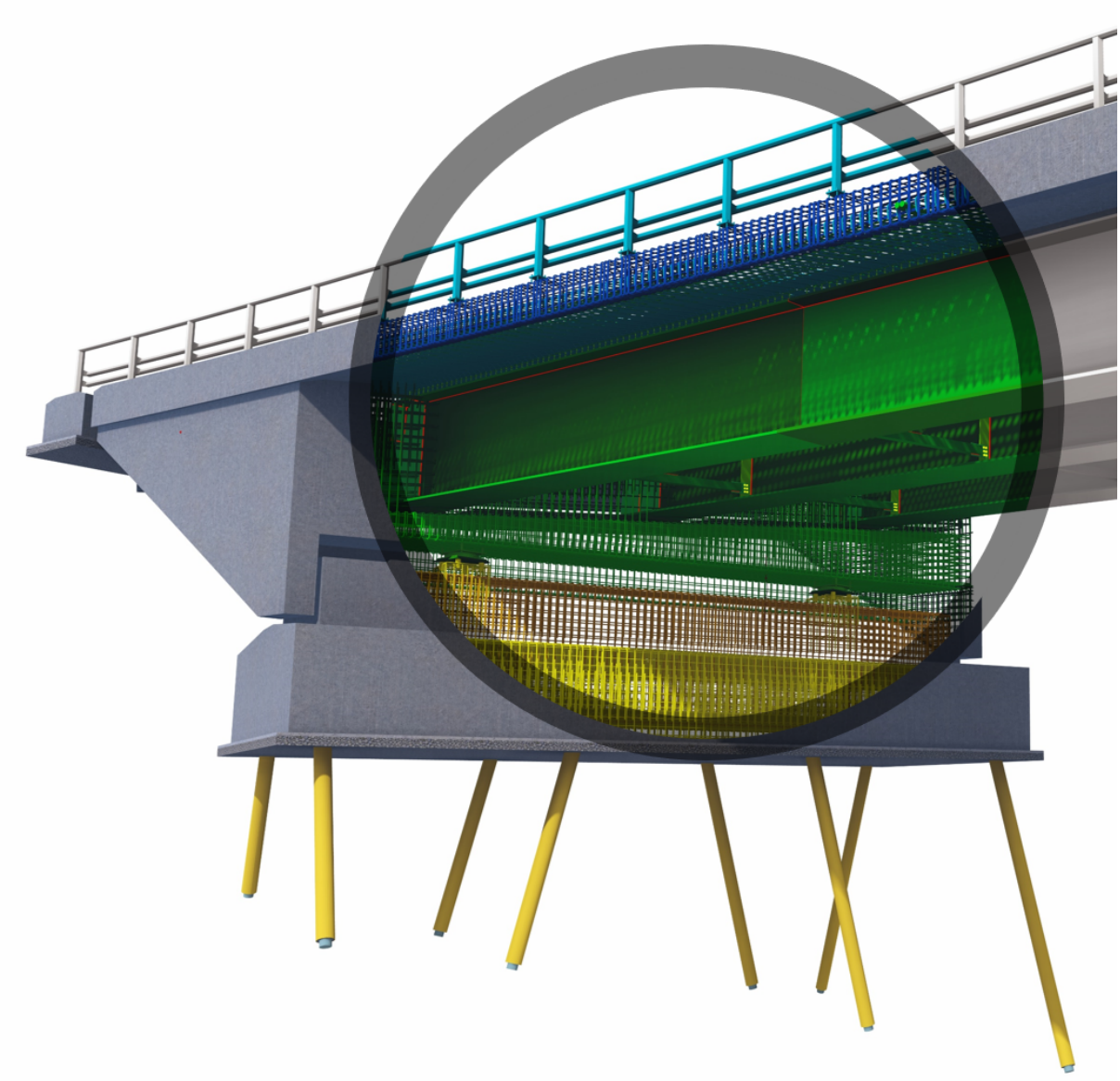
Standardization of Model-Based Deliveries in Norwegian Infrastructure Projects

Part 2: Final Report

December 2023



FOREWORD

This report has been prepared by Sweco Norway AS in collaboration with the Norwegian Public Roads Administration and is part of the effort to increase standardization in model-based deliveries for transportation infrastructure. The work has been conducted based on a framework agreement between the Norwegian Public Roads Administration Directorate and Sweco Norway AS. A project group was set up, consisting of representatives from both parties. The project group included the following members:

- Kristine Tybring Lindtveit (Norwegian Public Roads Administration Directorate)
- Gaute Nordbotten (Norwegian Public Roads Administration Directorate)
- Marie Eliassen (Sweco Norway AS)
- Øystein Ulvestad (Sweco Norway AS)
- Christoffer Nergaard Mikalsen (Sweco Norway AS)
- Torhild Bjørkevoll Ersland (Sweco Norway AS)

A reference group with relevant industry stakeholders was also established.

This report is part two of the project and presents the project group's proposals for addressing the needs identified in Part 1.

In this report, the following English translations and abbreviations will be used:

Norwegian	**English translation**	**Abbreviation**
Statens vegvesen	Norwegian Public Roads Administration	NPRA
Statens vegvesen Vegdirektoratet	Norwegian Directorate of Public Roads	NDPR

The report has been translated to English by Øystein Ulvestad

SUMMARY

This report presents the project group's proposals for meeting the identified needs and challenges outlined in " Standardization of Model-Based Deliveries in Norwegian Infrastructure Projects – Part 1: Needs Analysis."

It has been considered whether the proposals should become requirements or recommendations. Additionally, the project group have identified topics not deemed suitable for either requirements or recommendations. In certain cases, this is due to technology and software not yet being sufficiently developed.

The following suggestions are proposed as future requirements for models:

- Objects in bridge models should be organized using Spatial Breakdown System. See Chapter 4.4.3.
- Aggregated objects should not be used. See Chapter 4.5.2.
- Properties related to general project information and general construction information should not be linked to objects. They should rather be placed at a higher level in the IFC hierarchy. This way BIM Title Blocks can be eliminated. See Chapter 4.7.2.

The following suggestions are proposed as future recommendations for models:

- A standardization of object colours for concrete and earthworks is recommended. See Chapter 4.6.7.
- Gridlines are recommended to be designed as volumetric objects until rendering and snapping functionality of IfcGrid objects in software improves. See Chapter 4.6.8.

Furthermore, the project group considers that multiple properties and property sets are mature for standardization. However, further assessment needs to be done before requirements are imposed, and standardized properties should initially be limited to those most general and frequently used. This work should be prioritized in further standardization efforts.

There are also many aspects of model design that the project group considers suitable for, but not yet mature for standardization. Several of these aspects should be further pursued with the aim of providing future model requirements.

The engagement for this project has been significant, and stakeholders have demonstrated an impressive willingness to share knowledge and experience. Many people have made considerable efforts in the sharing process and have collaborated across organizations to agree on the best solutions. This level of trust and willingness to share is unique internationally and is a major reason Norway holds a leading position in the use of BIM.

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1. INTRODUCTION

1.1. Project Description

Structure types listed in requirement 2.1 - 1 of the NPRA standard N400 Bridge Design (2023-01-01) must be reviewed by a third party and achieved «technical approval» before construction can commence. Historically, the review has been based on drawings where geometry and properties has been specified. Since 2016, NDPR has allowed for reviews to be based on either models or drawings. The guidelines for model design has been vague, with the aim of encouraging innovation from stakeholders. From 2016 to present, this has led to experimentation and rapid development and improvements. New challenges have arisen as models replace drawings, but designers have created methods to incorporate information regarding geometry, properties, and other relevant aspects into the models. Contractors and clients have refined this information and found ways to integrate models into their processes. The industry is now a world leader in model-based delivery for infrastructure structures. Model design and methodology does however vary from project to project, making it challenging to reuse methodology. In addition, the lack of clear and detailed regulations generates unnecessary uncertainty regarding progress and costs.

The industry has therefore recognized the need to standardize regulations for model design in model-based infrastructure projects. NDPR has therefore initiated the project "Standardization of Model-Based Deliveries in Norwegian Infrastructure Projects." As part of this scope, a needs analysis has been conducted and summarized in the report "Standardization of Model-Based Deliveries in Norwegian Infrastructure Projects – Part 1: Needs Analysis."

Additionally, the project group have identified topics not deemed suitable for either requirements or recommendations. In certain cases, this is due to technology and software not yet being sufficiently developed.

The following report presents the project group's proposals for addressing identified needs and challenges. It has been considered whether the proposals should become requirements or recommendations. It is not in the scope of this report to conclude which regulations the requirements and recommendations should be included in.

This report also highlights aspects considered suitable for standardization, but that for various reasons are not yet mature for standardization. Further work should be done on these aspects, with the aim to defining future model requirements.

Additionally, the report identifies aspects that the project group considers not suitable for standardization.

1.2. Purpose of Standardization

The primary goal of the project is to identify the needs and challenges posed by the current model-based deliveries for stakeholders. Another objective is to propose regulations concerning requirements and provide recommendations where standardized solutions could benefit the industry. It is crucial, however, to evaluate whether the relevant technology and software are sufficiently mature. Standardizing model design can lead to a reduction in the resources required to produce models, which in turn will decrease uncertainty regarding progress and costs. The resource requirements for using models on site and for operations will also be minimized. Methodologies will

be easier to reuse, and the need for training at all stages will be diminished. This will also help reduce misunderstandings and misinterpretations of information. Furthermore, a standardized approach to model creation will encourage software vendors to develop better-suited digital tools, and it will simplify the process for stakeholders to create software "add-ins."

Standardization primarily mean that all models are structured the same way. However, it is important not to impose regulations that limits further innovation and creativity, as there will still be a future need for further development. The standardization should leave room to incorporating future innovation and improvements.

2. TERMINOLOGY EXPLANATION

The following definitions explain how different terms are used in this report:

Attribute
An attribute is linked to an IFC entity and provides specific information about the entity. Unlike properties, attributes are predefined in the IFC standard. An example of an attribute is "IfcElement.Length," which can be used to indicate the length of an object, such as part of a bridge.

BIM Title Block
"BIM Title Block" refers to objects or an object showing true north placed next to a construction. The BIM Title Block is intended to provide various information about the construction and/or links to external documents relevant to the construction (see also chapter 4.7.2).

BSDD (BuildingSmart Data Dictionary)
BSDD is a standardized terminology database within the construction industry. Organizations can share property sets in this database to facilitate standardization work. BSDD supports multiple languages, enabling specifications independent of language. For example, IfcWall may have names like Vegg/Wall/Wand/Parete, etc.

Data Structure
Data structure refers to which properties and property sets are used and where in the IFC Spatial Breakdown System (IFC hierarchy) these are placed (see also "IFC Spatial Breakdown System").

IDS (Information Delivery Specification)
IDS is a method for validating IFC files. For example, it can check whether IFC files contain the correct IFC structure. IDS can also be used to verify that desired properties are filled in and that they contain "valid" values.

IFC (Industry Foundation Classes)
IFC is an open file format for modelling, widely used in the construction industry to facilitate data exchange and collaboration between different software applications.

IFC Bridge
There are several specific subclasses of IFC for different use cases. IFC Bridge is one of these subclasses. It is available from IFC version IFC4.3 and provides specific objects and attributes relevant to bridge design, bridge construction, and bridge management.

IFC2x3
IFC2x3 is a version of the IFC format released in 2006. IFC2x3 is still widely used, but naming and advanced functionalities are best suited for buildings.

IFC4.3
IFC4.3 is an evolution of IFC2x3. Examples of improvements include better support for non-geometric data and enhanced geometry handling. In IFC4.3, for instance, road lines can be represented using the object type IfcAlignment. IFC4.3 also includes the IFC Bridge subclass, which contains IFC entities relevant to bridge design, construction, and management. It should be noted that as of December 2023 there are no commonly used modelling software that export IFC4.3 files in a satisfactory manner.

IFC Schema
A collective term for all the functionality the IFC format possesses.

IFC Spatial Breakdown System
The IFC Spatial Breakdown System is a functionality within the IFC format. It defines multiple levels of information in a hierarchy, where elements lower in the hierarchy inherit properties from elements higher up. It also provides a way to organize elements like piles, foundations, abutments, and bridge railings according to spatial placement. The Spatial Breakdown System is available in both IFC2x3 and IFC4.3.

IFC Entity
All objects in an IFC file are classified as some type of IFC entity. Examples of IFC entities include IfcBeam, IfcBearing, and IfcColumn. IFC entities can encompass anything from basic geometric shapes and building parts to more complex things like floors, constructions, and subprojects. Each IFC entity type have a predefined set of attributes.

Information Object
An information object does not represent a physical object. The sole purpose of an information object is to carry information. Figures 2.1, 2.2, and 2.3 show examples of information objects.

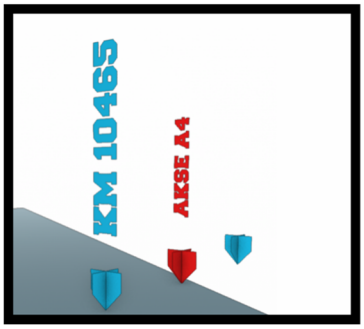

Figure 2.1 - Example of chainage information.

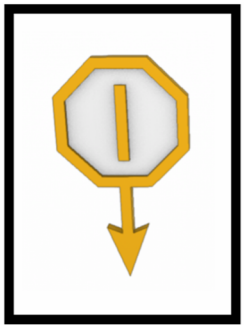

Figure 2.2 - Example of symbol (also known as information symbol).

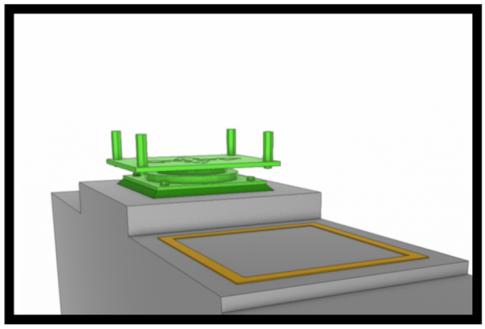

Figure 2.3 - Example of information about permitted jacking location at bearing.

Property
A property is associated with an IFC entity and provides specific information about the entity. Unlike attributes, properties are created and defined by the model creator and are not predefined in the IFC standard. An example of a property is "LOD." This property indicates the maturity of an object or model. See also chapter 4.5.3.

Property Set
A property set is a collection of properties. See also chapter 4.5.5.

Model
In this report, the term "model" is used to describe a IFC format BIM model.

Object
An object (also referred to as a volumetric object) is an IFC entity that cannot be broken down into smaller parts. The object can be assigned information in the form of properties and attributes.

Object Information
Object information is the information associated with an object through properties and attributes.

3. METHOD

The method for collecting and processing information is described in the report «Standardization of Model-Based Deliveries in Norwegian Infrastructure Projects - Part 1 - Needs Analysis»

4. RECOMMENDATIONS FROM THE PROJECT GROUP

4.1. Introduction

The project group's proposals are divided into the same main categories and subcategories (sections) as chapter 4 of "Standardization of Model-Based Deliverables (BIM) – Part 1: Needs Analysis."

The proposals are categorized as follows:

- Requirement for model design
- Recommendation for model design
- Recommendation for further standardization work
- No requirements or recommendations given

Explanation of proposal categories:

Requirements for model design – These are proposals that the project group suggests should be made requirements for model design and should be included in current regulations. They are limited to aspects where technology is sufficiently mature and resource needs for implementation are small. The proposals are also limited to measures where there is no significant need to change current working method.

Recommendations for model design – Proposals that the project group suggest should be recommendations when designing models. Some of these recommendations may eventually be replaced by requirements.

Recommendations for further standardization work – Proposals for future standardization work, with the aim of developing future requirements for model design.

No requirements or recommendations given – Aspects where the project group find it challenging to propose requirements or recommendations. This may be because the need has not been deemed significant enough. It also includes aspects where technology is not considered sufficiently mature.

4.2. Regulations

4.2.1. Introduction

The following sections present proposals on identified needs for regulatory improvements.

4.2.2. Clearer Regulations

Proposal:
Relevant regulations should provide more details on requirements and recommendations, potentially integrating the proposals from chapter 4 of this report.

Type:
Recommendation for further standardization work.

Comment:
A more detailed regulatory framework will reduce resource demands and uncertainties when producing and using models.

4.2.3. Design for the Construction Phase

Proposal:
Operators should define current model deficiencies and suggest improvements. How and when metadata relevant to operations should be applied to the model also needs to be considered.

Type:
Recommendation for further standardization work.

Comment:
The project group considers that many of the operators' needs on model information are still not identified. The needs should be thoroughly assessed before design requirements or recommendations are proposed.

4.3. Software

4.3.1. Introduction

The following sections cover proposals related to software improvement needs.

4.3.2. Model dimensions

Proposal:
Predefined dimensions in sections of special interest in models should be recommended. This specially include sections in superstructures where profile heigh and width vary along the length of the bridge and where acquiring measurements manually are prone to errors. Predefined dimensions for tendon layout should also be recommended.

In collaboration with software providers, models with these features should be made available in open formats. A requirement for predefined dimensions should be reconsidered after models with these features have been made available and reviewed.

Type:
Recommendation for further standardization work.

Comment:
Producing predefined model dimensions is still a complex process, often requiring parametric design and proprietary formats. The project group therefore considers a requirement for predefined dimensions in models to be premature.

With future improvements to software, the project group considers it likely that IFC-entities like IfcAnnotation can be used for this purpose, but this require using IFC4.3

4.3.3. Software Impact on Structure and Appearance

Proposal:
Variances in data structure and object colours in various software used to read IFC files should be addressed with developers.

Type:
Recommendation for further standardization work.

Comment:
As long as the data structure, colours of objects, and appearance of the model vary from one software to another, it will be challenging to design good universal solutions that fully exploit the potential of model-based deliveries.

4.3.4. File Sizes and Stability

Proposal:
The project group considers that software stability issues due to large file sizes can be managed by dividing the models into sub models where needed. This is further discussed in section 4.7.4.

Type:
No requirements or recommendations given.

Comment:
Many factors contribute to instability, making it difficult to provide precise avoidance measures.

4.4. IFC

4.4.1. Introduction

The following sections cover proposals related to improved utilization of the IFC format and its functionalities.

4.4.2. IFC4.3 and IFC Bridge

Proposal:
Revit and Tekla do not yet adequately export models in IFC4.3 format. Collaboration between software vendors and stakeholders is needed to overcome this challenge. Until improved export functionality has been developed, there should not be a requirement to deliver models in IFC4.3 format.

Type:
Recommendation for further standardization work.

Comment:
Modellers should aim to adopt to IFC4.3 when export functionality from major software vendors improves. That way features like IFC Bridge, IfcAlignment and IfcAnnotations can be utilized.

4.4.3. IFC Spatial Breakdown System

Proposal:
The project group suggests a requirement for bridge model elements to be structured using the Spatial Breakdown System. The structuring should be based on «Objektkode og -navn Brutus.xlsx» (Object codes and name used in Brutus, a system used by the Norwegian Public Roads Administration to manage and analyse bridge structures and related infrastructure data), which is available on the NPRA webpage. Examples of structural elements is shown in Figure 4.1.

Type:
Requirement for model design.

Comment:
The Spatial Breakdown System enables a structured division of a model into bridge elements. This will simplify the extraction of data from the models and the compilation of data from multiple models. The Spatial Breakdown System is available in IFC2x3 and IFC4.3, amongst others.

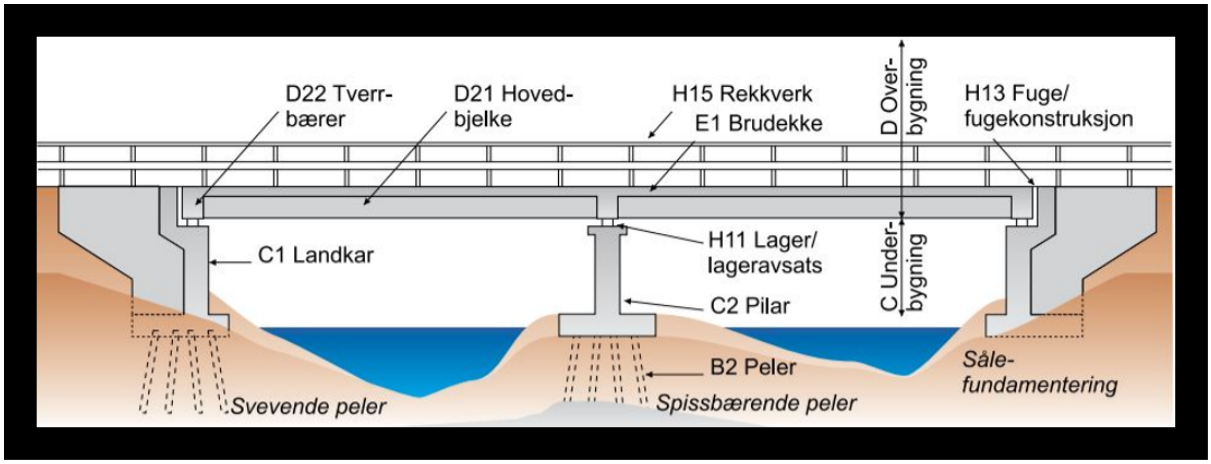

Figure 4.1 – An example of how a model can be divided into elements in accordance with «Objektkode og -navn Brutus.xlsx»

4.4.4. IFC Entities

Proposal:
The project group considers that no current requirement for assigning specific IFC entities to objects is needed.

Type:
No requirements or recommendations given.

Comment:
IfcBridge defines many entity types that are relevant for structures within infrastructure. A deliberate use of these entity types will likely simplify the extraction of data from the models. The project group has however yet to see examples where this has been methodically implemented. Furthermore, IfcBridge is only available in IFC version IFC4.3. It is therefore proposed that the requirements for the use of specific IFC entities be reconsidered when modelling tools like Revit and Tekla can export IFC4.3 files in a sufficiently satisfactory manner.

4.5. Properties

4.5.1. Introduction

The following sections provide the project group's proposals related to the use of aggregated objects as well as the standardization of properties, property values, and property sets.

4.5.2. Aggregated objects

Proposal:
Aggregated objects are not to be used.

Type:
Requirement for model design.

Comment:
The use of aggregated objects and properties on the IfcElementAssembly level (see Figure 4.2) has proven to cause many misunderstandings and errors at construction sites.

4.5.3. Properties

Proposal:
Properties should be standardized, but the project group recognises the need for continued work before requirements are imposed. Before requirements are proposed, example models with alternative solutions should be presented to stakeholders. This should be prioritized in further standardization efforts.

Work on standardizing properties has begun, and a working example is available.

Type:
Recommendation for further standardization work.

Comment:
The standardization of properties will enable the comparison of data from multiple models and the reuse of methodology. The list of standardized properties should initially be limited to those that are most general and most frequently used. It is further recommended that the standardization of properties is implemented in stages as standardization work matures.

This report does not address the standardization of naming and/or numbering of the properties.

4.5.4. Property values

Proposal:
Standardizing sets of allowed property values for selected properties is an important part of the standardization process. The project group does however see a need for continued work in this area before requirements are imposed.

Type:
Recommendation for further standardization work.

Comment:
In the development of methodology and the compilation of data from multiple models, it is essential that identical information is presented in the same format across models. Standardizing sets of allowed property values for selected properties is therefore very important.

4.5.5. Property Sets

Proposal:
Property sets should be standardized, but the project group recognises the need for continued work before requirements are imposed. Before requirements are proposed, example models with alternative solutions should be presented to stakeholders. This should be prioritized in further standardization efforts.

Work on dividing properties into property sets has begun, and a working example is available.

Type:
Recommendation for further standardization work.

Comment:
It is recommended to allow project-based properties to be added to standardizes property sets. It is further recommended that the standardization of property sets is implemented in stages as standardization work matures.

This report does not address the standardization of naming and/or numbering of the property sets.

4.6. Detail and Design

4.6.1. Introduction

The following sections provide the project group's proposals related to general design and the use of details in the model.

4.6.2. Details and Concepts

Proposal:
Relevant regulations should provide guidelines on which types of accompanying documents are accepted and in which cases they are accepted. The importance of conveying accurate information between parties should set a precedent for how the information is transferred.

Type:
Recommendation for further standardization work.

Comment:
For certain types of design, information regarding details, principles, or concepts can more easily be conveyed through drawings rather than shown as objects and metadata in models. It is therefore important that regulations allow for this, even though it is recognized that the extent should be limited. Currently NPRA standard N400 Bridge Design (2023-01-01) specifies that project deliverables either be delivered model-based or as drawings.

4.6.3. Level of Detail

Proposal:
Relevant regulations should clarify the recommended levels of detail for objects in the model. This can include both an upper and a lower limit for the level of detail. Additionally, example models should be made available. These models should showcase sufficient levels of detail for recurring details. Examples of such details are chamfers and typical bridge elements like snow proof railing panels.

Type:
Recommendation for further standardization work.

Comment:
A high level of detail in models can, in some cases, make file sizes unnecessarily large without adding significant value. On the other hand, experiences from construction sites show that models with poor levels of detail can cause errors to be made at site.

4.6.4. Clashes Between Objects in Model

Proposal:
Clashes in the model should generally be allowed if it is clearly indicated how the clashes are to be resolved at construction site. This can for example be conveyed by using metadata or by referring to external documents. A revision of requirement 1.4.6-5 in NPRA standard N400 Bridge Design (2023-01-01) should therefore be considered. In areas where very thin objects (like membranes) clash, referencing to drawings is advised. Examples of such areas are concrete joints and other similarly complex details where membranes overlap.

Type:
Recommendation for model design.

Comment:
Remove all clashes from a model can be very labour intensive. Additionally, a clash-free model does not necessarily add more value. The extent to which a clash in the model poses a problem should therefore be viewed in relation to its severity and consequence if not removed. The project group recommends that requirements allow for clashes in the model as long as it is clearly specified how a clash in the model should be resolved at construction site. It is however important that model designers thoroughly control that the clash can be resolved at site. Clashes in a model that could create uncertainty on how to solve at site and uncertainty on as built status in an operational phase should be avoided.

4.6.5. Product Neutral Components

Proposal:
In the long term, development of a standardized set of the most common product-neutral component should be considered. The components should be developed in an open format and used in models until final products/solutions have been chosen.

Type:
No requirements or recommendations given.

Comment:
The project group considers that standardized product-neutral components will be beneficial as they will clearly define the necessary level of detail needed at the relevant model phase. It will also provide a clearer indication of which objects in a model are product neutral. A parametric approach should be used for the components where relevant for flexibility. The project group does however not consider the standardization of product-neutral components a priority for further work.

4.6.6. Welds, Bolts and Cutouts

Proposal:
NPRA standard N400 Bridge Design (2023-01-01) requires that models must contain all bolts and welds. It is recommended that this requirement be continued.

The project group recognizes the need to document and better understand the challenges of using models in the production of steel components. It is also important to identify challenges related to the use of models during the assembly of steel components at construction site.

Type:
Recommendation for further standardization work.

Comment:
The use of models in the production of steel components and in assembly of steel components at construction site should be better documented to improve model for these purposes. It is for example important to get a better understanding of the challenges related to extracting information about welds, bolts, and recesses from models.

4.6.7. Colours

Proposal:
In models, concrete objects should be given light grey colours (for example, colour RGB: 200, 200, 200). Objects representing earthworks should be given light brown colours. To the extent possible, colours of different layers of earthworks should be differentiated. Consideration should be given to universal design, for example using colours with contrasts. As mentioned in section 4.3.3, challenges with software rendering colours differently should be identified in collaboration with software vendors.

Type:
Recommendation for model design.
Recommendation for further standardization work.

Comment:
When exporting IFC files from one specific software, objects are coloured based on their material. It is therefore challenging to provide complex guidelines on object colour. Additionally, the colours of objects when viewing IFC files vary significantly between software (see chapter 4.3.3). However, it is considered beneficial to give concrete objects and earthworks objects light and preferably natural colours so that smaller objects and details stand out more clearly in the model. More guidelines on the use of colours should be provided in the future.

4.6.8. Gridlines

Proposal:
Gridlines should be modelled as volume objects. In the future, if the software functionality improves, gridlines should be modelled as IfcGrid gridlines.

It is also recommended to identify challenges related to the display of - and dimensioning against IfcGrid gridlines in various software in collaboration with software vendors.

Type:
Recommendation for model design.
Recommendation for further standardization work.

Comment:
Gridlines modelled as volume objects are currently easier to snap to with the available functionality in most current software. Therefore, the majority of both designers and contractors prefer to use volume objects to model gridlines. Gridlines represented as volume objects also stand out more clearly in software commonly used in a construction phase, which is important at construction site. However, the advantage of IfcGrid gridlines is that they conform to the IFC schema and are “pre-standardized” according to the IFC format and other disciplines.

4.7. Methodology

4.7.1. Introduction

The following sections provide the project group's proposals related to methodology in model-based deliveries.

4.7.2. Alternatives to “BIM Tittle Block”

Proposal:
When delivering models in the IFC format, selected project- and construction properties should be placed at a higher level in the IFC hierarchy (see Figure 4.2) instead of attaching the information to model objects like a “BIM title blocks” object.

Type:
Requirement for model design.

Comment:
In most current models, general project information and general construction information is available as object metadata attached to a "BIM title block" object. However, placing this type of information at a higher level in the IFC hierarchy will better utilize IFC functionality. This will provide a standardized data structure across models. It will also ensure that the information is available in one place only and that it is valid and identical for all objects in the model.

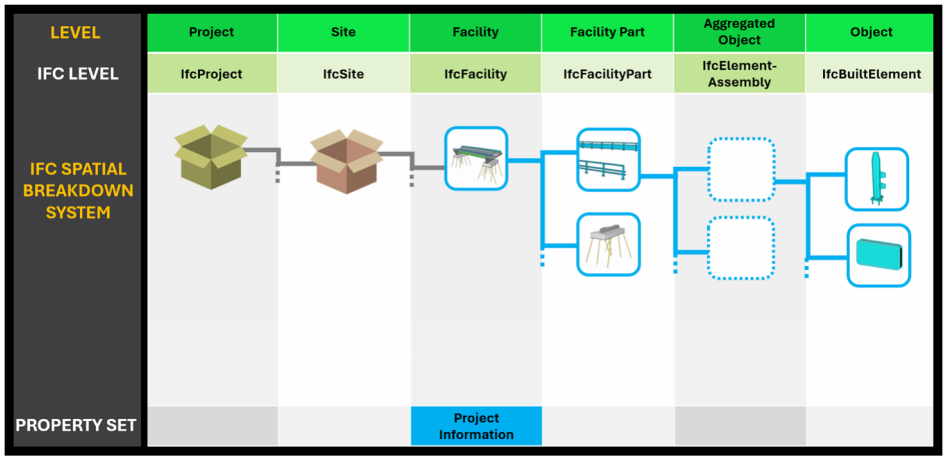

Figure 4.2 - If metadata (for example property sets with general project information) is placed at higher levels in the IFC hierarchy, all objects in the model will "inherit" the information

No recommendation has been made regarding the naming of the information tab containing general project information and general construction information.

4.7.3. Symbols

Proposal:
Symbols should eventually be phased out and replaced with annotations. Examples of models with annotations should be developed in collaboration with software vendors. The solutions should be created using open formats. Requirements on using annotations instead of symbols in models should be reconsidered after this has been presented to stakeholders and tested.

Type:
Recommendation for further standardization work.

Comment:
A symbol in a model can be a useful visual tool, for example to point to details that might be difficult to notice. However, as a principle, information should be attached to the object to which it pertains. One way to achieve this is to use annotations that show relevant object metadata instead of using symbols.

4.7.4. Division of Sub-Models

Proposal:
NPRA standard N400 Bridge Design (2023-01-01) recommends that BIM deliveries be divided into as few sub-models as possible when submitted. The project group suggest that this recommendation is left as is.

NPRA standard N400 Bridge Design (2023-01-01) recommends that as-built BIM deliveries for operations be delivered as one sole model when submitted. The project group suggest that this recommendation is reviewed by operators.

Type:
Recommendation for further standardization work.

Comment:
Many factors influence to what degree models are divided into sub-models. It is therefore difficult to propose a single best practice for how models should be divided into sub-models.

4.7.5. Revision management

Proposal:
Information on revisions should be added at both model and object level. Revision index, date, and description should be included. It is however not in the scope of this report to specify the structure of the data. The properties should be included in the standardized property sets (see section 4.5.5).

In addition, the project group recommends that challenges related to the communication of revision history should be identified in collaboration with software vendors.

Type:
Recommendation for model design.
Recommendation for further standardization work.

Comment:
In a construction phase it is exceedingly important that revisions are clearly conveyed. Standardizing how information on revisions is being managed is therefore necessary. This to avoid misunderstanding and errors at site.

4.7.6. Links to external documents

Proposal:
A standardized way of doing references to external documents in models should be developed. This is especially important during an operational phase. Relevant operator stakeholders should define the requirements for how this is to be done, as the solution ideally should be integrated in an archiving system. Requirement 1.5.4-2 in NPRA standard N400 Bridge Design (2023-01-01), which requires that accompanying documentation be located in folders with relative links to the model might therefore have to be revised.

Type:
Recommendation for further standardization work.

Comment:
To comply with requirement 1.5.4-2 in NPRA standard N400 Bridge Design (2023-01-01), all necessary accompanying documentation needs to be located in folders with relative links to the model. Not all projects are delivered this way, as implementation of this is particularly challenging at construction site. Furthermore, acquiring external documents from model links is more relevant at an operational phase. However, dedicated model resources needed to create and maintain the links to external documents might no longer be available in this phase. A more sustainable solution that minimizes maintenance needs should therefore be developed. A possible temporary solution is to reference to external documents by using document - and drawing numbers only.

4.7.7. Information on Earthworks

Proposal:
Models showing examples of how earthworks can be modelled should be made available. This will make it easier for future standardization projects to assess whether earthworks should be included in models or alternatively be shown as principles on drawings. For now, solutions for displaying earthworks should be kept flexible.

Type:
Recommendation for further standardization work.

Comment:
The needs analysis shows divergent preferences regarding information on earthworks. Many stakeholders wish to convey the information on drawings, while others prefer to show it in the model. The project group sees advantages and disadvantages with both methods. Maintaining the current practice, where the methodology is project-dependent, is therefore suggested until further studies have been done.

4.7.8. Standardization of BIM Manual

Proposal:
A standardized BIM manual should not be developed at this time.

Type:
No requirements or recommendations given.

Comment:
The standardization of model-based deliveries for infrastructure constructions is still under development. The project group therefore considers it too early to develop a standardized BIM manual. The manual should potentially be developed at a later stage when properties and property sets have been standardized. The need for a standardized BIM manual will however diminish if all models share the same data structure.

4.7.9. Predefined Sections in the Modell

Proposal:
Examples on how models can be enriched with predefined sections/views should be developed. It is important to focus on feasible solutions that meet the industry's needs. The solutions should preferably be created in open formats. Until example models have been developed and reviewed, there should be no requirements for predefined sections/views in models.

Type:
Recommendation for further standardization work.

Comment:
Models should in the future be enriched with predefined sections/views containing relevant information and dimensions. This will make it quicker and safer to extract data and accurate measurements from the models. There already exists procedures to create predefined sections/views in proprietary formats, but it is recommended to further develop methodologies using open formats before imposing additional requirements.

5. CONCLUSION

5.1. Summary

As part of the effort to enhance standardization in model-based deliveries for transportation structures, a survey on the design of future models was sent out on June 14, 2023. The proposals given in this report are based on feedback from the survey, as well as discussions and conversations with industry experts.

The topic is broad and covers multiple distinct aspects. It is therefore necessary to prioritize future work and assess if suggested improvements should be implemented as requirements or recommendations. Feasibility and level of maturement are key factors in this work.

5.2. Requirement for model design

The project group recommends that model requirements should be limited to aspects of model design where software and technology is sufficiently mature, and the resources needed for implementation is believed to be limited.

The requirements should also be limited to measures where there is no significant need to change current working methodology. This way, standardization of models can quickly benefit the industry without adversely affecting individual stakeholders.

In this report, the project group has proposed the following requirements for model design:

- Objects in bridge models should be organized using Spatial Breakdown System. See Chapter 4.4.3.
- Aggregated objects should not be used. See Chapter 4.5.2.
- Properties related to general project information and general construction information should not be linked to objects. They should instead be placed at a higher level in the IFC hierarchy. This way BIM Title Blocks can be eliminated. See Chapter 4.7.2.

5.3. Recommendation for model design

Recommendations for model design in this report are limited to areas where stakeholders' needs align, but where mandatory requirements would limit possibilities for further development. Furthermore, relevant software and technology must be considered sufficiently mature, and the resource requirements for implementation are relatively small. A recommendation is therefore seen as pragmatic, yet forward-looking.

In this report, the project group has proposed the following recommendations for model design:

- A standardization of object colours for concrete and earthworks is recommended. See Chapter 4.6.7.

- Gridlines are recommended to be designed as volumetric objects until rendering and snapping functionality of IfcGrid objects in software improves. See Chapter 4.6.8.

In time, some of the recommendations might be replaced with requirements.

5.4. Recommendation for future standardization

5.4.1. Introduction

As outlined in Chapter 4, there are many aspects of model design that are not yet ready for standardization. Many of these aspects should be further developed, and continuing the project will be essential to further enhance standardization in the industry.

The project group considers the following points as most important to further develop in the next phase of the standardization efforts. Among these, work on properties and property sets should be prioritized.

5.4.2. Future standardization aimed at consultants

- Requirements and recommendations for revision management should be developed in collaboration with contractors. Additionally, the necessity of revision logs and how they should be designed should be considered. See Chapter 4.7.5.
- Requirements and recommendations for displaying earthworks should be developed in collaboration with contractors and operators. See Chapter 4.7.7.

5.4.3. Future standardization aimed at contractors

- Challenges related to the use of models in the production and assembly of steel components should be documented. See Chapter 4.6.6.

5.4.4. Future standardization aimed at NPRA

- Current regulations should be made more detailed and comprehensive in the form of both requirements and recommendations. Additionally, it must be determined which regulations these requirements and recommendations should be included in. See Chapter 4.2.2.
- Requirements and recommendations regarding details and references to detail drawings in models should be clearly defined. See Chapter 4.6.2.
- Requirements and recommendations regarding the level of detail for objects in model should be clearly defined See Chapter 4.6.3.
- Requirements and recommendations regarding object clashes in the model should be clearly defined. See Chapter 4.6.4.

5.4.5. Future standardization aimed at operators

- Requirements for the division of models into sub models for operational purposes should be defined. See Chapter 4.7.4.

- Requirements for necessary model properties for use in an operational phase should be defined. How models should be enriched and update with relevant metadata during the operational phase should also be considered. See Chapter 4.2.3

- Requirements for model links to external documents should be defined.
  See Chapter 4.7.6.

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5.4.6. Future standardization aimed at software vendors

- Software's should be improved to produce and/or utilize IFC4.3 and IFC Bridge. Adequate visualization of gridlines modelled as "ifcGrid" and annotations modelled as "ifcAnnotations" is important. See Chapter 4.4.2, Chapter 4.6.8, and Chapter 4.7.3.

- Variances in data structure and object colours due to different viewing software should be addressed with developers and improved. See Chapter 4.3.3.

5.4.7. Future standardization aimed at the entire industry

- Properties, property sets, and property values should be standardized. See Chapter 4.5.3, Chapter 4.5.4, and Chapter 4.5.5.

- Requirements and recommendations for revision management should be developed. Additionally, the necessity of revision logs and their potential design should be considered. See Chapter 4.7.5.

- Methodology for the production of predefined dimensions in the model as well as predefined sections in the model should be developed. Improved functionality for acquiring manual measurements in models should be improved. See Chapter 4.3.2 and Chapter 4.7.9.

5.5. No requirements or recommendations given

- No proposal or requirements have been made to avoid large file sizes and stability problems. See Chapter 4.3.4.

- No proposal or requirements have been made regarding use of IFC entities. See Chapter 4.4.4.

- No proposal or requirements have been made regarding the use of model symbols. See Chapter 4.7.3.

- No proposal or requirements have been made regarding division of models into sub models. Chapter 4.7.4.

- No proposal or requirements have been made regarding development and use of product neutral components in models. See Chapter 4.6.5.

- No proposal or requirements have been made regarding the development of a standardized BIM manual. See Chapter 4.7.8.