Maintenance		x	
Monitor Space Utilization		x	
Monitor System Performance			x
Review Design Model(s)	x		
Site Analysis			x

ISO19650

FTIA has not implemented ISO19650. Discussions of the implementation have started.

IFC

IFC 4.3 will be the requirement for file delivery from 2023 on. FTIA plans to announce the requirement of IFC4.3 as the primary data transfer format to the Finnish infrastructure sector Q4 2022. During the transition period, the Finnish Inframodel XML and .dwg will be allowed as delivery formats alongside IFC.

Requirement DB

At FTIA a requirement database does currently not exist.

OTL

FTIA has set up an 3D-object library for railway objects such as signalling, turnouts and catenary system components. The library has been in use since 2020 and contains over 600 individual objects now. As the objects are made available as 3D dwg, the possibilities of including rich metadata are limited. However, with the transition to IFC in close future, the possibilities of carrying more relevant metadata with the objects expand significantly. It is planned to extend the library to cover also objects for roads and waterways in the future.

The library can be accessed at: https://vayla.sharefile.eu/d-sd933d61477240999

6.4 Norway

Nye Veier

Nye Veier is following a philosophy were by we abstain detailed requirements regarding information production methods and procedures in order to enable the industry to develop and mature at its own pace. Although our requirements remain abstract the general intention is to encourage potential information providers to accelerate their own development to generate more value within our projects.

Our understanding, as it is expressed through the requirements, is that there should be a single source of information. The expected benefits include ease of access and the possibility to establish relations between model, map, and document deliverables. These include some core disciplines like production planning, cost, environmental and health and safety aspects.

There are a couple of requirements where experience shows that it serves the purpose better if concrete requirements are stated, such requirements concern:

- Naming convention and classification based on IEC /ISO 81346
- Open file formats, preferably *.ifc as of today
- Terms and definitions according EN ISO 19650
- Standard documentation according to EN ISO 19650, i.e., BIM Execution Plan and others
- A couple of explicit requirements regarding viewer and its functionality

- We require the viewer to be able to show model and GIS data in conjunction although we know there is no quality-based distinction between BIM and GIS any more
- Requirements stated by third party remain obligatory and are expected to be handled completely by the appointed party

There is special focus on deliverables to the operational department with regards to format, content, and relationship between different deliverables. The classification is integral to that approach since it is a common identifier across types of information.

LOD/ LOIN

ISO 19650-1 and -2 are requirements in Nye Veier's contracts. It is a prerequisite that the delivery team has good knowledge of the standard. ISO 19650-1 introduces the term Level of information needed (LOIN) in order to define the need for information in the context of information management. There are several ways to measure LOIN in a project and Nye Veier wants to be open to the solutions the delivery team presents. This can be seen in the context of the philosophy were by we abstain detailed requirements regarding information production methods and procedures in order to enable the industry to develop and mature at its own pace.

MMI

Nye Veier has no intentions of developing its own set of status indicators and leaves the choice to the delivery team. There is an established industry standard, MMI, currently under revision that is applied in several projects and seems to work just fine.

Maturity Model

Nye Veier has previously demanded that the delivery team strive for BIM Level 3, described in "UK Government Construction Client Group - BIM Working Party Strategy paper", March 2011, pages 16-17.

Today, Nye Veier demands ISO 19650 in its projects. The standard itself must contribute with processes that will ensure that one reaches "BIM Level 3" through its own stages of maturity.

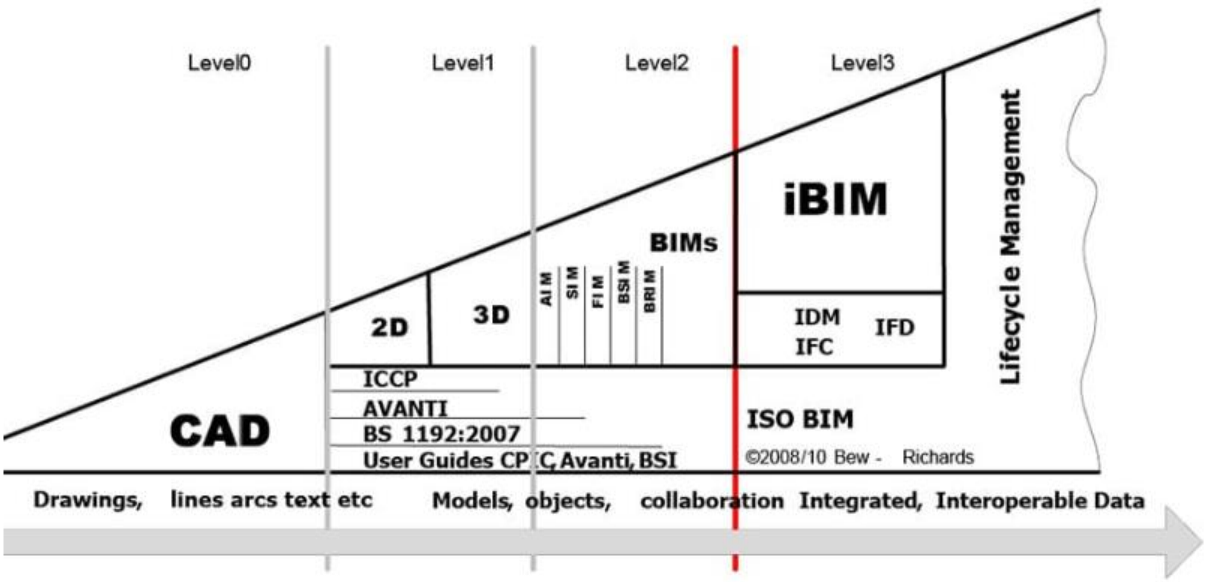


Figure 14 - *Based on BIM Level 3 - PAS1192*

Model Uses

Nye Veier's projects must be model-based. Drawings shall only be made as a supplement to the model in cases where the need dictates it. This could, for example, be for a third party who is not mature enough to receive models. This must be revealed when the information needs are described in the early phase of the project.

It has been proven that working model-based contributes to efficiency, cost savings and has a risk-reducing effect.

Models are used in the development phase (PIM) and are later used to describe as-built, before it's implemented in Nye Veier's Asset information model (AIM) as part of our Entreprise Management system (EAM). The models will be implemented in a dashboard and made available, and the models will also act as a supplement to the information used by the operating contractor in his work with inspections and maintenance.

Models must be object-based. Properties, identification, classification and maturity must be linked to the object and not just inside the model file. Nye Veier wants, in the long term, that geometry is related to an object register that contains all relevant information. This should make it possible to change properties without having to open the model after the geometry has been locked.

Nye Veier has few requirements for the model and its format, except that the format must be based on an open standard. In most cases, .ifc is delivered, as this format, as of today, has the best prerequisites to cover the information needs of all parties. Apart from this, Nye Veier has a few requirements for naming and attributes that must be added to the objects.

ISO19650

There is a requirement to apply part 1 and 2 in projects within the planning phase as well as detailed design and construction. Special focus is on the BIM execution plan with its constituent parts like mobilisation plan, TIDP, MIDP, Information production methods and procedures and others.

Simultaneously there is a certain awareness regarding our own lack of preparedness, we are lacking a couple of specifications to alleviate some uncertainties on behalf of the delivery team. A detailed description of our expectations regarding documentation is to be developed and an overarching strategy regarding information management must be put in place. As by today we are aware, and first action have already been taken.

The preferred contractual model makes it necessary that the delivery team fills some of the roles that the standard places within the responsibility of the appointing party, although it opens for delegation of the task onto the lead appointed party.

We are considering implementing part 3 and 5 in the not too far future.

IFC

We encourage the delivery team to use open formats during design and construction if it doesn't interfere with efficiency. It remains a strict requirement to deliver in open and original format in the realms of hand over documentation. The current enterprise asset management system relies on *.ifc as information bearer for model data. In conjunction with the classification, we can access documentation through the model and vice versa. Another point of access is through a national system for road assets (NVDB) where our project specific identificatory can be used to access data delivered in hand over.

Requirement DB

Nye Veier is in the process of defining all information needs, at organizational level and at project level, we will further define the information requirements. This is work that must mature over time to ensure that we get the information we need. In the long term, it may be relevant to implement some form of information requirements database.

OTL

Nye Veier have requirements for classification according to NEK IEC 81346-1, -2 and ISO 81346-12, which also describe standardized naming convention, in relation to the classification. This is possibly the closest requirement seen in context of Object Type Library (OTL).

Nye Veier have previously had a requirement that the breakdown of objects must be in accordance with Statens vegvensen handbook V770, Brutus and NVDB. This means that structure and definitions of objects was done in accordance with this breakdown.

The delivery team must also deliver information to NVDB and Brutus's systems and in that context must do so in accordance with the requirements set for naming, properties and object breakdown.

Bane NOR

LOD/ LOIN

Bane NOR has not yet adapted any LOD standard, but has for several years had general BIM requirements. This documents describes content requirements in models for existing conditions and discipline models. The table below shows an example of detailed requirements for level of detail in discipline models for railway disciplines for a building plan.

In addition we have a template for project specific requirements describing level of geometry in a text table, see table 6, for each discipline and plan phase. Our requirement database will include LOIN requirements.

***Table 6** - Example of requirements and details in an project*

Tema/fag	Filnavn	Byggeplan	Generell beskrivelse
TRASE	NN_F_SPOR_XX	Alle spor og sporveksler med tilhørende anlegg	Trase senter spor av nye prosjekterte løsninger Hvert spor skal ha sin egen fil med spornummer eller spornavn Alle nødvendige tekster samt kilometrering.
OVERBYGNING	NN_F_OB_XX	Alle lag i overbygningen	Viser oppbygging av ballast, spor og sviller Gjelder også sporveksler, skjøter, sveiser, m.m.
UNDERBYGNING	NN_F_UB_XX	Alle lag i underbygningen	Grunnarbeider for underbygning med markering av traubunn, frostsikringslag, skråningsutslag, skjæringer, formasjonsplan Viser oppbygging av underbygning ut fra dimensjoneringsgrunnlag.
FELLES ELEKTRO	NN_F_ELEKTRO_XX	Føringsveier, fundamenter, el-teknisk hus, kabelgjennomføringer. Alle kabelkanaler, rørgjennomføringer med kummer skal vises	Føringsveier, fundamenter, el-teknisk hus, kabelgjennomføringer. Alle kabelkanaler, rørgjennomføringer med kummer skal vises Kabelføring delt i lavspenning og høyspenning. Eksterne elektro anlegg dersom dette blir påvirket av anlegget.

MMI

Bane NOR has implemented MMI as a basic BIM requirement and is part of the working group that is developing new MMI requirements for both building and infrastructure.

MMI is used in most large railway projects and is the closest we have to a standard for progress plans (4D) in models.

Maturity Model

Bane NOR has not defined the Maturity Model for our organisation.

Model Uses

Bane NOR has not defined the Model uses for our organisation. We have several uses for models that is described in our general requirements for model use and in project specific requirements for several projects.

ISO19650

Bane NOR has collaborated with the largest public owners in Norway regarding implementing ISO19650. This is among others Statsbygg, Sykehusbygg, Statnett and Nye Veier. The goal has been to discuss and share experience and information on how ISO19650 will influence our organizations.

Bane NOR has not yet implemented all aspects if ISO19650 in our organization but all BIM requirement documents is based on the principles and terminology in ISO19650.

Together with Statens vegvesen and Nye Veier we have startet a work group to share information and experience in using BIM for maintence. The newest part of ISO 19650 will also be a topic for that workgroup.

IFC

Bane NOR is planning to have IFCRail 4.3 as the future requirement for file formats. We plan to announce this to the Norwegian marked late 2022. As of now more and more projects implement delivery on IFC format, but DWG format is still in use in many ongoing projects and will probably be so for several year. All new projects will require IFC 4.3

In addition to open formats we always demand origital delivery formats based on the software used by our consultants and contrators.

Requirement DB

Bane NOR has for the last couple of years worked on our project KIM (Requirements for information models) https://banenor.no/kim. This project will set up information requirement for railway, buildings and road for all projects and all plan phases and include LOIN. The goal is to complete this project by the end of 2023. By completion of the project all information requirements will be available in a BIM-Q database (as of writing of this document) and we will use this in all projects in Bane NOR. One goal is to have the requirements machine readable and enable automatic controls of delivery from consultants and contractors, as well as control of delivery to maintenance.

An important input to the KIM projects is a development program, Epoke BIM / maintenance documentation. This Bane NOR program has two important goals;

1. To once and for all define the total delivery of technical documentation from railway projects to maintenance. That includes object specific information for our maintenance database, supplementing drawings and other documentation
2. To redefine and simplify information flow between the many software systems we use in our projects today. The major systems are BIM, our maintenance database based on Maximo and Omega 365 for mechanical completion

OTL

Bane NOR has a object type library for the most common railway object that we use in our projects. The object type library is primarily used for efficient design in railway projects. The available objects is simplified, is general and not vender specific.

The object type library is based on the use of DWG as a file format. There is as of now no plans for other formats or further development of the object type library above the most basic correction.

We challenge all consultant and contractors that use the object type library to participate in keeping the library up to date.

Bane NOR har started looking into how to use BIM models in maintenance. When we get further in that process were we need to update models after a maintenance periode or to recreate models based on maintenance data. As a result of that the object type library may need to be restructured and updated as well as implement open standard file formats like IFC

Link to Bane NORs object type library: https://proing.banenor.no/wiki/objektbibliotek/start

Statens vegvesen

The Norwegian Public Roads Administration's development initiative VU-053 Model-based road projects shall further develop the model-based working method defined in handbook V770 Model basis. Therefore, we are in a transitional phase where the existing handbook V770 model basis is beeing phased out and replaced by handbook R000. The content of this document therefore focuses on the content defined in the forthcoming handbook R000.

The Norwegian Public Roads Administration sets requirements for several types of documentation:

- Basic data document:
  - Existing situation and existing plans in the project area as they exist with the data owner
- Registrations document:
  - Basic data recorded by road projects
  - How components are built/executed
- Models document:
  - Existing situation
  - Planned interventions
  - Performed situation
- Result data documents:

- Data exported from, or prepared on the basis of, models

How the contractor *(internal and/or external resource)* produces these types of documentation is up to them to decide. We have experienced that different performers have different skills, tools, work methods and policies adapted to their business. In order to minimize the risk where the client has to pay extra to send performers on courses / competence enhancement, we instead only set requirements for result data and not how performers must work to achieve the desired result. This minimizes the risk of a project going outside the planned finances and future plan.

Our tender documentation and manuals are therefore structured to provide a clear and unambiguous requirement for what result data the client wants to receive from the contractor, and that it is then up to the executor to decide the best working methodology for the premises given on the road project.

In that context, the Norwegian Public Roads Administration considers that the following points are a work process that is used to achieve a desired result:

- LOD/LOIN
- MMI
- Maturity Model

Therefore, the Norwegian Public Roads Administration has not stipulated requirements for these points.

LOD/LOIN

As described in the introduction, the Norwegian Public Roads Administration interprets LOD/LOIN as a work process and not a result data.

In this context, we have not defined a standard for LOD/LOIN, as we believe this is up to the executor to decide.

That said, handbook R000 stipulates requirements for how the Norwegian Public Roads Administration should quality assure the work carried out by contractors in a model-based road project. Among other things, we use "Fullføringsgrad" *("Completion rate" in english)*
More information about "Fullføringsgrad" can be read about here.

If the contractor has used a LOD/LOIN value that is or is not standardized *(e.g. project-specific)* then it is up to the executor to decide what relationship this has to the "Fullføringsgrad" of the current road project.

Otherwise, the Norwegian Public Roads Administration has set requirements to property information on objects. A temporary list of property information requirements can be found here

MMI

As described in the introduction, the Norwegian Public Roads Administration interprets MMI as a working process and not a result data.

In this context, we have not defined a standard for MMI, as we believe this is up to the executor to decide. RIF, EBA and The Architectural Firms are responsible for defining and revising MMI in Norway, and we believe that this responsibility should remain with them.

That said, handbook R000 stipulates requirements for how the Norwegian Public Roads Administration should quality assure the work carried out by contractors in a model-based road project. Among other things, we use "Fullføringsgrad" *("Completion rate" in english)*

More information about "Fullføringsgrad" can be read about here.

If the executor has used an MMI value that is or is not standardized *(e.g. project-specific)* then it is up to the executor to determine what relationship this has to the "Fullføringsgrad" of the current road project.

Otherwise, the Norwegian Public Roads Administration has set requirements to property information on objects. A temporary list of property information requirements can be found here.

Maturity Model

The Norwegian Public Roads Administration has not defined the "Maturity Model".

Model Uses

The Norwegian Public Roads Administration's forthcoming handbook R000 sets requirements for how the models should be structured and used in a model-based road project. See here for more information.

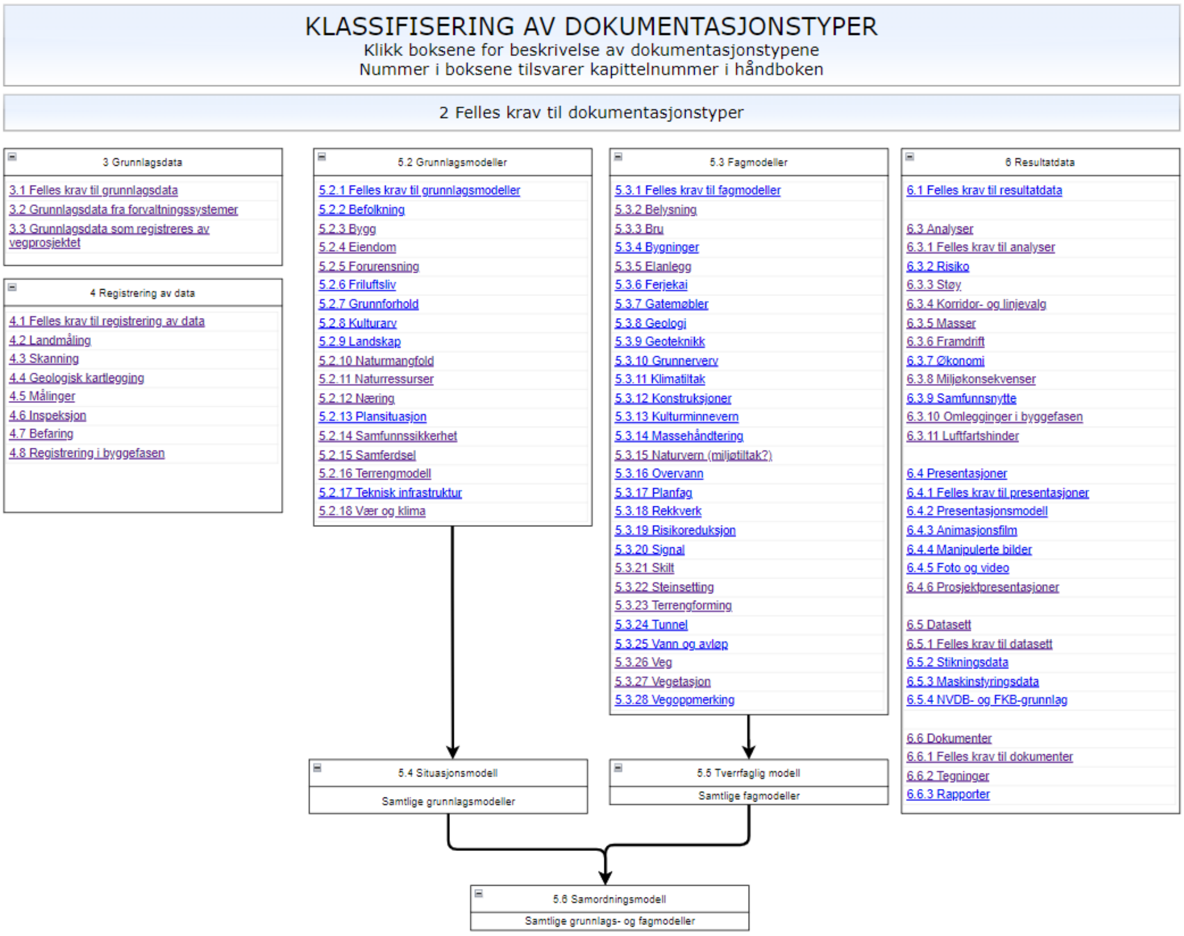


***Figure 15** – Classification of document types*

Common requirements for models:

Definition:

Existing situation, planned interventions or performed situation on, below and above ground are documented in models. Models are built up of components that are described with 3D geometry and other property data. The components can describe physical objects or states in the project site.

Model types:

The following model types are defined:

- Foundation model
  - describes the existing situation for one topic
- Situational model
  - describes the existing situation for all topics in the project
- Subject models
  - describes the planned situation for a topic
- Interdisciplinary model
  - describes the planned situation for all topics in the project
- Coordination model
  - describes the planned situation inserted into the existing situation

Purpose:

Models will be used for or form the basis for:

- Analyzes, e.g. negative consequences of planned interventions for:
  - nature
  - climate
  - people
- Development of planning proposals and technical solutions
- Quality assurance
- Communication with project participants, the public and decision-makers
- Quantity calculation and other technical calculations
- Price calculation
- Production of performance data
- Mass handling planning
- Cost-effective implementation:
  - realistic progress plans
  - control of executed components against projected
  - building with machine control and other modern production methods
- Updating management systems

Note: The use of the model varies depending on what is defined in the road project's tender documentation. See here for more info about tender documentation in model based projects.

ISO19650

Road projects are interdisciplinary and complex, and there is a need to divide the documentation into manageable categories. Finding adequate names and definitions for the types of documentation is called classification. In some countries, "classification systems" have been established. These were evaluated at the start of the VU-053 project, and we concluded that UML modeling is a more appropriate way to organize the information. Building Smart's ISO 19650 standard is another template that can be used to classify documentation. In cases where appropriate, the types of documentation for the Norwegian Public Roads Administration can easily be mapped to ISO 19650's conceptual framework, but this is not prioritized in the VU-053 project.

IFC

Upon final delivery, we require contractors to deliver data files in both original file format and an open file format.

- Documentation in data files must be submitted in the data format in which the software normally stores data, herein referred to as the original format of the software.
- Documentation must also be submitted in an open, standardised format:
    - Calculation parameters should accompany export to open format
    - For geometry without calculation parameters, the maximum deviation is 3 mm in arrow height between original geometry and exported geometry in basic outline and height
    - Information missing in open format should be delivered with the original format
- It is not permitted to provide /link to information that triggers subscription or license obligations without it being agreed in a contract.
- Other data format requirements are given in the description for each type of documentation in this document.

Requirement DB

- Databases containing localised documentation on road projects shall be organised in such a way that the requirements for metadata for data files given in the points above are met. *(See the points under IFC)*
- It is not permitted to provide/link to information that triggers subscription or licensing obligations
- Documentation types are named according to the same principle as data files, but without period and file formats.
- Delivery of databases to another party is delivered as agreed by contract.

OTL

Objects in projected 3D models should have names and properties according to requirements and definitions in the manuals. Requirements and definitions in manuals must easily be made available in software. To achieve this, a system based on international standards and adapted to Norwegian regulations is used.

Information is organized in UML class diagram according to the following standards:

- The Norwegian Mapping Authority's standard "Rules for UML modelling"
- OGC's standard LandInfra/InfraGML

The following components should be prepared:

- UML Models - diagrams describing documentation types, object types, properties, and relationships
- XSD schema - machine interpretable version of the UML diagrams
- Product specifications - describes data deliveries, which parts of the UML model's content are to be delivered in different contexts

Guidelines and sketches have been drawn up that form the basis for the UML modelling of various types of documentation.

The BA network has done a great job of UML modelling object types for subject model road in the project "SOSI road body".

Work on UML modelling started in the autumn of 2021 and will continue through 2022. So far, prototypes have been made for the following topics:

- common requirements for documentation
- base model terrain
- subject model road

UML models and XSD forms can be viewed/downloaded here:

- UML models in html format for access
- XSD Form
- UML models are available in the SOSI Model Register

7 Nordic overview of LOD and related work

The goal for the workgroup has been to analyse and identify previous and ongoing national and international standardisation as well as relevant initiatives as a way to agree on a common Nordic baseline for LOD, for the Nordic public owners for road and rail.

To make this clearer, collection and mapping has been documented in this report to give an overview that will depict work as basis for decision-making as well as for broader communication and understanding.

Agreeing on a common baseline for LOD will make it easier to work over boundaries and will facilitate for both Nordic public owners for road and rail as well as software developers, consultants and contractors.

International standards, industry initiatives, concepts and definitions is presented (chapter 4-5) and some of the most relevant ones is accounted for more in detail for all the Nordic countries. Chapter 6 gives a status for the Nordic countries based on level of details/information/geometry/reliability (LOD/LOIN), maturity model index (MMI), maturity model (MM), model uses (applications), ISO 19650, IFC, requirement databases and object type library (OTL). See overview in table 7 and in appendix A.

Table 7 - Nordic overview of active work: I=implemented, D=in Development, N=Not at this point

Active Work & Followed Standards	Nye Veier	Statens vegvesen	Bane NOR	Väylävirasto / FTIA	Vejdirektoratet	Banedanmark	Trafikverket
LOD/LOG/LOI	N	N	D	I	I	I	D
LOIN	N	N	D	I	D	D	D
MMI	N	N	I	N	N	N	N
Maturity Model	N	N	N	I	I	I	D/I
Model Uses	I	I	N	I	I	I	D
ISO 19650	D/I	N	D	N	D	D	D
IFC	I	I	I	I	D	D	D/I
Requirement DB	D	I	D	N	D	D	D/I
OTL	N	D	I	I	D	D	D

8 Summary and background for agreement

Relevance

NBC is a Nordic cooperation between road and railway public clients regarding BIM issues. In addition to this workgroup, focusing on LOD, NBC addresses topics like classification, maturity models and IFC. This work is important to NBC, both to communicate that the cooperation exists and that we focus on common issues and standardisation between the Nordic countries. It is important for us to describe the issues discussed in this workgroup, what we find is the most pressing topics right now and what is relevant for the other themes NBC is working on. NBC wants to communicate current discussions and topics across our separate organisations and countries to support the consultants and contractors that work across our borders. It is also important for everyone involved to communicate coming requirements to the market to make the transition process more open and to cultivate predictable processes.

The Nordic countries are also collaborating outside of NBC, where BIM and digitalization are becoming more and more relevant. When it comes to BIM, the same persons are often involved, but it is today not possible to refer to a common Nordic understanding regarding BIM. This has the effect that each discussion or development project starts over understanding and defining the BIM approach. It would be helpful if we could collect and publish both the NBC findings but also examples of BIM uses in each organization, within a common NBC framework.

BIM Uses

Regarding BIM Uses it is important to understand the process of BIM executing planning and why e.g. LOD or MMI are needed. Biminfra.dk has previously done some work based on Penn State material and the Cowi BIM use wheel. The purpose of biminfra.dk has been to have a dialogue tool for project planning. It is supplemented with a BIM measurement tool – amongst others: https://biminfra.dk/testmodel/wp-content/uploads/2021/04/BIMInfra-Maturity-Measure-ver.1_english_22042021.xlsx

The aim of the working group was to agree on common BIM uses. As the work progressed, the group realised that before we can find a common agreement, we need to address this topic further before we can agree on BIM uses. There are many uses and definitions of BIM and the working group recommends to the NBC that further work on this topic be done before we are ready to agree on a common Nordic definition of BIM uses in the Nordic countries.

LOIN – Level of Information Need

The work with LOIN, as described in chapter 4.3, is not finished. Right now we don't have information of the status of this work and exactly what is planned.

If we decide on common levels and definitions for the Nordic countries for LOD it would probably be easier to implement the Level of Information Need standard when it is completed. The workgroup therefore suggests that NBC return to the LOIN standard when that is published and discuss the need for a new workgroup to address the standard.

LOD

The LOD system is flexible and can contain different levels for geometry and information. The suggested model will work as a good base line. Each country and organisation can freely set their description within each discipline.

In the DIKON work LOD is combined of LOR (Level of reliability), LOI (Level of Information) and LOG (Level of Geometry). It is possible to both combine and differentiate between the definitions. For example an object can have LOG 200, LOR 200 and LOI 300 as shown below. It is also very important to note that a project can and probably will have different LOD definitions within different parts of the project. An example could be that a bridge can have LOG 325 in a city or station area where space is limited and LOG 200 in an open area, where there is more than enough space. This principle makes the LOD system flexible for project specific use.

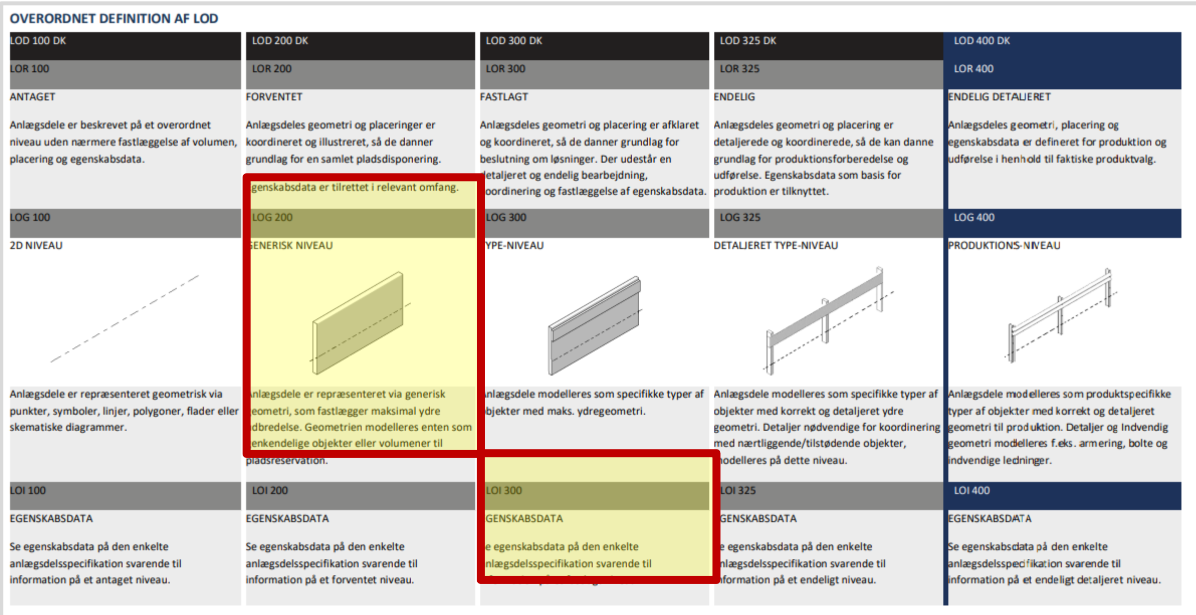


Figure 16 - *Illustration of the possibility to use different levels, for LOG and LOI, for the same object.*

This workgroup has not discussed a possible need for a separate level of LOD for BIM models in maintenance. None of the organisations in the workgroup has defined BIM for maintenance yet and we suggest that this can be a topic for further work in this or a new workgroup in 2023-2024.

This report describes several different standards and initiatives that have interfaces to levels of details and information. The number of different standards and initiatives shows the importance of the process. We have found that a common baseline for LOD levels (100, 200, 300, 325 and 400) with a written definition is a very good start. This is based on the DIKON work in Denmark. See further description under the chapter 9 Agreements on LOD regarding project goal and the need of connected tools for management.

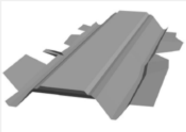
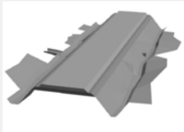
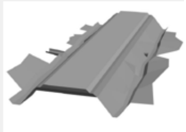
9 Conclusion and recommendation on LOD

The working group for this report suggests that we should and can agree upon:

1. Number of levels and names of levels for LOD and LOG
2. Definitions of levels for LOD and LOG

The following table describes the conclusion upon definitions and levels for LOD and LOG. Note! *2D equals elements with Easting and Northing coordinates, 3D equals elements with Easting, Northing coordinate and Elevation, point clouds and existing conditions geodetic points are excluded from this scale.*

***Table 8 –** Suggestion for LOD levels and definition of LOG*

Nordic Infra LOD					
LOD Level	**LOD 100**	**LOD 200**	**LOD 300**	**LOD 325**	**LOD 400**
Description	LOD 100 defines objects as 2D on an low level of detail without volume, placement or properties.	LOD 200 defines objects as generic volume objects with properties on an expected level of detail.	LOD 300 defines objects as specific types of objects with attached properties. All information is defined one a fixed level of detail.	LOD 325 defines objects modelled as specific detailed objects with specified properties attached. All information is defined on a final level of detail.	LOD 400 defines objects as product specific objects with products specific properties. All information is defined on a final as-build level of detail.
Level of Geometry (LOG)	**LOG 100**	**LOG 200**	**LOG 300**	**LOG 325**	**LOG 400**
Description	**2D**	**Generic**	**Type**	**Detail Type**	**Production**
					
	2D Objects represented as symbols, points, lines or polygons, or schematic diagram.	3D geometry where elements are generic placeholders. They may be recognizable as the components they represent, or they may be volumes for space reservation.	3D geometry represented as correct outer geometry. They must be recognizable as the components they represent.	3D geometry represented with correct detailed outer geometry. All details must be recognizable as the components they represent	3D geometry where elements are modelled at sufficient detail and accuracy for fabrication of the represented component, including all related elements e.g. reinforcements, bolts and internal wiring.

10 Further work

Issues that this workgroup has found interesting to follow-up is listed below:

- Formulate common requirements for LOD
- Instruction and examples for how to use the levels
- Adaption to the LOIN work of CEN TC442 and ISO 19650
- The use of LOR when using LOD levels for both design and maintenance.
- Common BIM Uses connected to the maturity model
- LOD-levels and IFC
- Common MMI–status

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Appendix A - Status BIM for Road and Rail in Nordic countries

This is an overview on active work with BIM in Infrastructure, within Infrastructure clients in the Nordic countries, complemented with relevant links to information in specific areas. Dated **September 2022**

Nordic overview of active work: **I**=implemented, **D**=in Development, **N**=Not at this point

Denmark

Active Work & Followed Standards	Vejdirektoratet	Links
LOD/LOG/LOI	I	Modelstandards
LOIN	D	Leveransspecifikation
MMI	N	
Maturity Model	I	BIM Infra.dk Modenhedsmodel BIM Infra.dk Maturity Measure
Model Uses	I	Model Anvendelser
ISO 19650	D	Ongoing process of mapping our existing BIM approach
IFC	D	buildingsSmart Danmark
Requirement DB	D	BriefBuilder
OTL	D	http://digitalvej.vejdirektoratet.dk/Modelstandard/Generalinfor-mation/TypeID/Documents/Klassifikation%20af%20anlægsob-jekter.pdf

Active Work & Followed Standards	Banedanmark	Links
LOD/LOG/LOI	I	https://www.dikon.info/download/dikon-bim-infra-dk-an-laegsdelsspecifikation-r1/?wpdmdl=4051&mas-terkey=624d7ab5c4f1e
LOIN	D	Leverancespecifikation
MMI	N	
Maturity Model	I	BIM Infra.dk Modenhedsmodel BIM Infra.dk Maturity Measure
Model Uses	I	Model Anvendelser
ISO 19650	D	N/A
IFC	D	BSDK
Requirement DB	D	N/A
OTL	D	N/A

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Finland

Active Work & Followed Standards	Väylävirasto/ FTIA	Links
LOD/LOG/LOI	I	FTIA's BIM guidelines and requirements https://vayla.fi/palvelun-tuottajat/inframallit/tietomalli-ohjeistus
LOIN	I	FTIA's BIM guidelines and requirements https://vayla.fi/palvelun-tuottajat/inframallit/tietomalli-ohjeistus
MMI	N	
Maturity Model	I	Not published
Model Uses	I	Not published
ISO 19650	N	
IFC	I	FTIA's BIM guidelines and requirements https://vayla.fi/palvelun-tuottajat/inframallit/tietomalli-ohjeistus
Requirement DB	N	
OTL	I	https://vayla.sharefile.eu/d-sd933d61477240999

Sweden

Active Work & Followed Standards	Trafikverket	Links
LOD/LOG/LOI	D	N/A
LOIN	D	N/A
MMI	N	
Maturity Model	D/I	N/A
Model Uses	D	N/A
ISO 19650	D	N/A
IFC	D/I	Öppen standard införs för enhetligt utbyte av anläggningsdata - Bransch (trafikverket.se) Trafikverket styr mot öppna format - BIM Alliance
Requirement DB	D/I	N/A
OTL	D	N/A

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Norway

Active Work & Followed Standards	Bane NOR	Links
LOD/LOG/LOI	D	General BIM requirements.
LOIN	D	
MMI	I	www.mmi-veilederen.no
Maturity Model	N	
Model Uses	N	
ISO 19650	D	
IFC	I	
Requirement DB	D	https://banenor.no/kim
OTL	I	https://proing.banenor.no/wiki/objektbibliotek/start

Active Work & Followed Standards	Statens vegvesen	Links
LOD/LOG/LOI	N	
LOIN	N	
MMI	N	
Maturity Model	N	
Model Uses	I	Model uses
ISO 19650	N	
IFC	I	
Requirement DB	I	
OTL	D	

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Revision history

Revision number	Date	Major changes
1.0	December 2nd 2022	Document established